Introduction to Implant Prosthodontics

A case-based Clinical Guide

Stefanos G. Kourtis

with contributions
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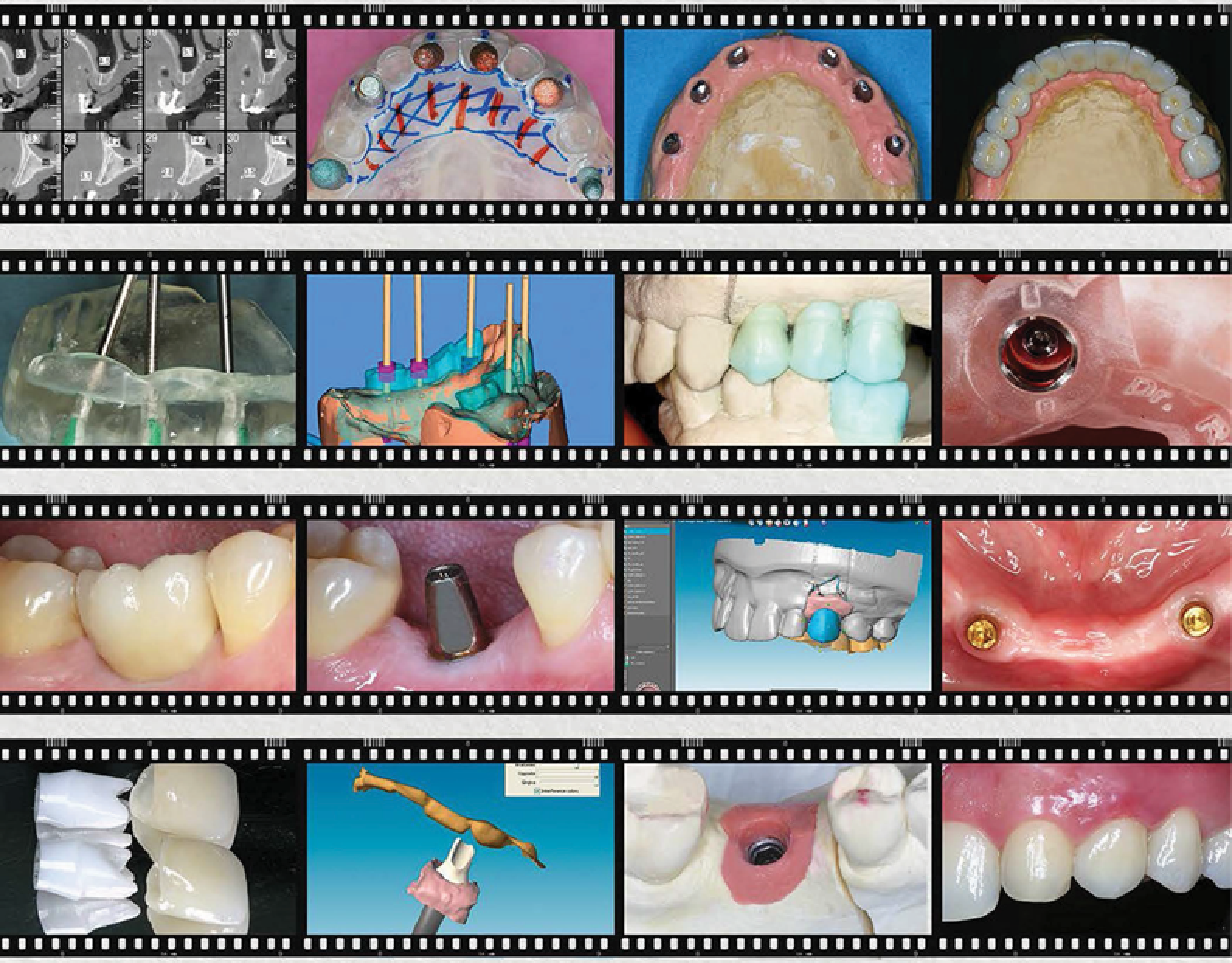

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To my family,
for the time that belonged to them
but I have not devoted.

Table of Contents

Abbreviations used in the text

CAD/CAM	Computer Aided Design / Computer Aided Manufacturing
CBCT	Cone Beam Computed Tomography
CT	Computer Tomography
DICOM	Digital Imaging and Communication in Medicine
FDP	Fixed Dental Prosthesis
IOS	Intra-Oral-Scanning
OHRQoL	Oral Health Related Quality of Life
PEEK	Poly-Ether-Ether-Ketone
PMMA	Poly-Methyl-Methacrylate
STL	Standard Tesselation Language

Prologue

Writing a textbook is always a challenge for any scientist. The main question that arises after the author has come up with the initial idea is *"…What should I write about?"* or *"…What is new? What have all previous authors not reported or explained?"* These questions are a difficult task to answer and keep bothering the author before starting writing, during the whole procedure and even at the final stages. Sometimes only the acceptance can justify the effort and the time needed to write a book.

Dental implants have been an established treatment option for partially and completely edentulous patients for decades. In the first years of their clinical use, the theoretical background on Osseointegration and Implant Prosthodontics was covered by few textbooks that had been characterized as "classical" and any research results were reported in scientific papers. Over the years, the evolutions in Implant Prosthodontics have led to a continuing introduction of innovations in prosthetic components and treatment options.

Clinicians are informed on these innovations from research papers and seminars. However, each of them is focused on a specific topic, a single innovation or technique.

The purpose of this book is to offer a thorough introduction to current Implant Prosthodontics by combining theory and practice in an easy-to-read manner. In each chapter, the needed theoretical background and principles are reported, and the techniques are presented with clinical examples in step-by-step manner. The aim is to guide the dentist in their practice by combining the needed knowledge with its clinical application and relevance. For this reason, this book can be characterized as *"A case-based Clinical Guide."* To make the text easier to read and comprehend, the theoretical parts are marked with a green title while the clinical cases are marked with a blue one.

Clinicians, on their part, are always concerned about the stages or steps required in each technique, and for this reason, special emphasis has been placed on the detailed description of each case as it is followed by a critical discussion on the selection of each specific treatment option.

Concluding the prologue, I need to sincerely thank my co-authors for their contributions, both in writing the text and in sharing their clinical cases. I would also like to express my thanking to all the colleagues who have entrusted me with their clinical cases, which have been used to underline the theoretical part and are followed by a special reference to every contributor.

As mentioned above, it remains to the reader to evaluate if the effort was worthwhile.

Stefanos Kourtis

Athens 2022

CHAPTER 1

Diagnostic Elements for Treatment Planning in Implant Restorations

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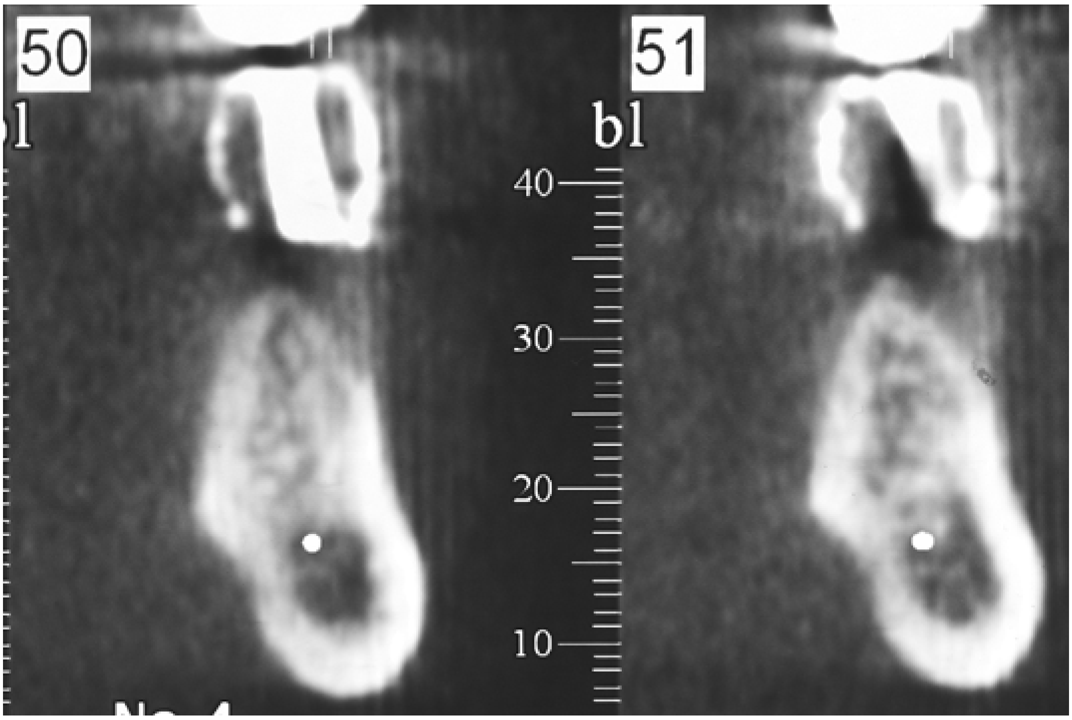

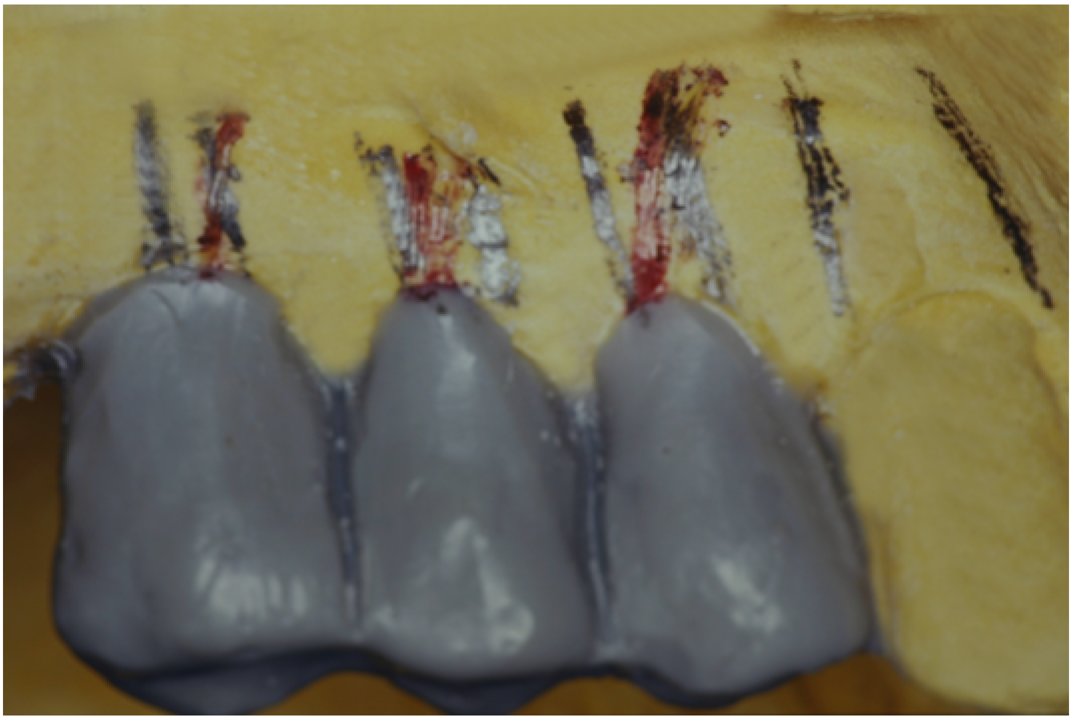

Abstract

In the early days of clinical application of osseointegration, implants were placed where adequate bone was available. The evolution of prosthetic components and the technique of Guided Tissue Regeneration have offered increased possibilities in implant restorations. Proper presurgical diagnosis is essential for a detailed treatment plan in implant restoration. The diagnostic elements that are essential for the diagnosis and treatment plan in implant restorations include the panoramic radiography, the tomographic imaging (as CT or CBCT), the study casts and the diagnostic wax-up. The aim of this chapter is to focus on comprehensive presurgical planning taking under consideration all case-specific details.

Knowledge background

To understand the content of this Chapter, the reader must be familiar with the basic principles of treatment planning for prosthetic restorations on natural teeth.

1.1 Introduction

In the early days of clinical application of osseointegration, implants were placed where adequate bone was available, and the prosthetic restoration was a screw-retained Fixed Dental Prosthesis (FDP). The evolution of prosthetic components and the technique of Guided Tissue Regeneration have offered increased possibilities in implant restorations. Proper presurgical diagnosis remains, however, a crucial stage when planning an implant restoration (**Arlin, 1990; Wolf, 1994; Callan and Strong, 1995; Buck, 1996**). Moreover, the increased need for predictability mandates a close cooperation between the clinician and the dental technician to plan and predict a functional and esthetic outcome (**Jansen and Weisgold, 1995; Lang, 1998**).

The treatment planning should define the kind and extent of the prosthetic restoration, which will dictate the number, position, and inclination of the needed implants. For this reason, presurgical planning must be accomplished in detail using all available means that contemporary technology may offer. Numerous techniques have been proposed for the fabrication of radiographic and surgical guides (also referred to as templates, splints, or stents) using various radiopaque materials as markers (**Takeshita et al., 1997; Israelson et al., 1992; Solow, 2001; Ku and Shen, 2000; Forbes-Haley and King, 2013; De Kok et al., 2014; Kourtis et al., 2014**).

1.2 Aim

The aim of this chapter is to focus on comprehensive presurgical planning taking into consideration all case-specific details. The presented cases were selected because each one had one or more complicated stages that could be recognized during the planning phase avoiding further complications.

1.3 Diagnostic elements

The diagnostic elements for the presurgical evaluation and treatment planning in implant restorations include:

- Detailed and thorough medical and dental record with a special interest in medications and existing medical conditions.
- Detailed intra- and extraoral examination.
- Periapical radiographs of the region(s) of interest or a panoramic radiograph in large edentulous areas for an initial assessment.
- Study casts mounted on a semi-adjustable articulator.
- Detailed wax-up / set-up.
- Fabrication of a radiologic guide.
- Tomographic imaging, preferably Cone Beam Computed Tomography (CBCT) or Computed Tomography (CT) in the absence of CBCT.
- Fabrication of a surgical guide.

If the presurgical examination is not detailed, the clinician may encounter unexpected difficulties during treatment, either in the surgical or in the prosthetic phase.

Tomographic imaging (CBCT or CT) is considered nowadays a standard procedure for precise and detailed examination of the bone substrate prior to implant placement. It should be combined with the use of a radiologic guide with proper radiopaque markers and followed by an appropriate image reconstruction to produce accurate cross-section images of the examined region (**Ganz, 2011; Angelopoulos and Aghaloo, 2011; Jacobs et al., 2018**).

The following cases represent some indicative examples that emphasize the need for careful examination and planning. Beside the zone of implantation, a thorough intraoral examination is necessary to assess the entire area of the planned restoration. Anatomical structures, interarch relationship, occlusal situation in the whole dental arch should be carefully evaluated before initiation of the treatment. In certain cases, an extra oral examination may also reveal some factors that have to be taken into consideration during the treatment planning.

The clinician should always combine the information from all the above mentioned presurgical means of examination to establish a solid and predictable treatment plan that focuses on the difficulties of each case and also includes alternative treatment options. The initial steps of the presurgical diagnosis are analyzed with clinical examples at the beginning of this Chapter. Selected clinical cases are presented underlining the diagnostic value of each step and showing how the combined information can and should be evaluated before any irreversible treatment step is undertaken.

1.4 Panoramic Radiography and Computed Tomography

Panoramic radiography has been used for the initial evaluation of the implant patient from the early years of clinical application of implants. It is a valuable diagnostic tool as it allows an overall view of the existing teeth, the supporting hard tissues and relevant anatomical structures, all in one diagnostic image. Its main role, along with complimentary periapical radiographs, is that of a gross assessment of the edentulous spaces, the status of existing teeth and possible dental pathology as well as anatomical limitations for implant placement.

The panoramic radiograph is a magnified diagnostic image and it is essential that the induced magnification be recognized on the film (**Batenburg et al., 1997; Scarfe et al., 1998; Gomez-Roman et al., 1999; Stramotas et al., 2002**). The magnification factor is variable among different panoramic machines and ranges between 1,18-1,33. A fixed magnification (the one provided by the manufacturer of the machine) is achieved when the patient is ideally positioned in the machine and, thus, initial measurements may be accurately performed. When positioning errors occur, which is not rare, the panoramic image is distorted (different magnification in different areas of the image) which makes it unsuitable for accurate bone height estimation.

Contemporary digital panoramic machines provide automated magnification correction tools which may be useful when the radiograph is made without patient positioning errors and no distortion has been induced. It must be emphasized, however, that automated magnification correction function will not correct possible induced distortions, and measurements rendered should be verified and confirmed by the clinician as shown in the presented clinical case (**Case A**). In any case, current digital panoramic machines in the hands of knowledgeable operators and proper patient positioning may minimize distortion and allow acceptable accuracy for the initial evaluation of the bone substrate in height (**Vazquez et al., 2013**).

Beyond that, there is a general agreement in the literature that surgical planning even in simple cases should be accomplished with a tomographic study (CT or CBCT examination). Both CT (with the proper dental scan protocols) and CBCT allow a precise evaluation of the hard tissue substrate and the anatomical points of interest in all three dimensions (**Jacobs et al., 2018**). CBCT stands out as an imaging modality which is readily available nowadays and at advantage in comparison to CT because of the lower radiation (**Angelopoulos and Aghaloo, 2011; Mandelaris et al., 2018**). It is nowadays considered an absolute prerequisite for a safe and precise presurgical planning with safety in every case, even when the initial panoramic shows no need for additional diagnostic imaging as shown in **Case B**. The CT and CBCT images have no magnification and allow precise measurement of the bone substrate in height and width by means of the software. In this way, the presurgical planning can be accurate and detailed, minimizing the risk of hurting any vital anatomic structure or fenestration.

1.5 Study casts/diagnostic wax-up

Study casts are an essential element in presurgical planning. They are the reference point to every stage of the treatment and allow a precise evaluation of the intraoral situation even after the end of clinical examination. The study casts should always be mounted on a semi-adjustable articulator and be kept even after the end of the treatment for reasons of documentation. The mounted casts allow the evaluation of the occlusal relationship of the maxillary and mandibular arch and the prosthetic space. They are also necessary for a detailed wax-up and the fabrication of a radiographic and surgical guide, which correlate the radiographic images with the clinical conditions.

The role of study casts and the wax-up in the presurgical diagnosis and planning for implant restorations is clearly shown in **Cases C and D**. In complicated cases, all diagnostic elements should be used and taken into consideration to make a detailed treatment plan with all the possible points of difficulty, as shown in **Cases E, F and G.**

1.6 Case A (Figs. 1.1 to 1.4)

In this clinical case (Case A), the patient had received several implants in the maxilla and the mandible some years ago. For the recall appointment a panoramic x-ray was needed, and the patient was referred to a radiologist. On the panoramic x-ray, however, where a 1:1 magnification was marked, the implants appeared longer and wider than their original dimensions, which were recorded in the patient's file (***Fig. 1.1***). For example, in regions #27 and 36 a D 5,5/L 15 mm implant had been inserted (***Figs. 1.2 and 1.3***). The superimposition of the plastic transparent sheet showing the implants in their exact dimensions revealed that the panoramic x-ray had a severe magnification. This finding was confirmed by periapical x-rays in region 36 and the superimposition of the transparent sheet (***Fig. 1.4***).

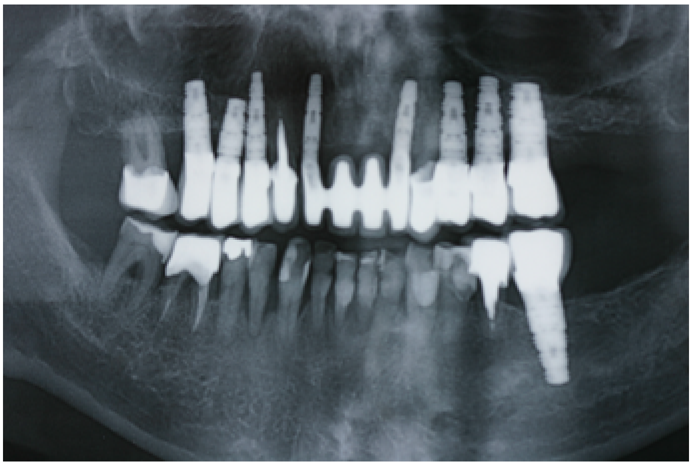

Fig. 1.1 *Case A: Panoramic radiography of a patient at a recall appointment. The implants appear longer and wider.*

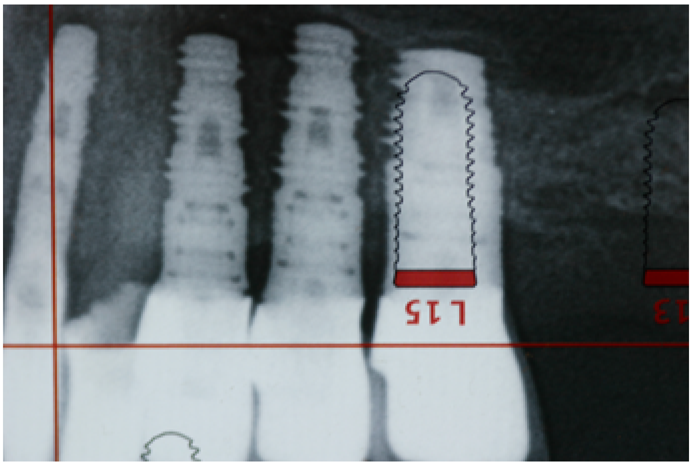

Fig. 1.2 *Superimposition of a measuring plastic transparent sheet on the panoramic film in region #27.*

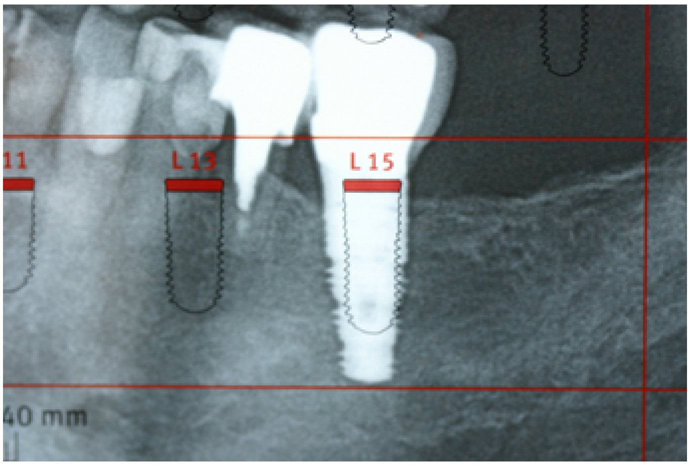

Fig. 1.3 *Superimposition of a measuring plastic transparent sheet on the panoramic film in region #36.*

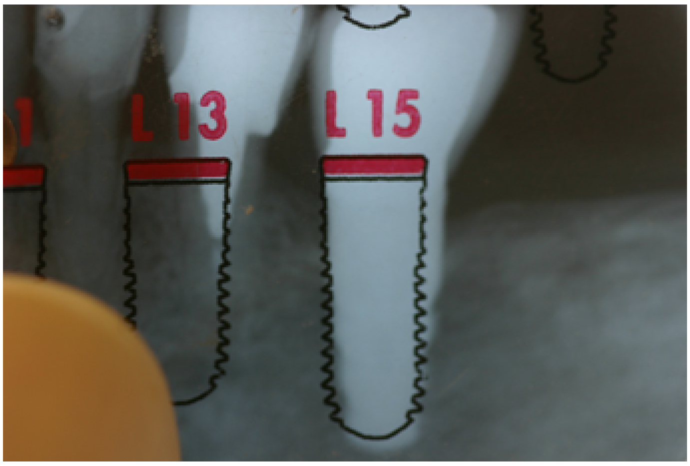

Fig. 1.4 *Superimposition of a measuring plastic transparent sheet on the periapical film in region #36.*

1.7 Case B (Figs. 1.5 to 1.8)

In Case B, the panoramic x-ray of a patient is presented upon the initial clinical examination (***Fig. 1.5***). The initial treatment plan in this case was a fixed restoration with four implants in the mandibular interforaminal area. The bone substrate in this area appears adequate in height and the alveolar crest has usually also adequate width. Even if the alveolar crest is sharp and narrow on its peak—with sufficient height—it can be usually grinded and flattened to create a plateau to allow implant placement. In the Computed Tomography of this case, however, the alveolar crest appeared extremely narrow and consisted practically of a labial and lingual cortical plate without any spongious bone. In some areas, it could be characterized as an "8-shaped mandible" (***Figs 1.6-1.8***). Based on the findings of the Computer Tomography, an augmentation technique for lateral increase of the width should be performed prior to the insertion of implants or the treatment plan could be modified accordingly.

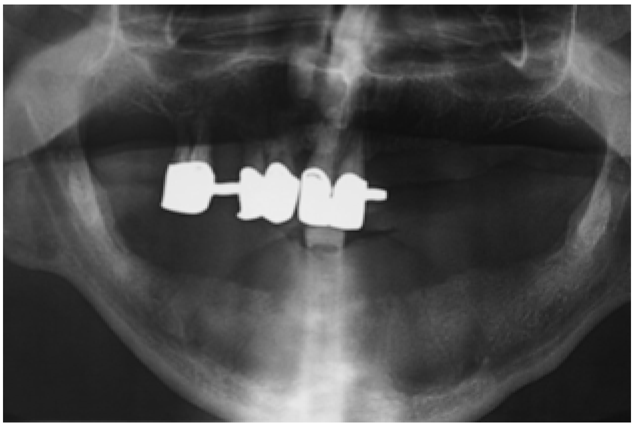

Fig. 1.5 *Case B, initial panoramic radiography of the patient.*

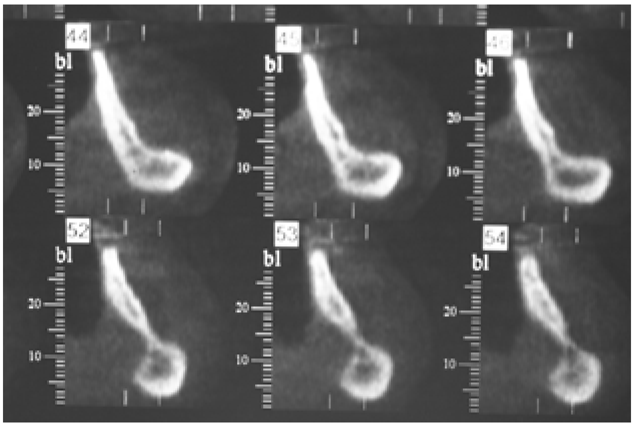

Fig. 1.6

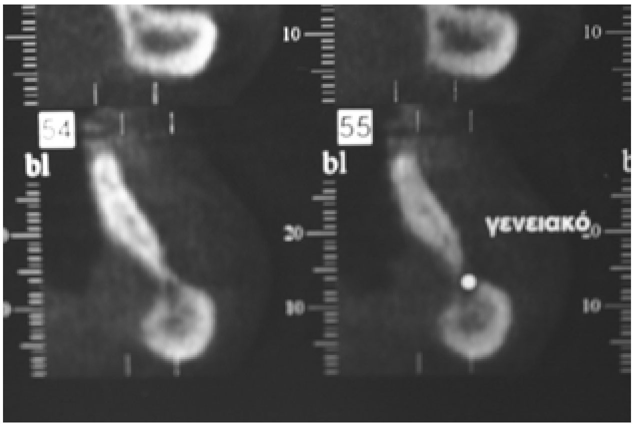

Fig. 1.7

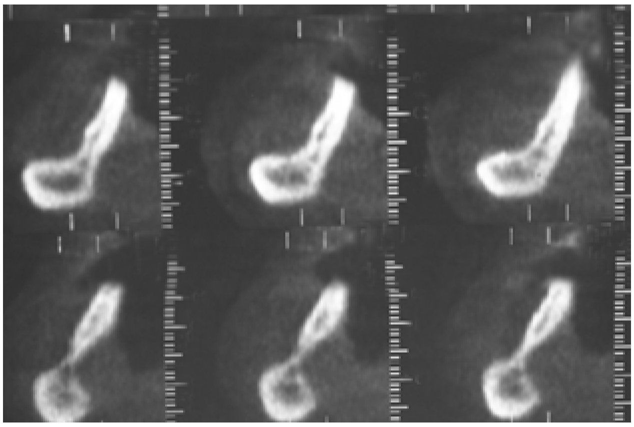

Fig. 18

Figs. 1.6, 1.7 and 1.8 *Cross-section images of the Computed Tomography of the mandible. Extremely absorbed alveolar crest and "8-shaped" mandible.*

1.8 Case C (Figs. 1.9-1.16)

The patient presented for restoration of the mandibular left quadrant. The patient wished a fixed restoration instead of the existing Removable Partial Denture. The initial clinical and radiographic examination revealed an alveolar crest reduced in height and severely absorbed in width (***Figs. 1.9-1.12***). The occlusal relation was found acceptable without any need for excessive occlusal corrections except for the canine areas #23/33.

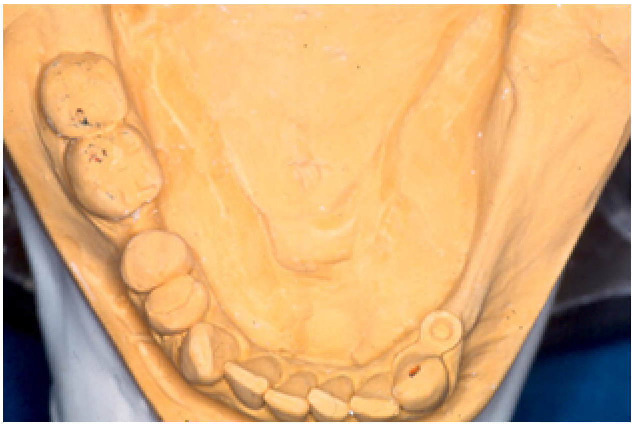

Fig. 1.9

Fig. 1.10

Figs. 1.9 and 1.10 *Case C: Study casts of the patient. Bone resorption is obvious, both in height and width.*

Fig. 1.11

Fig. 1.12

Figs. 1.11 and 1.12 *Panoramic radiography of the patient. The height of the alveolar ridge allows insertion of implants with adequate length.*

The Computed Tomography showed that a bone augmentation technique was necessary on the labial side of the alveolar to allow placement of the implants, as there was minimal spongy bone between the cortical plates (***Figs. 1.13 and 1.14***). Before any treatment procedure, the patient was carefully examined to verify the extent and expected efficacy of the augmentation procedure on the planned restoration. The needed surgical steps and the time needed for the implant restoration were explained to the patient, who wished to avoid extended surgical procedure.

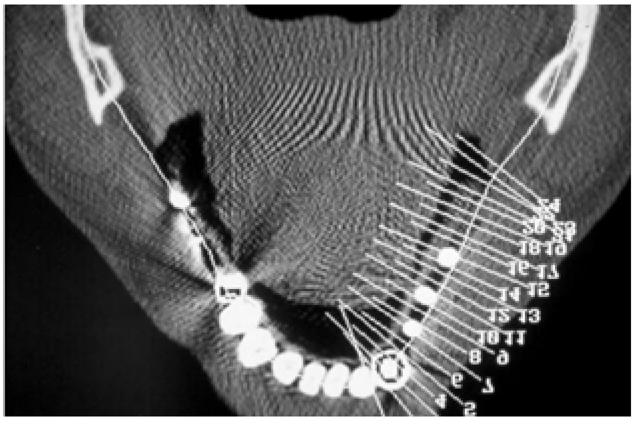

Fig. 1.13

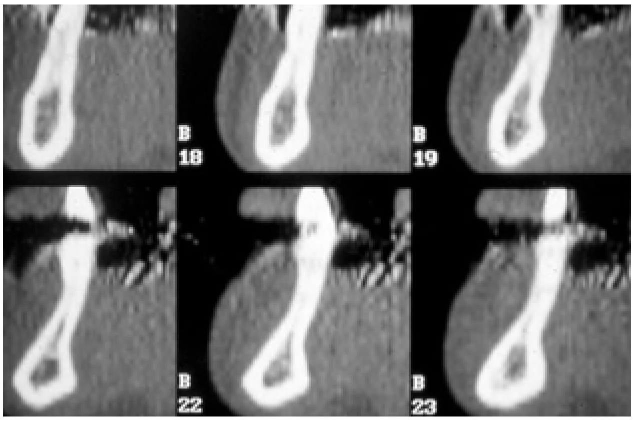

Fig. 1.14

Figs. 1.13 and 1.14 *Computer Tomography of the patient. The alveolar ridge is severely resorbed in width, and lateral augmentation is needed.*

1.9 Case D (Figs. 1.15-1.22)

The patient presented for treatment of the missing teeth #26, 36 and 37 (***Fig. 1.15***). The initial clinical examination revealed a normal alveolar crest with minimum absorption both in height and width for the mandibular posterior region. The patient expressed an intense wish to maintain her remaining teeth. On the panoramic x-ray (***Fig. 1.16***), several endodontic and periodontal problems of teeth #27 and 28 were recognized.

Study casts were fabricated and mounted on a semi-adjustable articulator (***Figs. 1.17 and 1.18***). On the study casts, severe overeruption of the maxillary molars was obvious protruding from the occlusal level. The prognosis of the molars was doubtful to poor due to the periodontal condition that included furcation involvement. If the teeth #27 and 28 would be maintained—according to the patient's wish—extensive periodontal treatment including bone surgery would be necessary and their prognosis would remain doubtful. Additionally, new root canal treatment and crown restoration would be necessary for both teeth #27 and 28, while their prognosis would remain doubtful.

Fig. 1.15

Fig. 1.16

Figs. 1.15 and 1.16 *Case D, initial clinical situation and panoramic radiography of the patient.*

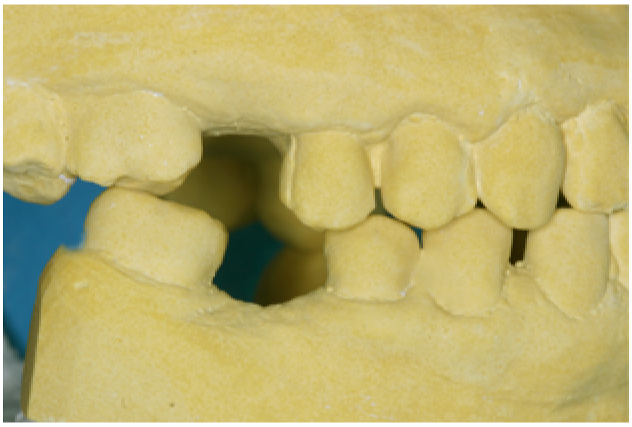

Fig. 1.17

Fig. 1.18

Figs. 1.17 and 1.18 *The study casts mounted on the articulator.*

Based on these findings, a treatment plan was made that included extraction of both maxillary molars and insertion of two implants in areas #26 and 27. As these teeth were over-erupted, the bone absorption following the extractions with minimum osteoplastic surgery could create adequate interarch space in the area. On the other side, the maxillary implants would have a better prognosis compared to the existing teeth in the present situation. Soft tissue surgery to reduce gingival thickness was also decided for the left distal side of the mandible that could be accomplished simultaneously to implant insertion.

The treatment plan was presented to the patient with details in all aspects. The patient consented for extraction of the teeth and insertion of two implants in the maxilla and two in the mandible. The case could be accomplished uneventfully (***Figs. 1.19 to 1.22***).

Fig. 1.19

Fig. 1.20

Figs. 1.19 and 1.20 *The final restorations of the working cast and in occlusion.*

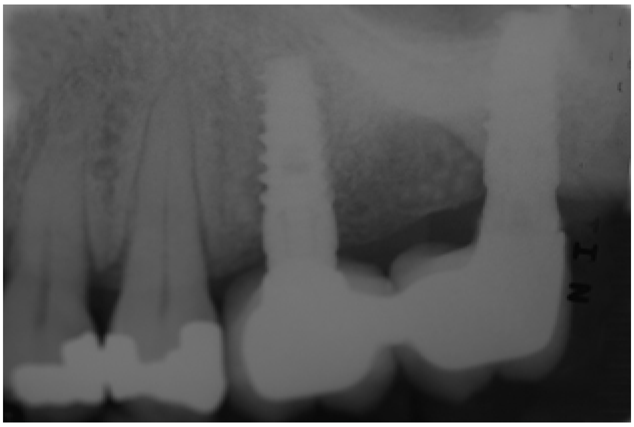

Fig. 1.19

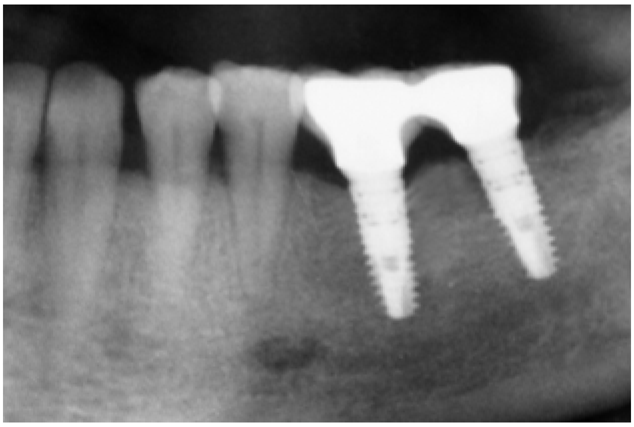

Fig. 1.20

Figs. 1.21 and 1.22 *radiographic examination at the recall.*

1.10 Case E (Figs. 1.23-1.27)

The patient presented for the restoration of the edentulous posterior areas in the mandible. Following the initial clinical examination and panoramic x-ray (***Fig. 1.23***), study casts were fabricated to evaluate the resorption of the alveolar space, the available interarch space and the occlusal relationship (***Figs. 1.24 and 1.25***). The available vertical space was extremely reduced due to over-eruption of the antagonist maxillary teeth. To restore the occlusal level on the maxillary teeth, segmental osteotomy was necessary bilaterally. Additionally, as shown on the cross-section images of the Computer Tomography, the edentulous alveolar ridges bilaterally were extremely resorbed and vertical augmentation procedure with bone grafting was necessary for implant placement (***Figs. 1.26 and 1.27***).

The treatment plan was explained to the patient; four surgical steps would be necessary for proper implant placement and increased time would be needed for the final restoration. Alternatively, a full-mouth restoration including all maxillary and mandibular teeth should be undertaken in an increased vertical dimension to compensate for the limited interarch space. The patient preferred to retain the existing Removable Partial Denture.

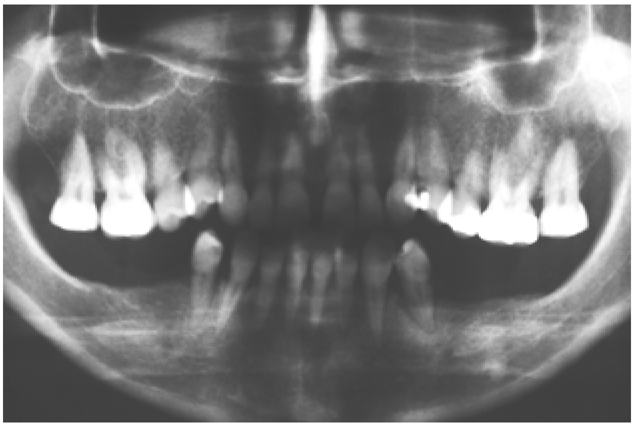

Fig. 1.23 *Case E, initial panoramic radiography.*

Fig. 1.24

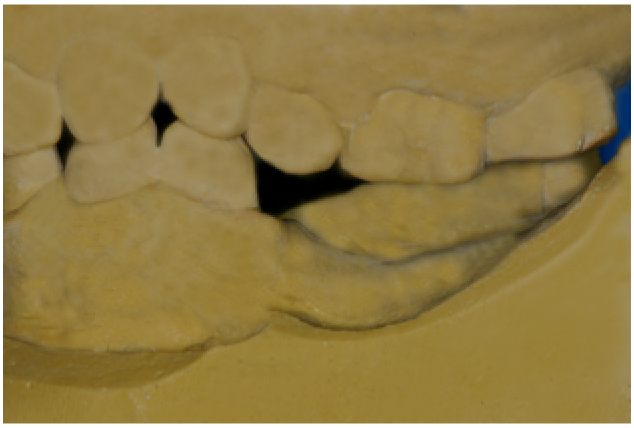

Fig. 1.25

Figs. 1.24 and 1.25 *The study casts mounted on the articulator.*

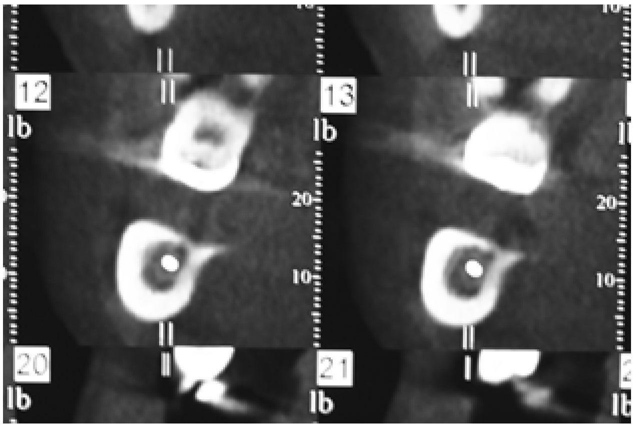

Fig. 1.26

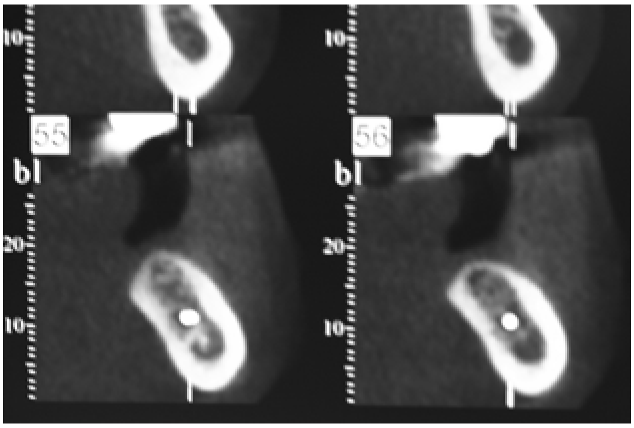

Fig. 1.27

Figs. 1.26 and 1.27 *Cross-section images of the mandibular posterior areas in the Computer Tomography.*

1.11 Case F (Figs. 1.28-1.40)

The patient presented for treatment of the maxillary right quadrant, where all posterior teeth were missing. The initial clinical and radiographic examination with a panoramic x-ray showed medium absorption of the alveolar crest in height and width (***Figs. 1.28-1.30***). A full wax-up was performed on the edentulous area to determine the exact position and size of the teeth on the planned restoration. According to the wax-up the most favorable position and inclination of the implants could be planned.

On the study casts, red lines were drawn to facilitate the wax-up for the dental technician (***Fig. 1.31***). These lines were drawn arbitrarily without the proper attention. The wax-up was accomplished and a radiographic template was fabricated with radiopaque markers (Guttapercha) along the axes of the teeth. On the CT-Dental Scan that was taken with the radiographic guide in-situ, it was obvious that the bone quantity allowed implant placement, but the planned direction and drilling for the first premolar would result to severe injury of the canine root (***Figs. 1.32 and 1.33***). The study casts were re-examined having taken into consideration the inclination of the canine root (***Figs. 1.34 and 1.35***).

Fig. 1.28

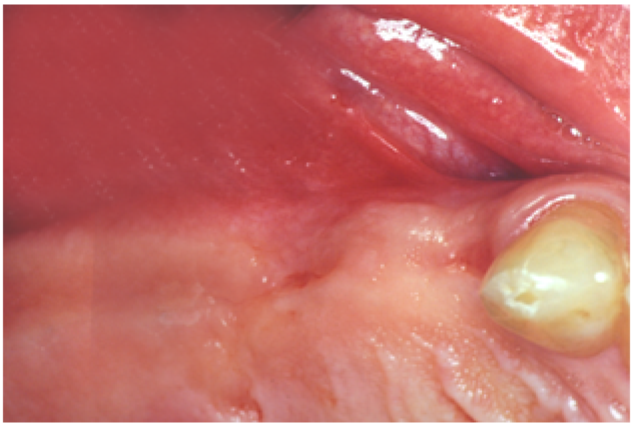

Fig. 1.29

Figs. 1.28 and 1.29 *Case F, initial clinical situation.*

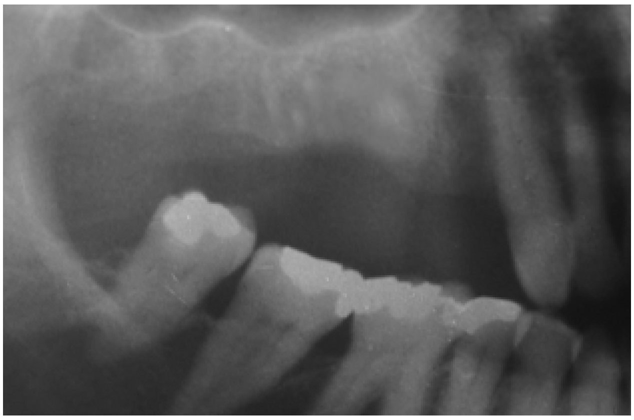

Fig. 1.30 *Panoramic radiography.*

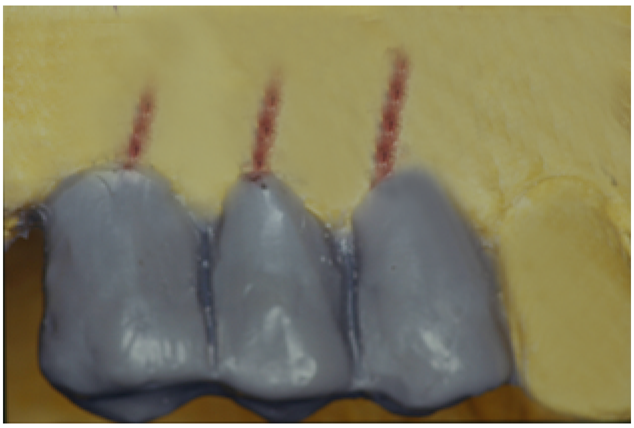

Fig. 1.31 *Study cast with the initial (red) incorrect markings for the wax up.*

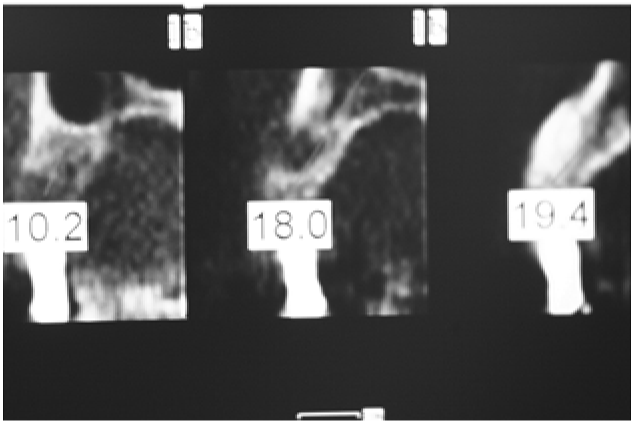

Fig. 1.32

Fig. 1.33

Figs. 1.32 and 1.33 *Computed Tomography of the region #13-17. There is adequate bone volume in width and height, but the planned inclination of the implant for the first premolar (#14) would result in injury of the canine root.*

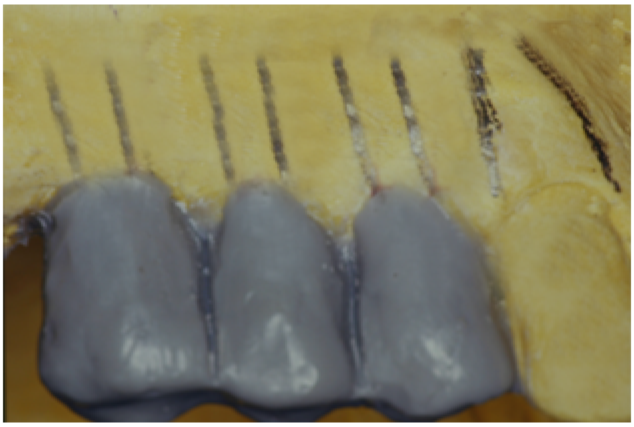

Fig. 1.34

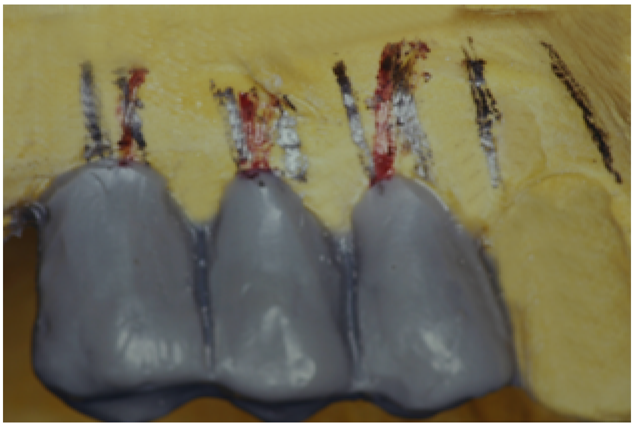

Fig. 1.35

Fig. 1.34 *The study cast with markings for the root of the canine.*

Fig. 1.35 *The study cast with the previous incorrect markings (red) and the corrected markings (black).*

The surgical guide (template), that was fabricated as a duplicate from the wax-up, was transformed accordingly by changing the axis of the first premolar implant. The surgical flap allowed visual examination of the canine root, and the drilling for the first premolar was performed with low speed to the adequate inclination (***Figs. 1.36 and 1.37***). As a result, the implants could be inserted without any injury on the root and the implants could be restored uneventfully (***Figs. 1.38 and 1.39***). The implants and the restoration remain in function for a long time as it can be seen on the radiographic examination of the 12-year recall (***Fig. 1.40***).

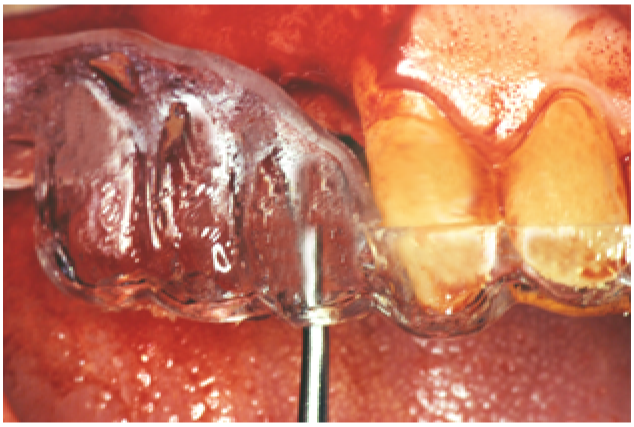

Fig. 1.36

Fig. 1.37

Figs. 1.36 and 1.37 *Initial drilling through the surgical guide and positioning indexes after the first drilling.*

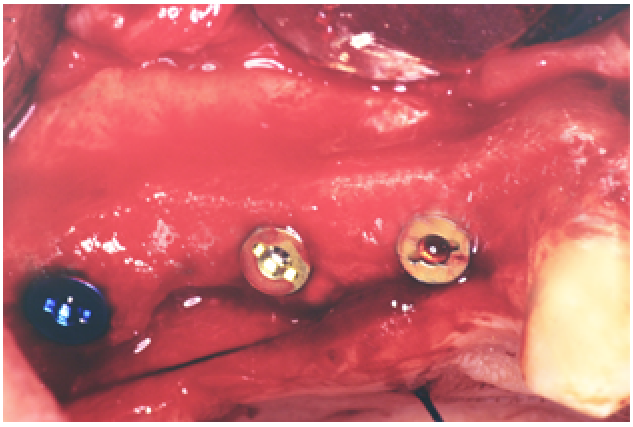

Fig. 1.38

Fig. 1.39

Figs. 1.38 and 1.39 *Implant placement and the final restoration.*

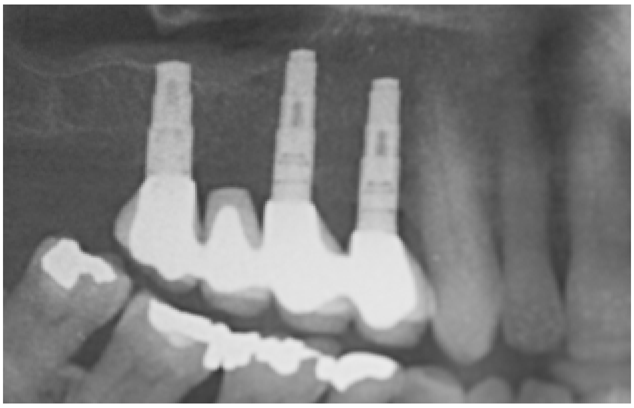

Fig. 1.40 *Case F, radiographic examination at the 12-years recall.*

1.12 Case G (Figs. 1.41-1.66)

1.12.1 Initial treatment steps

A 50-year-old male Caucasian patient was referred for prosthetic restoration (***Fig. 1.41***). The treatment plan included full-mouth rehabilitation with implant restorations. On the left side of the mandible, the second premolar (#35) had a poor prognosis and should be extracted. Single crowns for teeth #34 and #37 were planned and two implant-supported crowns for the region of teeth #35 and #36. On the right side, two single implant crowns for the second premolar and first molar (teeth #45 and 46) were planned (***Figs. 1.42 and 1.43***).

A radiographic template (guide) was fabricated from a thermoplastic Omnivac sheet as a duplicate from the diagnostic wax-up. The outer surfaces of the teeth on the template were covered with radiopaque material (amalgam powder diluted in transparent nail varnish) to indicate the contour of the planned restoration on the Computer Tomography. Guttapercha points were inserted in the center of the acrylic teeth along the planned implant axis (***Fig. 1.44***).

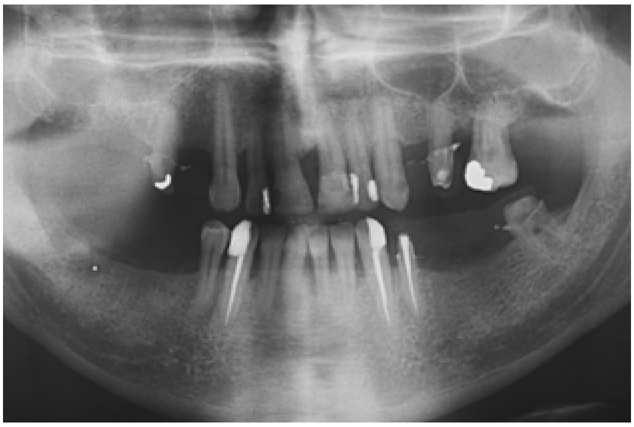

Fig. 1.41 *Case G, initial radiographic examination.*

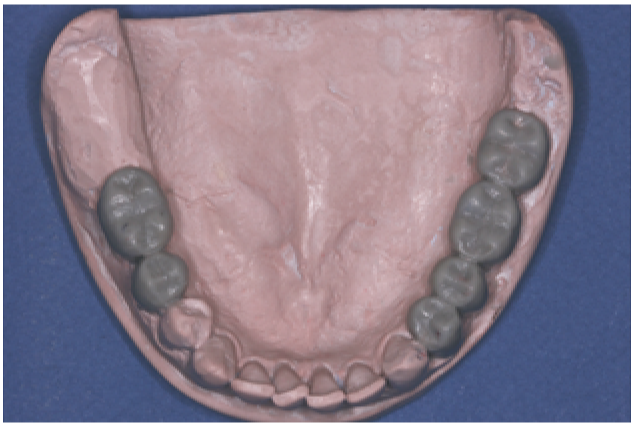

Fig. 1.42

Fig. 1.43

Figs. 1.42 and 1.43 *Diagnostic wax-up.*

Fig. 1.44 *Radiographic guide with radiopaque material (amalgam powder) to indicate the contour of the planned restoration and guttapercha for the implant axis on the CBCT.*

The use of a radiographic guide during Cone Beam Computed Tomography (CBCT) facilitates the orientation of the scanning level and the recognition of the exact areas of concern at the cross-section images (**Israelson et al., 1992; Forbes-Haley and King, 2013**).

This kind of radiographic guide offers two significant advantages: The long axis of the implant is indicated from guttapercha and the contour of the planned restoration is reproduced on the images from the amalgam powder. It is also an easy and low-cost technique requiring no additional equipment. Compared to other radiopaque materials, such as barium sulfate or zinc foil, amalgam powder offers a sharper image with minimum thickness. Additionally, the fabricated radiographic guide can be transformed to a surgical template in a very short time by removing the amalgam powder and the guttapercha points with diluting agents such as acetone and chloroform.

1.12.2 Surgical planning based on CBCT and comparison of reconstructions

The patient was referred for a Cone Beam Computed Tomography (CBCT) with the radiographic guide in situ. The desired shape of the planned restoration and its relation to the bone substrate could be clearly recognized. Furthermore, inclination, length and diameter of the desired implants could be selected. For the mandibular left second premolar (#35), a D4/L15mm implant (***Fig. 1.45***) and for the left first molar (#36) a D4/L13mm implant were initially selected (***Fig. 1.46***).

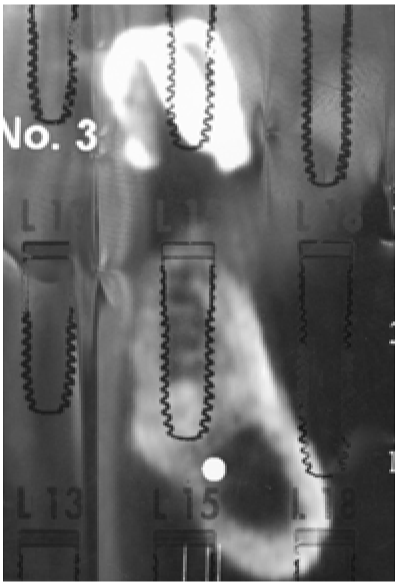

Fig. 1.45

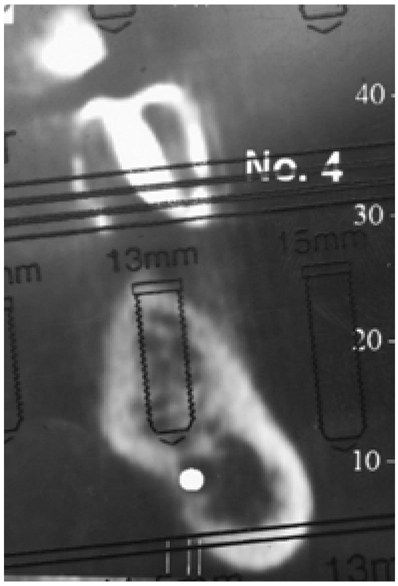

Fig. 1.46

Fig. 1.45 *Cross-section image of the left mandibular second premolar region (#35) at the first reconstruction. A D4xL15 mm implant was initially selected.*

Fig. 1.46 *Cross-section image of the left mandibular first molar region (#36) at the first reconstruction. A D4/L13mm implant was initially selected.*

On the CBCT it was observed that the transverse orientation lines—that are drawn before the 3D reconstruction and serve as a frame for the cross-section images—were aligned parallel to the inferior border of the mandible and not parallel to the occlusal plane, as depicted from the radiographic template (***Fig. 1.47***). For this reason, a new digital reconstruction of the existing CBCT was decided without exposing the patient to additional radiation. The base orientation line in the new reconstruction was parallel to the occlusal plane and new cross-section images were obtained. Consequently, the inclination of the transverse images was altered compared to the previous reconstruction. The different orientation lines in the two reconstructions of the same CBCT can be clearly observed on ***Figs. 1.48 and 1.49***.

Focusing on the definition of the occlusal plane for the CBCT reconstruction, there are two options that can be applied; the occlusal plane can be recognized either by the teeth (if existing) or alternatively by the occlusal surfaces of the teeth on the radiographic template. In the described case, the occlusal plane as defined by the maxillary teeth was selected. Alternatively, the mandibular teeth on the radiographic template could also have been used as reference points (***Figs. 1.48 and 1.49***).

In ***Figs. 1.50 and 1.51*** the panoramic views of the two separate reconstructions are shown. The inclination of the guttapercha markers towards the long axis of the existing premolars was significantly influenced by the alignment of the scanning level (***Fig. 1.50***). In the second reconstruction (***Fig. 1.51***), the guttapercha markers appeared parallel to the premolars, as they were originally placed during the laboratory fabrication of the radiographic guide. The second reconstruction was obviously closer to the clinical situation with significantly less distortion.

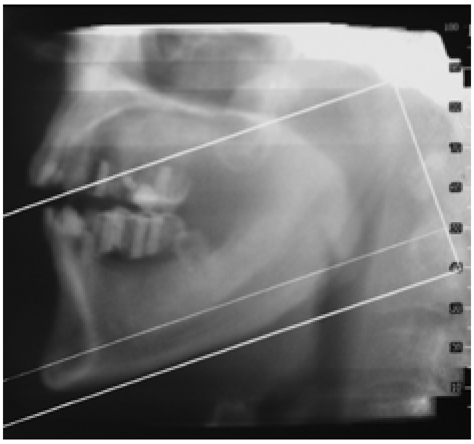

Fig. 1.47 *The transverse orientation lines were drawn parallel to the inferior border of the mandible and not parallel to the occlusal plane.*

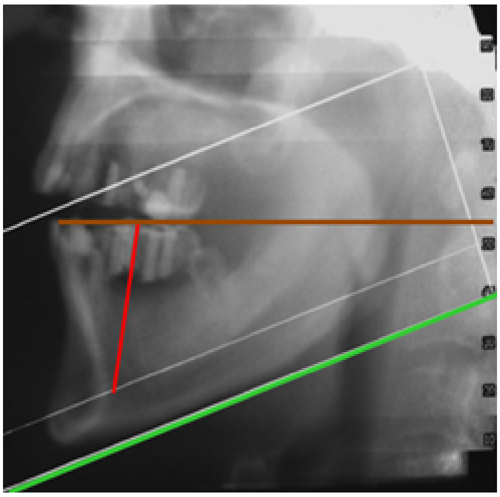

Fig. 1.48

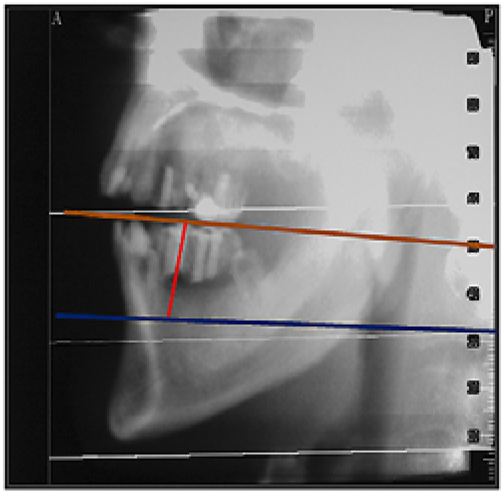

Fig. 1.49

Figs. 1.48 and 1.49 *The transverse orientation lines on the two reconstructions: The first reconstruction on the left and the second reconstruction on the right. The red lines indicate the axis of the implant and the restoration. The brown lines indicate the occlusal plane as depicted by the radiographic guide. The green line indicates the inferior border of the mandible. The blue line indicates an orientation line parallel to the occlusal plane.*

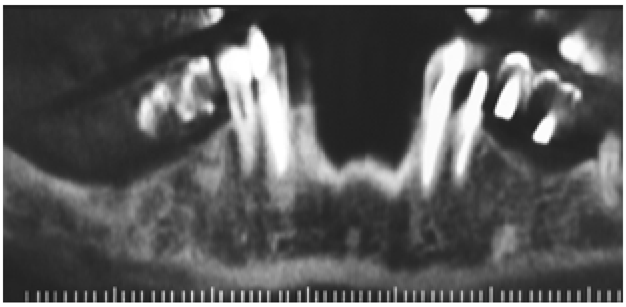

Fig. 1.50

Fig. 1.51

Figs. 1.50: and 1.51 *Panoramic views of the two reconstructions: the first one on the left side and the second one on the right. The second image shows reduced distortion.*

When comparing the cross-section images from the two reconstructions, different morphology of the left side of the mandible was also observed. The inclination of the alveolar crest to the sagittal plane (labial-lingual) appeared different. Both the second premolar (***Figs. 1.52 and 1.53***) and the first molar region (***Figs. 1.54 and 1.55***) appeared significantly different in the cross-section images. According to the second reconstruction, a D3.25/L10mm implant (***Fig. 1.56***) for the second premolar and a D4/L10mm implant (***Fig. 1.57***) for the first molar region were selected. The implant length—that was initially planned—was 15mm for the premolar and 13mm for the molar (***compared with Figs. 1.45 and 1.46***). The implant length that was finally selected was reduced to avoid any injury to the mandibular nerve.

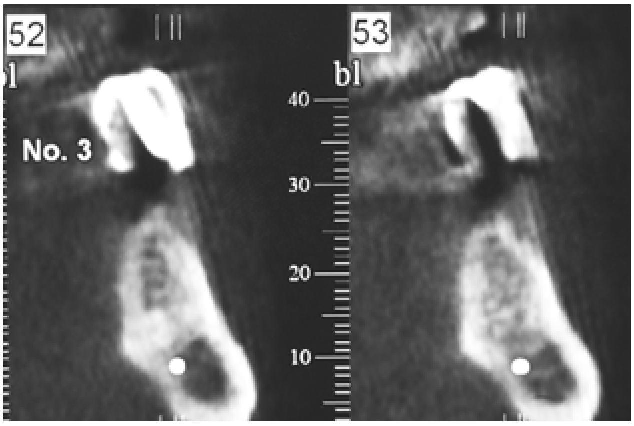

Fig. 1.52

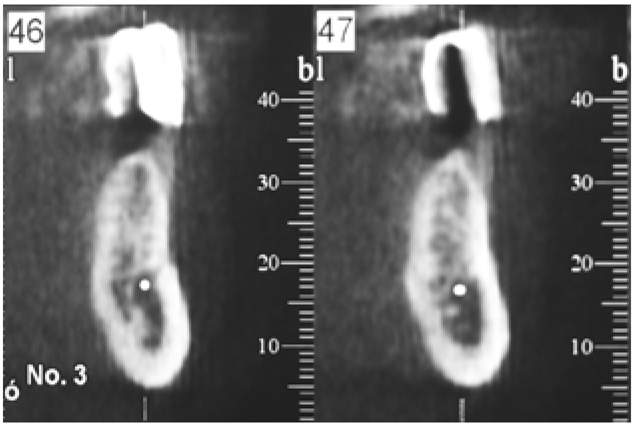

Fig. 1.53

Figs. 1.52 and 1.53 *Cross-sectional images of the mandibular second premolar region (#35): On the left side the first reconstruction and on the right side the second one can be seen. The difference in the depicted morphology of the alveolar ridge is obvious.*

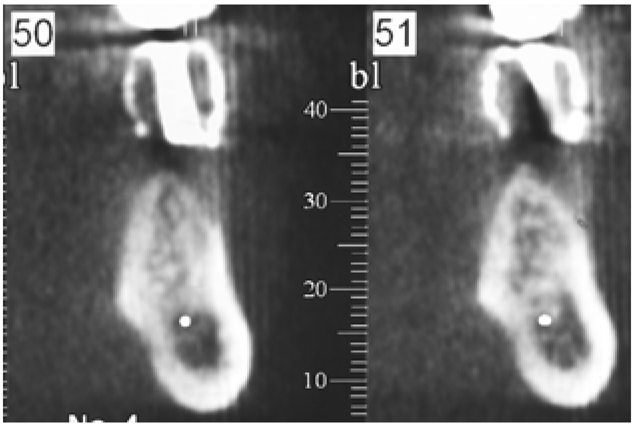

Fig. 1.54

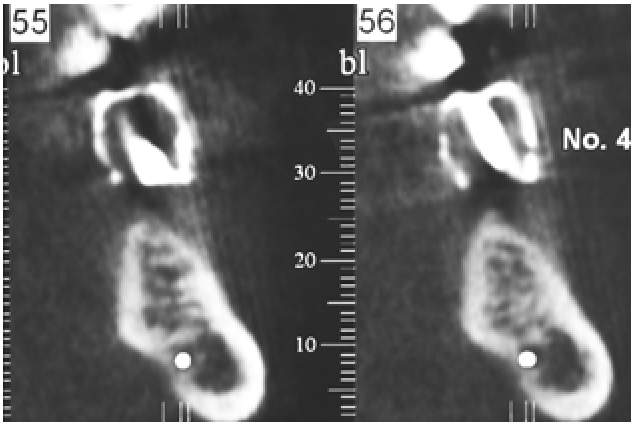

Fig. 1.55

Figs. 1.54 and 1.55 *Cross-section images of the mandibular first molar region (#36): On the left side the first reconstruction and on the right side the second one can be seen. The difference in the depicted morphology of the alveolar ridge is obvious.*

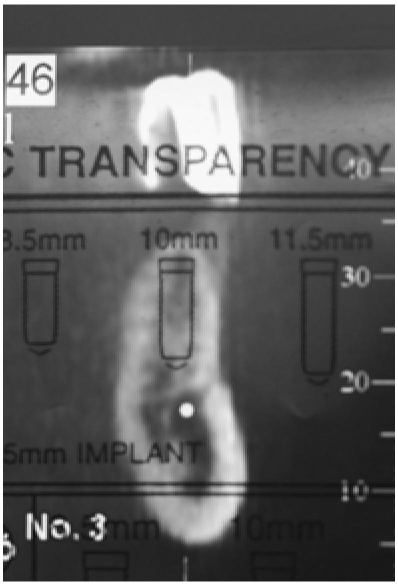

Fig. 1.56

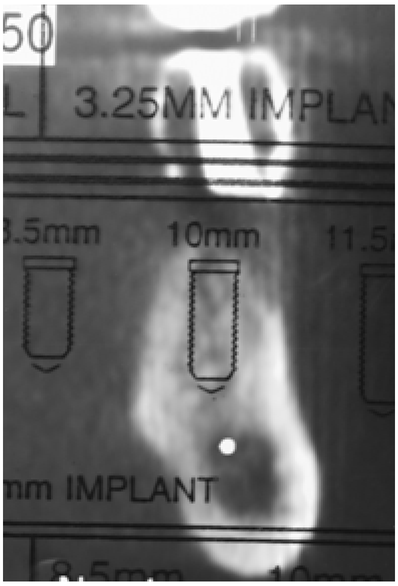

Fig. 1.57

Fig. 1.56 *For the second premolar region (#35, cross-section #46) a D3.25/L10mm implant was finally selected, according to the second reconstruction. Compare with Fig 1.45.*

Fig. 1.57 *For the first molar region (#36, cross-section #50) a D4/L10mm implant was finally selected, according to the second reconstruction. Compare with Fig 1.46.*

The horizontal distance between the mental foramen and the crown of the second premolar (#35)—as indicated by the radiopaque material on the radiographic template—also appeared different in the cross-section images in the two reconstructions (***Figs. 1.58-1.60***). In the first reconstruction, the second premolar crown (#35)—as depicted on the radiographic template—appeared in cross-section image #48 (***Fig. 1.58***). The mental foramen was observed in cross-section image #52 (4 transverse images away), thus indicating a horizontal distance of 8mm (***Fig. 1.59***).

In the second reconstruction (***Fig. 1.60***), the mental foramen appeared right under the second premolar crown, on the same cross-section image #45. If the implant insertion was based on the images of the first reconstruction, an injury of the mental nerve would be possible due to the selected length and inclination of the implant.

In the presented case, the first CBCT reconstruction was performed using the inferior border of the mandible as orientation line and resulted in distorted cross-sectional images. A second reconstruction of the existing CBCT, using the occlusal plane of the patient as orientation line, produced cross-sectional images that depicted the alveolar crest more accurately.

A possible explanation for this finding may be the angle at which the cross-sectional images are produced. If the posterior areas of the mandible are considered a cylinder that is “sliced” perpendicular to its long axis, the cross-sectional images appear as a circle with a certain diameter. These images are closer to the clinical situation and to the surgical anatomy. If the cylinder is “sliced” to an angle declining from the perpendicular line, the cross-section is depicted as an ellipse with greater phenomenal diameter and increased height (***Fig. 1.61***). The influence of the orientation line to the accuracy of the reconstruction and of the cross-section images has already been analyzed in detail in a previous publication (**Kourtis et al., 2012**).

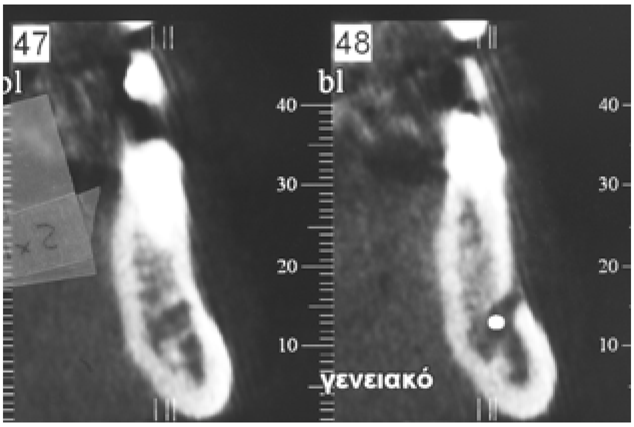

Fig. 1.58

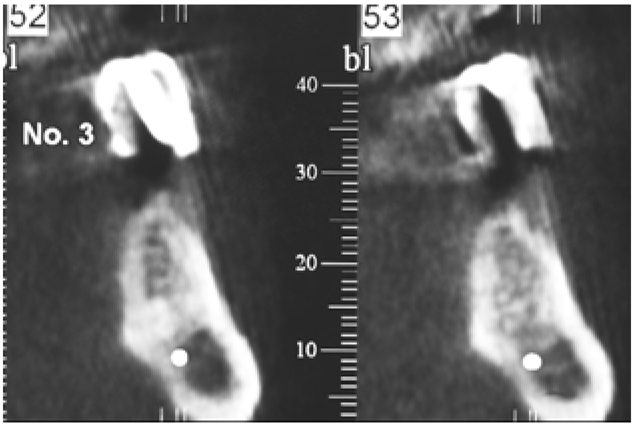

Fig. 1.59

Figs. 1.58 and 1.59 *The left mandibular premolar area on the first reconstruction: On the left image, the mental foramen appeared at cross-section image #48. On the right image, the crown of the 2nd premolar (region #35)—as depicted by the radiographic template—was observed after 4 cross-sections (#52) indicating 8mm distance.*

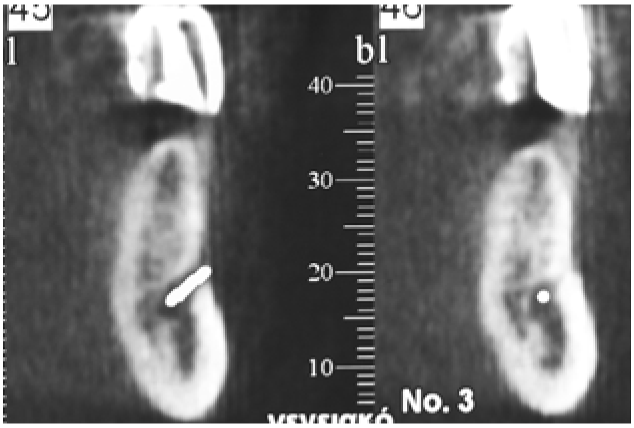

Fig. 1.60 *At the second reconstruction, the mental foramen appeared underneath the crown of the second premolar (# 35), as shown from the radiographic guide.*

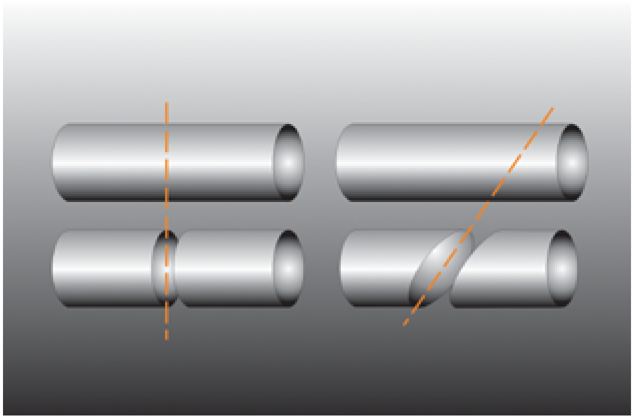

Fig. 1.61 *Diagrammatic cross-sections of a cylinder sliced perpendicular to its long axis (upper) and with side inclination (lower) (From Kourtis et al., 2012).*

1.12.3 Modification of the surgical plan and restoration

Based on the analysis of the images in the second reconstruction of the CBCT, the surgical plan was slightly modified aside from the implant length: The implant of the second premolar (#35) was placed in the predetermined position but the axis was changed with a labial inclination according to the alveolar crest to ensure a safe distance from the mental foramen. The implant for the first molar (#36) was shifted distally—closer to the second molar (#37)—to avoid creating an intra-coronal cantilever on the restoration (***Figs. 1.62 and 1.63***).

After uneventful osseointegration, the prosthetic restoration was completed with inclined abutments to compensate for the divergence of implants (***Fig. 1.64***). As it was already planned before implant placement, on the extended edentulous area of the mandibular left side (#34-37) a premolar was added between implant crowns #35 and #36 as a pontic (***Fig. 1.65***). In this way, over contouring of the restoration and an intra-coronal cantilever on the implant-supported molar crown could be avoided. The implants showed no signs of complications or infection at the annual recall (***Fig. 1.66***).

As demonstrated in this case, the initial scanning images of the CBCT must be drawn parallel to the occlusal plane as defined by the diagnostic wax-up of the final restoration. The radiographic guide offers valuable information about the planned location and inclination of the implant and the restoration. Proper image reconstruction following the dental scan can contribute significantly to accurate cross-section images and detailed presurgical planning. Using the occlusal plane as a reference point can result in more accurate cross-section images. The occlusal plane cannot always be recognized in partially or especially completely edentulous patients without the use of an accurate radiographic guide.

The guide should depict the outer surface of the planned restoration in order to facilitate its recognition on the CBCT images. If only guttapercha is used to indicate the long axis of the implants, the contour of the restoration is not shown on the CBCT and proper image reconstruction as well as implant positioning may be more challenging.

The bone drilling for implant placement is most frequently performed perpendicular to the peak of the alveolar crest, along the axis of the tooth in the planned restoration. Variation declination from the planned axis may lead to improper implant placement. The distance from the adjacent teeth and the mental foramen may also be affected. For these reasons, it is essential to use an accurate radiographic guide representing the occlusal plane of the patient.

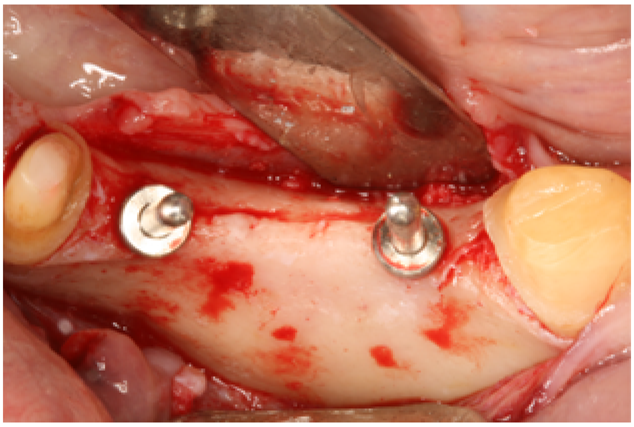

Fig. 1.62

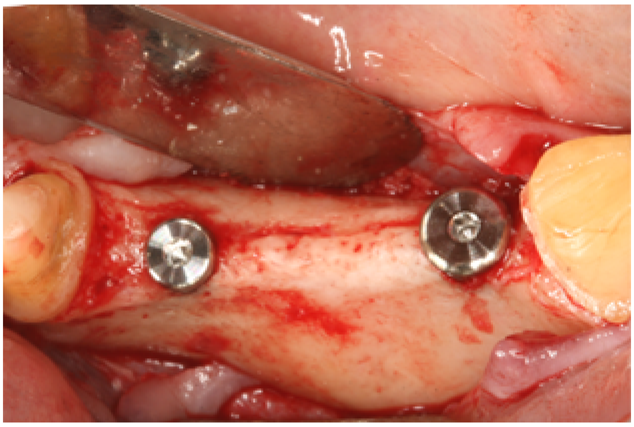

Fig. 1.63

Figs. 1.62 and 1.63 *The positioning indexes and the implants after insertion. (Courtesy of Dr. E. Skondra).*

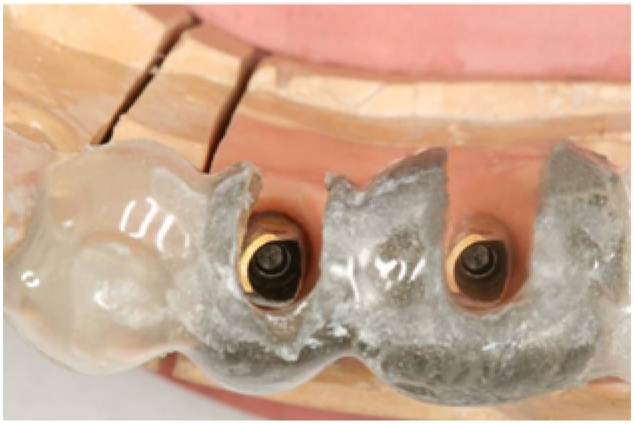

Fig. 1.64 *The surgical guide on the working cast. The implant for the first molar (#36) has been shifted distally according to the modified surgical plan to avoid over contouring. (Courtesy of Dr. E. Skondra).*

Fig. 1.65 *The restorations on the working cast. A premolar has been added between the implant crowns to avoid over contouring of the restoration. (Courtesy of Dr. E. Skondra.)*

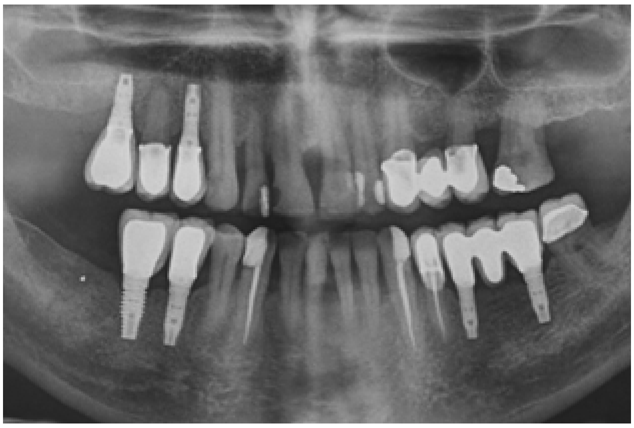

Fig. 1.66 *Radiographic examination at the annual year recall. The mental foramen is located right underneath the implant #35, as was noted at the second image reconstruction of the Computer Tomography (see Fig. 1.60).*

1.13 Clinical relevance

Presurgical planning is a crucial stage in implant restorations, both in the surgical and the prosthetic phase. Its necessity has been emphasized from the early years of osseointegration, but the extended possibilities offered by the augmentation techniques have also underlined the importance of the detailed treatment planning.

In every clinical case it is essential to collect and combine all the available information from the presurgical phase so as to make a detailed treatment planning. The cost-to-benefit ratio should always be evaluated and presented to the patient, who should be aware of all clinical stages, to obtain his informed consensus.

The treatment planning should always be based on the expected prosthetic restoration that can be visualized through a detailed wax-up. The possibility of completing the prosthetic restoration as initially planned should be based on the radiographic examination by Computed Tomography (CB or CBCT) with the radiographic template in-situ. Through this procedure, unforeseen difficulties can be recognized early, avoiding further complications or a compromised prosthetic restoration.

Although digital solutions (CAD/CAM planning, guided implant insertion) gain more ground in everyday practice, the clinician should always be able to make a precise treatment planning based on the established clinical and laboratory procedures. Even the most evolved digital systems have a degree of inaccuracy, and the end result remains always the responsibility of the clinician (**Turbush and Turkyilmaz, 2012; Hu et al., 2012; Platzer et al., 2013**). Due to these reasons, it remains essential—even if a digital system is being used—that the clinician can and should check and confirm the proposed treatment plan based on their extended knowledge of the whole procedure (**Binnon, 2007; Kourtis et al., 2012**).

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CHAPTER 2

Radiographic and Surgical Guides

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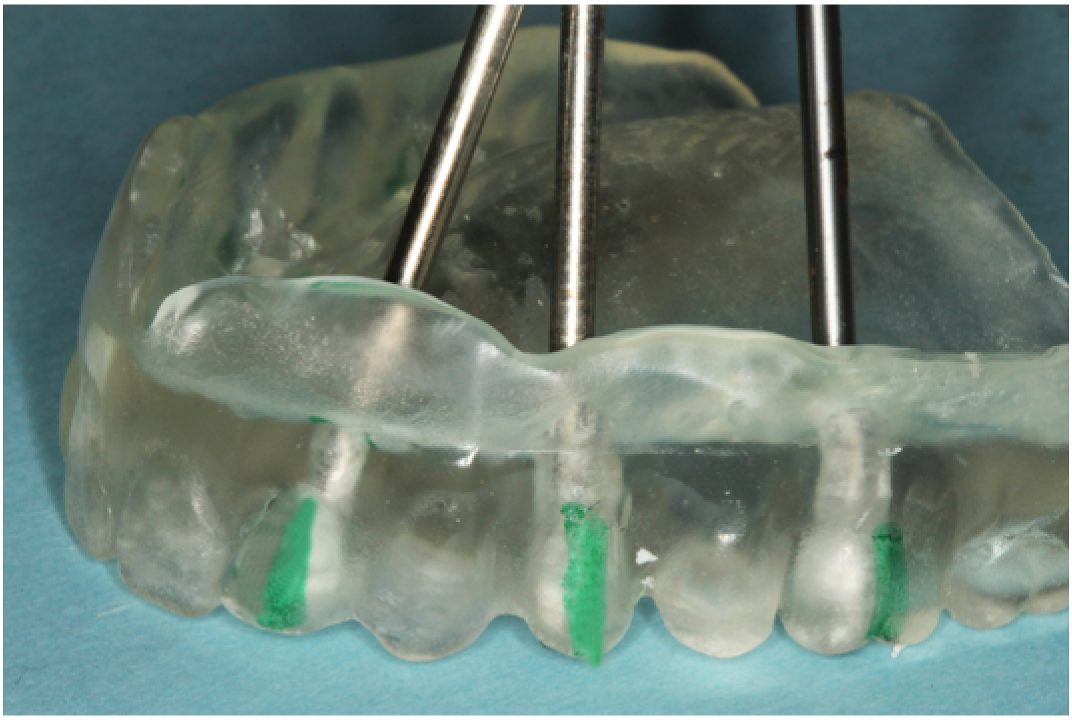
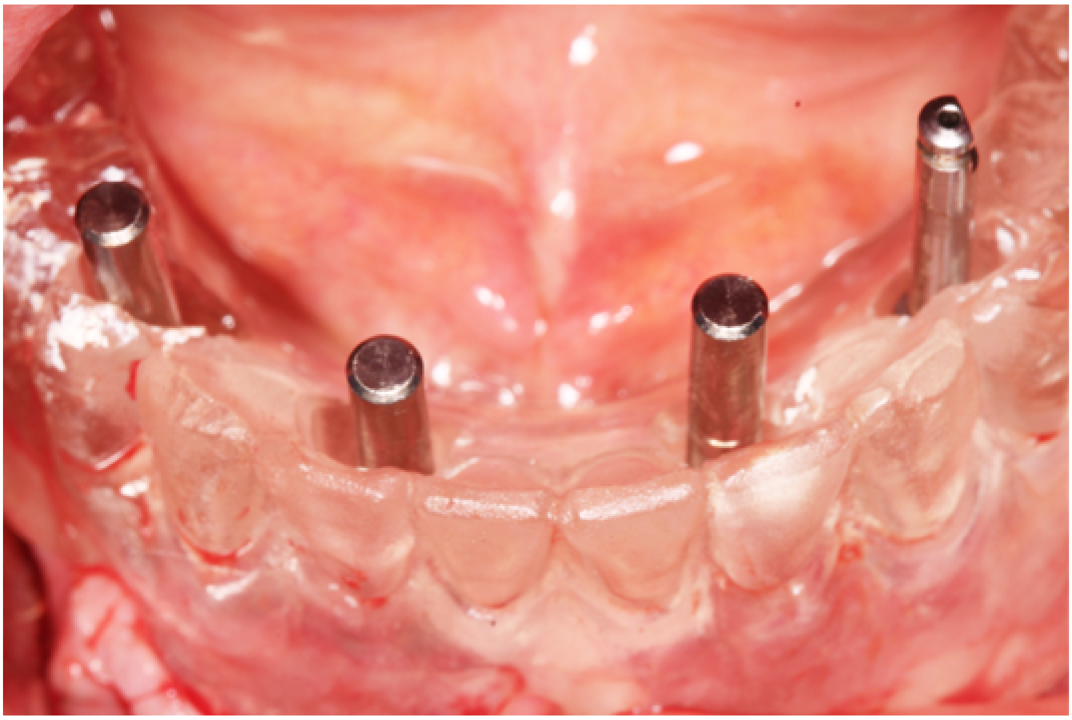




Abstract

Implant restorations are nowadays a treatment option in daily clinical practice. Both the patients and the clinicians, however, are concerned for the outcome of the planned restoration from a functional and esthetic point of view. Beside the correct surgical procedure, the clinician is challenged to predict the final result from the initial stages of the treatment. The radiographic and the surgical guides are valuable means to establish a solid treatment plan and orientate the clinician in the presurgical and the surgical steps of the treatment.

The aim of this chapter is to describe the fabrication of radiographic guides by using various radiopaque markers and their transformation to surgical guides for clinical use with clinical examples.

Knowledge background

*To understand the content of this chapter, the reader must be familiar with the initial steps of planning for a prosthetic restoration and the radiographic techniques, as mentioned in **Chapter 1**.*

2.1 Introduction

Implant restorations are nowadays a treatment option mostly accepted from the patients in the daily clinical practice. Both the patients and the clinicians, however, are concerned for the outcome of the planned restoration from a functional and an esthetic point of view. Beside the correct surgical procedure, the clinician is challenged to predict the final result from the initial stages of the treatment.

The position and inclination of the implants should be decided before any surgical procedure based on a detailed presurgical examination and evaluation. Vital anatomic structures (e.x. mandibular nerve, sinus), antagonist teeth and the available prosthetic space should be taken into consideration during the presurgical planning to ensure the best possible outcome of the restoration. The length, width and inclination of the implants can and should be decided based on the presurgical evaluation. Areas, where the bone substrate is insufficient or inadequate, should be recognized presurgically and if an augmentation procedure is considered as necessary, the patient should be informed and give their consent. A detailed presurgical evaluation and planning may minimize surgical difficulties and lead to a predictable outcome, and this has been recognized from the early days of clinical use of implants (**Lekholm, 1983; Murel and Davis, 1988; Lazzara, 1993**).

As described in the previous Chapter (Chapter 1), the available means for presurgical evaluation include the diagnostic casts, the diagnostic wax-up and the radiographic examination with a Panoramic x-ray and a Computer Tomography. The radiographic guide (also referred to as template, stent or splint) is a precious tool to transfer all the needed information from the diagnostic wax-up to the radiographic examination. In this way, the planned position and inclination of the implant can be depicted on the radiographic image (film or computer image) and possibly the contour of the planned restoration.

Based on this information the clinician can predict the final result, recognize the difficulties in specific regions and proceed to a prosthetically driven implant restoration. For this reason, the radiographic guide is usually transformed into a surgical guide (also referred to as template or stent) that can be used during surgery and transfer the acquired information on the surgical field. In this stage, it is also possible to correct the axis of a planned implant or select another region for implantation if a specific region is recognized as non-favorable from the radiographic examination. These corrections should be made upon transformation of a radiographic guide into a surgical guide. Although both the radiographic and the surgical guide will be used for very limited time during the presurgical and surgical steps of the treatment, they remain a valuable means to predict and achieve a good final result (**Mizrahi et al., 1998; Kopp et al., 2003**).

2.2 Aim

The aim of this chapter is to describe the fabrication of radiographic guides by using various radiopaque materials as markers and their transformation into surgical guides for clinical use with representative cases.

2.3 Radiographic Guides

Various types of radiographic guides have been proposed for clinical use over the years, and different radiopaque materials serving as indicators have been used. Each type has advantages and disadvantages. The purpose of the radiographic guide is to enable the clinician to correlate and correspond each anatomic region with the underlying bone structure. It can also depict the direction of the planned implant or even visualize the contour of the planned restoration—as it is formed from the diagnostic wax-up—on the radiographic image (printed on film or in digital image).

The clinician who analyzes a Computer Tomography or a CBCT (Cone Beam Computed Tomography) without a radiographic guide cannot always recognize the specific edentulous region of a tooth on the section images with accuracy, as for example in ***Figs. 2.1 and 2.2***. Although this case is a partially edentulous patient with missing teeth on the mandibular left side, it is hard to correspond accurately the cross-section image, where the mental foramen is shown with the exact location in the mouth.

The only possible method is to recognize the specific cross-section image on the Computer Tomography and then measure the distance from the adjacent tooth taking into consideration the number and "thickness" of the cross-section images. In cases of completely edentulous patients (***Figs. 2.3 and 2.4***), it is even more difficult to identify a specific region and correspond the bone substrate—as depicted on the cross-section images—to a specific edentulous region. In this way, it is not possible to have accurate measurements for each region and transfer this information on the surgical field.

The most common types of radiographic guides are fabricated from autopolymerizing or heat-polymerizing resin with radio-opaque materials (usually guttapercha) used as markers for specific anatomical regions.

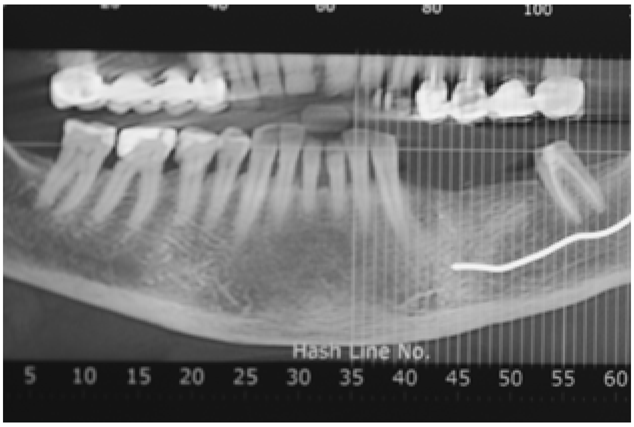


Fig. 2.1

Fig. 2.1 *CBCT of a partially edentulous patient in the mandible.*

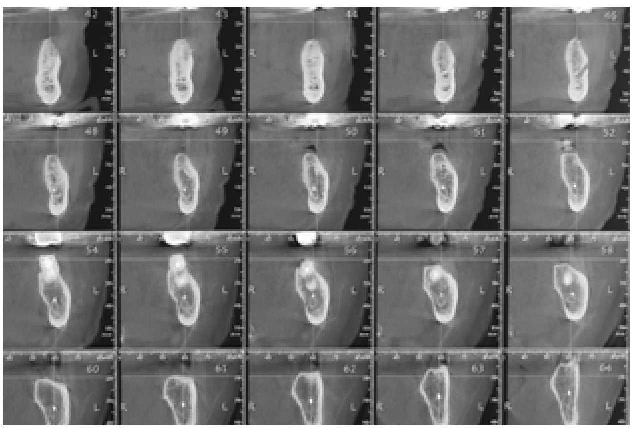


Fig. 2.2

Fig. 2.2 *Cross-section images of the edentulous area of Fig. 2.1. It is not possible to accurately correspond the cross-section image of the mental foramen to the clinical location.*

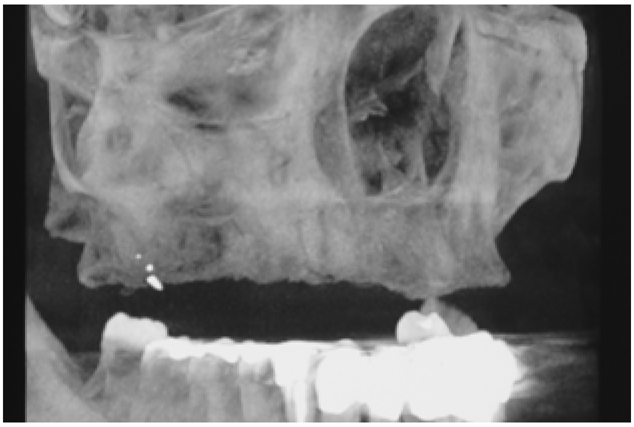


Fig. 2.3
Fig. 2.3 *CBCT of a completely edentulous patient in the maxilla.*

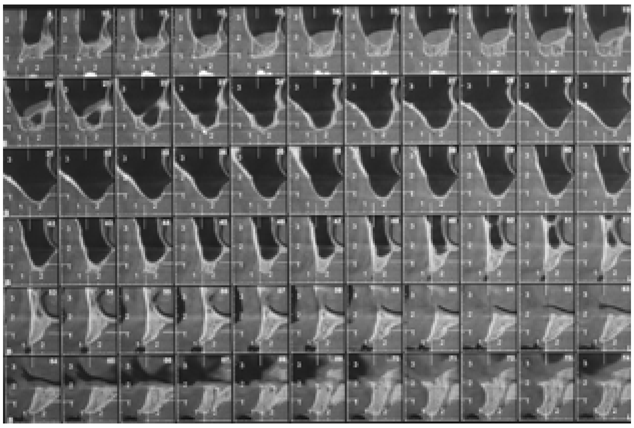


Fig. 2.4

Fig. 2.4 *Cross-section images of the edentulous maxilla of Fig. 2.3. It is not possible to correspond the images to the clinical regions.*

2.4 Radiopaque Materials

Beside guttapercha, other radiopaque materials have been proposed for use in the fabrication of radiographic guides to indicate the planned axis of the implant such as orthodontic wire, titanium rods, lead foils (from x-ray periapical films) and composite resin (**Pesun and Gardner, 1995; Borrow and Smith, 1996; Kraut, 1997; Rosenfeld and Mecall, 1998; Rothman, 1998; Rosenfeld and Mecall, 1998; Zitzmann and Marinello, 1999; Almog et al., 2001; Ganz, 2001; Kopp et al., 2003**).

Guttapercha is the most widely used material as it is easy to use, cost effective, and offers a clear radiographic image without "noise" or distortion. Finally, it can easily be removed from the guide during transformation into a surgical guide. The guttapercha cones are condensed in the hollow space—created by drilling—and are cut with hot instruments. Titanium rods are also an option, but wider drilling is needed to insert and fix the rods on the guide. Lead foils are extremely radiopaque, and if they are not shaped properly, they may cause distortion. Even if no radiopaque material is used, the hollow space in the guide will appear as a dark line on the radiographic image, since the autopolymerizing resin has a low but distinguishable radiopacity.

Other materials have been used as radiopaque coating for the outer surface of the guide, such as zinc foil, lead foil or guttapercha diluted in chloroform (**Israelson et al., 1992; Guerra et al., 1997; Tsuchida et al., 2004**). Barium sulfate has also been proposed as a radiopaque material added in the mass of acrylic resin (**Basten and Kois, 1996; Shahrabasi and Hansen, 2002**). However, the radiographic image created by the amalgam powder on the cross-section images of the Computer Tomography or CBCT is sharper compared to other materials (**Kourtis, 2002; Kourtis, 2018**).

2.5 Marking of the implant positions on the study casts (Case A, Figs. 2.5-2.8)

As explained in the previous chapter (Chapter 1), study casts and diagnostic wax-up are essential steps for the presurgical evaluation. For the fabrication of a radiographic guide two sets of study casts are needed; one set will be used for the wax-up and the other intact set will be used for the fabrication of the guide. The study casts should be mounted on a semi-adjustable articulator and the positions of the implants should be marked on the edentulous alveolar ridge on the casts (***Figs. 2.5 and 2.6***). In this stage, it is easy to measure distances from neighboring teeth and between implants. The implants should have a minimum distance of 1,5-2 mm from the adjacent teeth and 3 mm from each other. Taking into consideration that the usual implant diameter is 3,75-4mm, the minimum distance between the centers of adjacent implant centers should be 7mm (**Lazzara, 1993; Tarnow et al., 2000; Belser et al., 2000**). If wider implants are planned, the distance between implants centers should be calculated accordingly. These marks on the study casts can be helpful orientation points for the wax-up (***Figs. 2.7 and 2.8***).

For the diagnostic wax-up it is important to evaluate and consider the inclination of the roots of the neighboring teeth. A line marking the distal edge of the adjacent root is helpful to orientate the axis of the most mesial or distal implant to avoid contact or hurting of the root (***see also Case F in Chapter 1***).

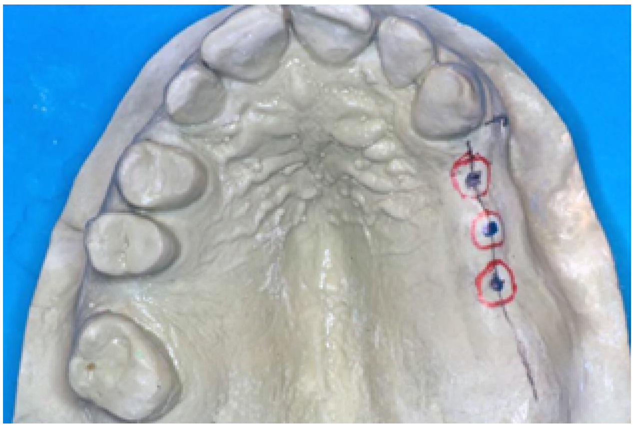


Fig. 2.5

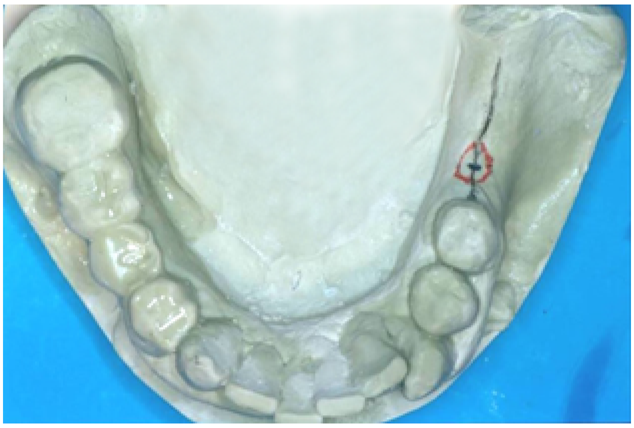


Fig. 2.6

Figs. 2.5 and 2.6 *Case A, study casts with marked positions of the implants on the alveolar ridge.*

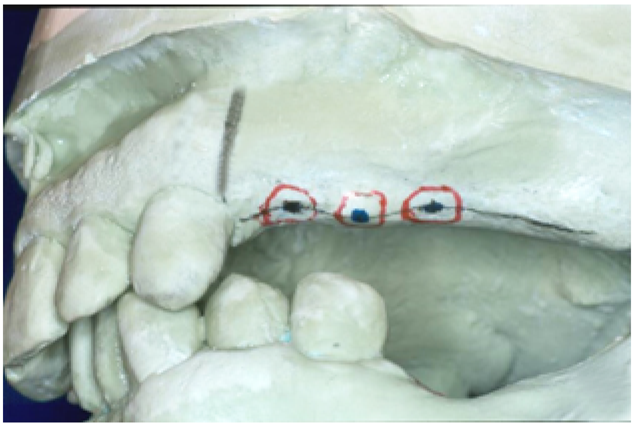


Fig. 2.7

Fig. 2.8

Figs. 2.7 and 2.8 *The articulated casts and the wax-up. A line showing the edge of the canine root has been marked on the study cast.*

2.6 Fabrication of a radiographic guide for a partially edentulous patient (Case B, Figs. 2.9-2.24)

As mentioned in the previous case, the first step is the fabrication and articulation of the study casts in a semi-adjustable articulator. The positions of the planned implants are marked on the alveolar ridge (***Figs. 2.9 and 2.10***). A full diagnostic wax-up is made on the articulated casts with the planned teeth of the restoration in full contour (***Figs. 2.11 and 2.12***). The cervical part of the teeth in the wax-up should mimic the contour of the natural teeth taking into consideration the bone resorption. As the edentulous alveolar ridge is usually resorbed on the labial side, the neck of the planned implant is located more lingually or palatally than the natural tooth.

Alternatively, a diagnostic set-up on the edentulous areas can be made using denture teeth. In these cases, however, attention should be given in the contour of the cervical part of the tooth and on the mesial-distal dimension of the tooth, as the denture teeth are usually narrower than the natural teeth (**Almog et al., 2001; Greenstein and Cavallaro, 2007**).

Fig. 2.9

Fig. 2.10

Figs. 2.9 and 2.10 *Case B, maxillary and mandibular study casts.*

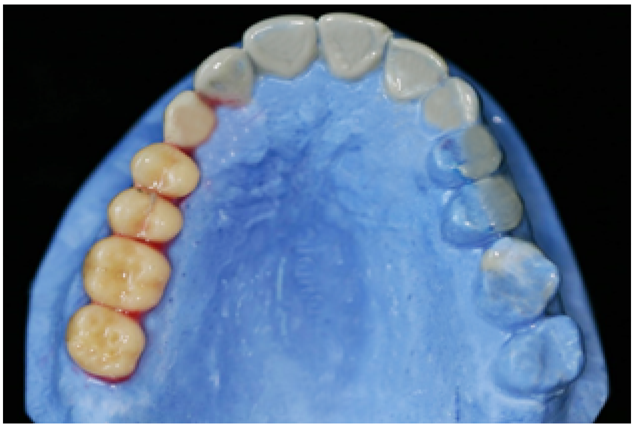


Fig. 2.11

Fig. 2.12

Figs. 2.11 and 2.12 *Diagnostic wax-up and set-up.*

The wax-up (or the set-up) is duplicated using an alginate or silicone impression. On the duplicate cast a thermoplastic sheet (***Figs. 2.13 and 2.14***) is formed by heat and pressure in a special device (e.g., Essix or Omnivac machine). The sheet should have a medium thickness of 1,5mm to keep its form after removal from the duplicate cast.

The thermoplastic sheet is cut to the proper shape 2-3 teeth away from the edentulous area. The sheet is then adapted on the intact (original) study cast and the fit is checked (***Figs. 2.15 and 2.16***). The hollow space in the sheet (that represents the teeth to be restored with implants) is filled with autopolymerizing resin, usually white in color or translucent. The sheet is then fixed on the study cast with rubber rings to avoid any micromovement during the final polymerization.

Fig. 2.13

Fig. 2.14

Figs. 2.13 and 2.14 *Thermoplastic sheet formed by heat and pressure on the duplicate casts from the wax-up.*

Fig. 2.15

Fig. 2.16

Figs. 2.15 and 2.16 *The thermoplastic sheets after trimming on the study casts.*

After polymerization of the resin, the formed guide is removed from the cast and trimmed to the final shape. The center of the occlusal surface is marked, and orientation lines are drawn with a marker along the labial and lingual surfaces of the teeth on the guide indicating the planned implant axis (***Figs. 2.17 and 2.18***).

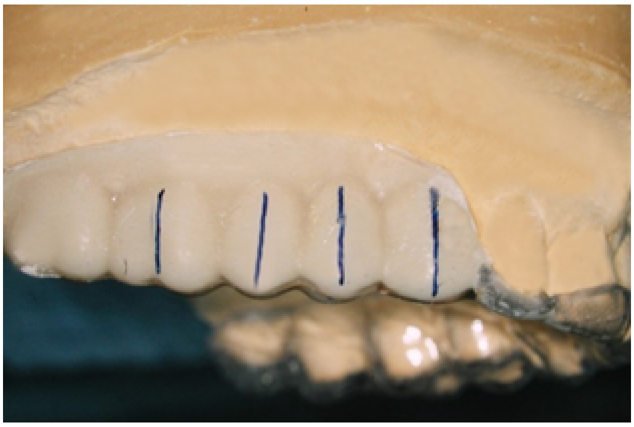


Fig. 2.17

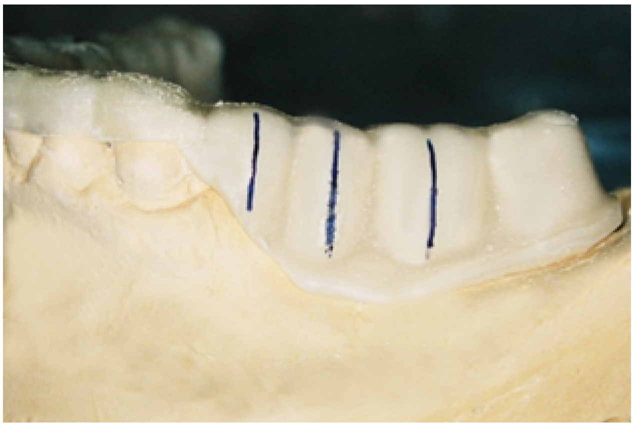


Fig. 2.18

Figs. 2.17 and 2.18 *The hollow space on the thermoplastic sheet is filled with autopolymerizing resin. Orientation lines are marked on the outer surfaces.*

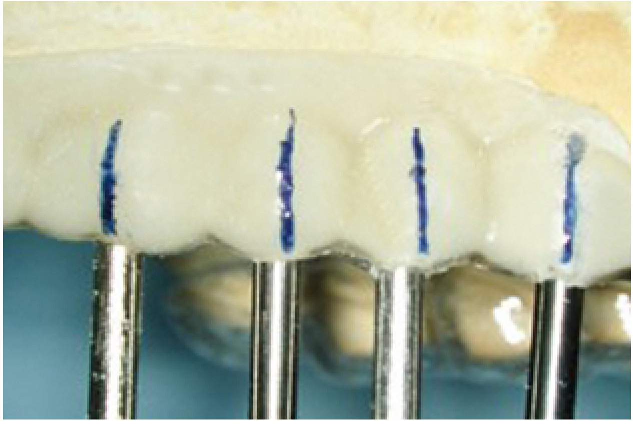


Fig. 2.19 **Fig. 2.20**

Fig. 2.19 *Drillings are made through the mass of the resin indicating the implant inclination.*
Fig. 2.20 *The drillings are filled with guttapercha.*

The guide is drilled along the marked lines from the occlusal surface to the alveolar crest pointing the mark on the basal surface of the guide. The drilling should be at least 2,5mm wide to allow the use of the guide with the pilot surgical drill, which is usually 2mm in most implant systems. The parallel axis of the drillings can be checked visually by inserting laboratory rotating instruments in the drillings (***Fig. 2.19***).

The hollow space of the drillings is filled with a radiopaque marker, usually guttapercha (***Fig. 2.20***). Alternatively metal rods, preferably titanium, with the corresponding diameter can be used. The radiopaque material will indicate the planned implant axis on the radiographic examination.

The contour of the planned restoration can also become radiopaque using amalgam powder diluted in nail varnish (**Kourtis, 2018**). The outer surface of the acrylic teeth is covered with amalgam powder dissolved in transparent nail varnish. The varnish is applied with a soft brush as a thin layer on the whole outer surface (labially and palatally) up to the cervical areas (***Fig. 2.21***). The varnish layer should be restricted to the areas where implants are planned to avoid unnecessary image "noise" and to facilitate area recognition of specific regions on the cross-section images of the Computer Tomography (Figs. 2.22 and 2.23).

The patient is then referred for a Computer Tomography. On the reconstructed cross-section images the radiopaque markers can be easily identified in the specific areas. The planned implant axis and the contour of the restoration can be correlated (with/ related to) to the existing bone substrate (***Fig. 2.24***). In this way, it is easy to recognize any unfavorable implant inclination that may jeopardize vital structures (see also Chapter 1) and predict in advance the need of augmentation in specific regions. Any needed corrections can be made upon transforming the radiographic guide into a surgical guide.

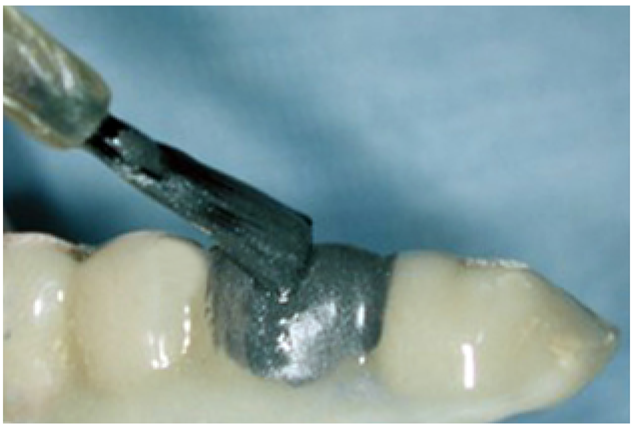


Fig. 2.21

Fig. 2.21 *A thin layer of amalgam powder diluted in nail varnish is applied on the outer surfaces of the guide.*

Fig. 2.22

Fig. 2.23

Figs. 2.22 and 2.23 *The radiographic guides before delivery.*

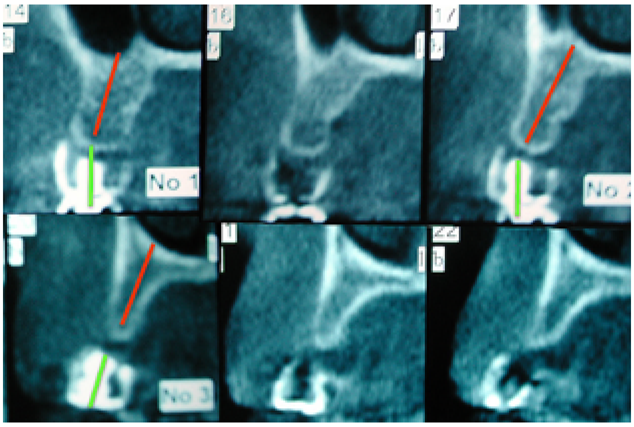


Fig. 2.24 *Cross-section images of the maxillary edentulous areas. Both the implant axis and the contour of the restorations can be distinguished on the radiographic image. The green line indicates the axis of the restoration, and the red line shows the long axis at the middle of the alveolar crest.*

In cases of partially edentulous patients that have prepared teeth mesially and distally of the edentulous space, the radiographic guide can be fabricated in the form of a provisional Fixed Dental Prosthesis supported on the prepared teeth. An existing provisional restoration may also be modified to be used as a radiographic guide (**Stellino et al., 1995; Rosner et al., 2006**). The provisional restoration can be coated with amalgam powder and the drillings in the center of the tooth can be filled with guttapercha, as mentioned above.

2.7 Fabrication of a radiographic guide for a completely edentulous patient (Case C, Figs. 2.25-2.36)

In completely edentulous patients the first steps are the same as if a new denture would be fabricated. Study casts are made and the interocclusal relation is registered with base plates and wax rims. The study casts are mounted on a semi-adjustable articulator and a complete tooth-set up is made following the rules for the fabrication of a complete denture. The set-up is tried intraorally, and all needed corrections are made accordingly (**Sadan et al., 1997; Zitzmann and Marinello, 1999**). If the patient has a denture that fulfills their demands and has acceptable esthetic appearance, the existing denture can be duplicated and be used as a radiographic guide.

An impression of the base plate and the tooth set-up is obtained with alginate or silicone using a special device (e.g. a denture duplicator) or two metal impression trays, or two plastic bases for casts that fit to each other (***Fig. 2.25***). The basal surface of the denture is pressed into one base filled with the impression material (***Fig. 2.26***). After its setting, the baseplate with the wax-up (or the denture) is left in place and the impression material is cut level to the rim of the base.

The surface of the impression material is covered with Vaseline or other separating medium to avoid sticking of the impression material on the two bases. The other base is filled with impression material and the two bases are fitted together. Triangle-shaped indentations are made on the impression material of the one bass to facilitate the exact positioning of the two bases. After polymerization, the impression material is also cut level on the side rims of the bases and the base plate with the wax-up is removed (***Fig. 2.27***).

The created hollow space is filled with autopolymerizing resin and the two bases (or the metal trays) are fitted together till the final polymerization of the resin material. Translucent resin is preferred as it facilitates the later drillings in the mass of the guide and its transformation into surgical guide. The bases are held together with rubber bands to avoid any movement during the polymerization. The radiographic guide is removed from the bases (or the duplicator), trimmed to the final shape and polished (***Fig. 2.28***).

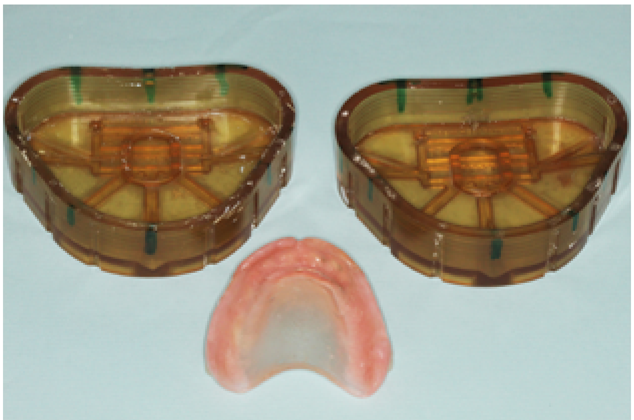


Fig. 2.25

Fig. 2.25 *Case C, the existing denture and the plastic bases for duplication.*

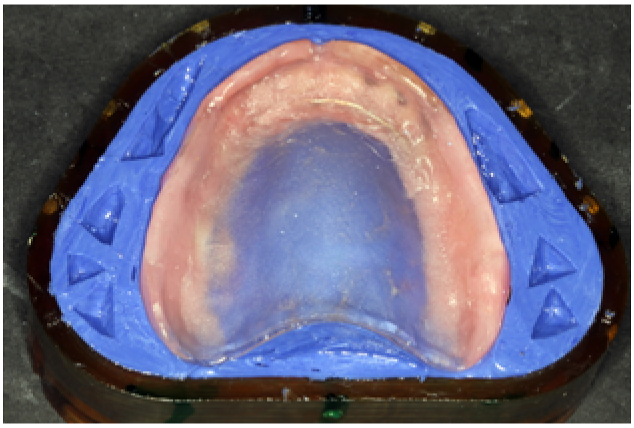


Fig. 2.26

Fig. 2.27

Figs. 2.26 and 2.27 *Duplication of the denture.*

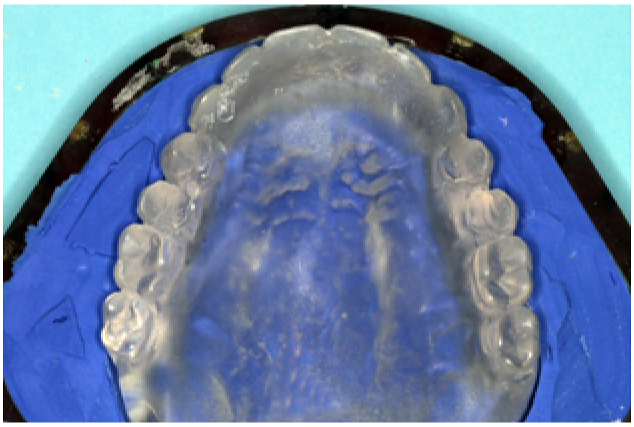


Fig. 2.28

Fig. 2.28: *The radiographic guide fabricated from autopolymerizing translucent resin.*

On the occlusal and palatal surfaces of the teeth, markings are drawn to identify the most favorable position of the planned implant (***Figs. 2.29 and 2.30***). Orientation lines are drawn on the labial surface to indicate the inclination of implants. The radiographic guide is drilled in the center of the teeth where implants are planned, and the drillings are filled with guttapercha (***Figs. 2.31 and 2.32***).

Fig. 2.29

Fig. 2.29 *Markings on the occlusal surface of the teeth indicating the implant positions.*

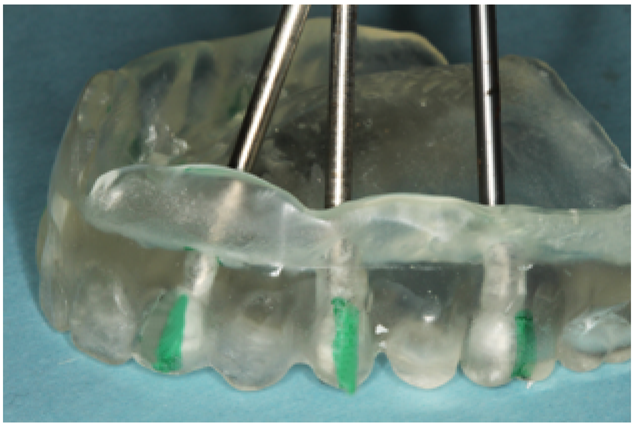


Fig. 2.30

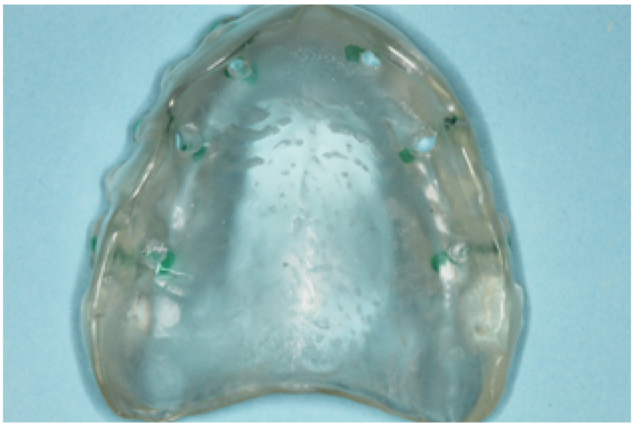


Fig. 2.31

Figs. 2.30 and 2.31 *The guide is drilled following the orientation lines that indicate the planned inclination of the implants.*

Fig. 2.32

Fig. 2.32 *The hollow spaces are filled with guttapercha.*

The contour of the teeth can also be made radiopaque by coating the outer surface of the teeth with amalgam powder diluted in nail varnish (***Figs. 2.33 and 2.34)***, as described previously (**Kourtis, 2018**). The patient is referred for a Computer Tomography and the final treatment plan can be decided based on the correlation of the planned position of the teeth to the existing bone substrate (***Figs. 2.35 and 2.36***).

The use of a radiographic guide in the form of a complete denture also facilitates the radiographic examination; the patient can keep the mandible stable to maximum intercuspation, and the image reconstruction can be made perpendicular to the occlusal level (see also Chapter 1), as defined from the denture, and recognized on the radiographic imaging (**Floyd et al., 1999; Kourtis et al., 2012**).

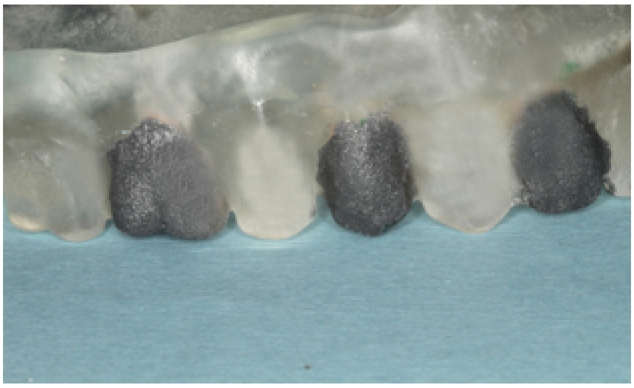


Fig. 2.33

Fig. 2.34

Figs. 2.33 and 2.34 *Coating of the outer surfaces of selected teeth with amalgam powder.*

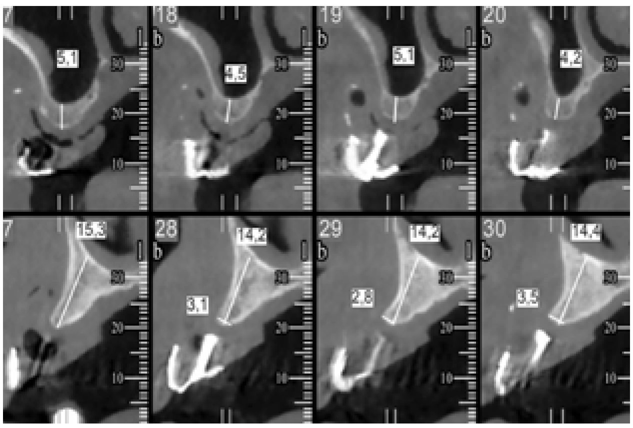


Fig. 2.35

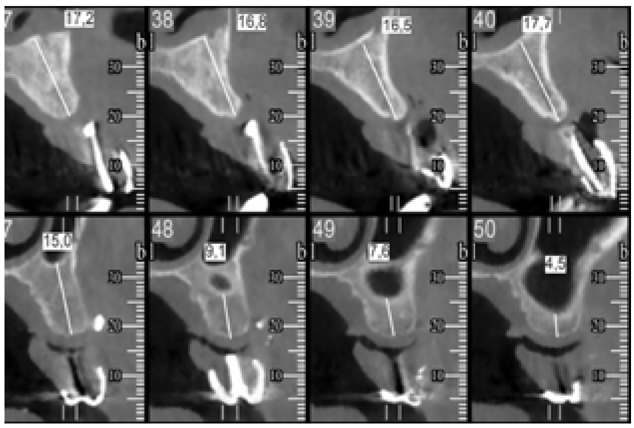


Fig. 2.36

Figs 2.35 *and 2.36: Cross-section images of the edentulous alveolar ridge. Both the implant inclination and the contour of the planned restoration are clearly marked and recognized.*

2.8 Surgical Guides

According to the Glossary of Prosthodontic Terms (**Academy of Prosthodontics, 2017)** the surgical guide (also referred to as template, stent or splint) is defined as "…a guide to assist in proper surgical placement of dental implants." The surgical guide for partially edentulous patients should be fitted on the adjacent teeth and remain stable during the surgical procedure. It should also indicate the planned axis of the implant and the contour of the restoration in the surgical field, as designed from the wax-up.

The guide should allow the elevation of a flap without restricting the surgical drillings (**Sadan et al., 1997; Almog et al., 2001; Meitner and Tallents, 2004**). In all cases, the communication of the restoring dentist with the surgeon is of crucial importance, as the use of the surgical guide intraoperatively depends on its design and on the ease of use during the surgical procedure (**Burns et al., 1988; Becker and Kaiser, 2000**).

The surgical guides are usually fabricated by transforming the radiographic guide after the radiographic examination (***Figs. 2.37 and 2.38***). The radiopaque materials are removed and the drillings are cleaned and prepared for use with the surgical drills. The openings should have a minimum diameter of 2,5-3mm to allow the use of the pilot drill, which is usually 2mm in most implant systems. The amalgam powder is removed from the occlusal surfaces using a dissolvent for nail varnish (e.g. acetone) and the surface is thoroughly cleaned with alcohol solution. The marking line along the labial side may be redrawn to facilitate the paralleling of the implants.

Fig. 2.37

Fig. 2.38

Fig. 2.37 *Radiographic guide to be transformed into a surgical guide.*

Fig. 2.38 *Transformation into a surgical guide. The labial surfaces have been removed.*

There are different types of surgical guides; usually the labial surface of the radiographic guide is removed to allow easy positioning of the pilot drill (***Fig. 2.38***). Alternatively, the lingual surface can be removed, and the labial surface can be left intact to show the contour of the restoration (***Fig. 2.39***). Another type of surgical guide can be fabricated from a thin thermoplastic sheet from the duplicate cast of the wax-up and can be drilled on the occlusal surface (***Fig. 2.40***). This type of guide allows better visualization of the position, inclination and contour of the restoration during drilling (**Wat et al., 2002**).

Fig. 2.39

Fig. 2.40

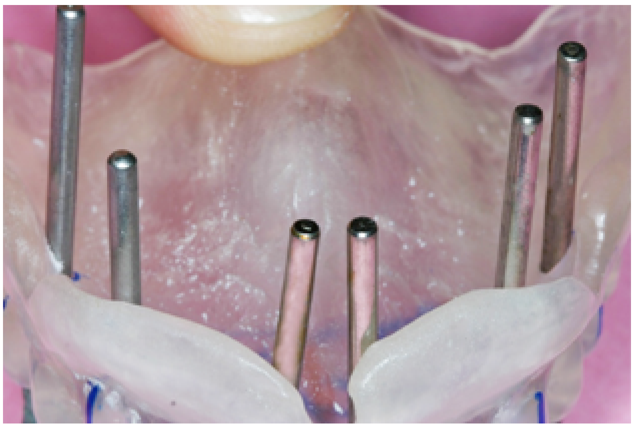
Fig. 2.39 *Surgical guide where the lingual surface has been removed.*

Fig. 2.40 *Surgical guide fabricated as a thin thermoplastic sheet from the wax-up.*

The use of metal tubes incorporated in the surgical guide has been proposed to indicate the planned axis of insertion of the implant in the surgical field (**Annibali et al., 2009**). Although this technique can orientate the surgeon to the optimal prosthetic inclination of the implant, surgical defects or absorption of the alveolar ridge may impose a different insertion of the implant.

In case that a modification of the implant inclination is needed, it should be performed in this step and the drilling axis should be modified accordingly to avoid trauma on the root of the adjacent tooth. This is usually encountered in the first premolar region if the root of the canine has distal inclination (see Chapter 1). In these cases, the implant should be parallel to the root of the neighboring tooth (**Sethi et al., 2002**).

The surgical guide for completely edentulous patients is usually fabricated as a transformation of the radiographic guide by removing the radiopaque materials. For completely edentulous patients in the maxilla, the surgical guide has usually the form of a duplicate complete denture where a "window" is created on the palatal surface to allow flap elevation and control of the implant position (***Figs. 2.41-2.44***). The surgical guide should have adequate thickness to ensure stability during the surgical procedure.



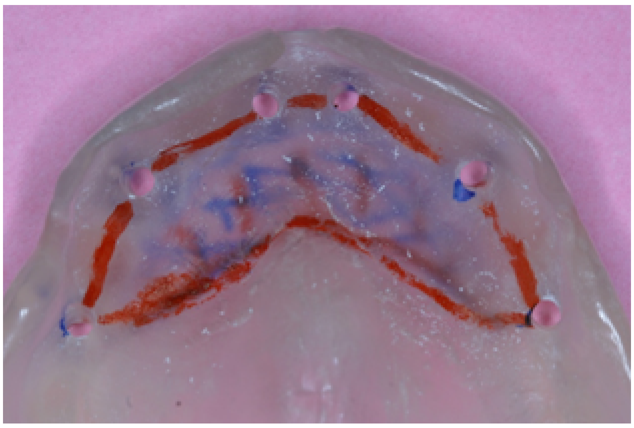


Fig. 2.41

Fig. 2.42

Fig. 2.41 *Surgical guide for a completely edentulous patient as a duplicate from the existing denture with metal rods indicating the implant inclinations.*

Fig. 2.42: *A "window" is drawn on the palatal surface to indicate the planned opening.*

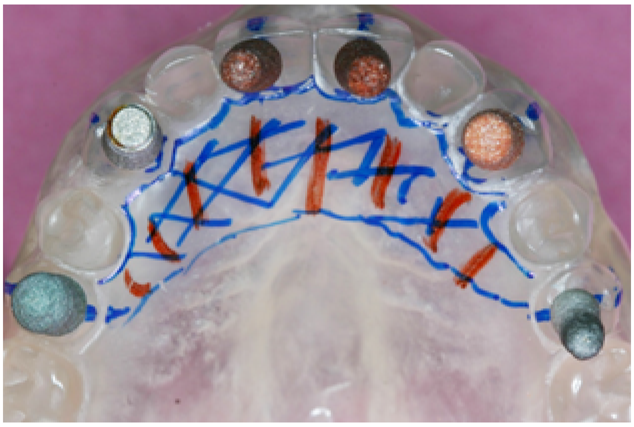


Fig. 2.43

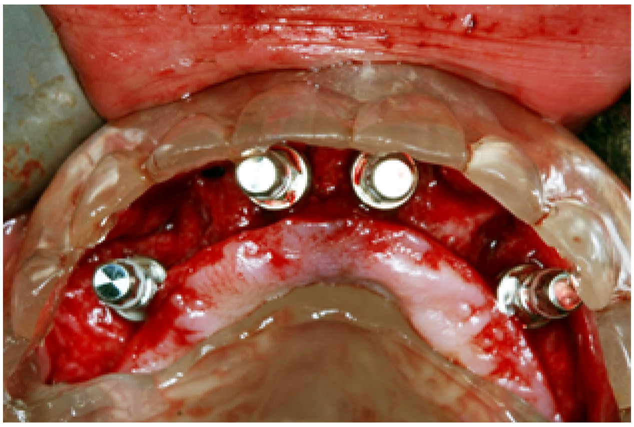


Fig. 2.44

Fig. 2.43: *The opening should extend to the drillings.*

Fig. 2.44: *Intraoperative control of the implant positions and inclinations with the surgical guide.*

For edentulous patients in the mandible, the surgical guide is also fabricated as a duplicate from the set-up or the existing denture (***Fig. 2.45***). The creation of a "window" on the labial surface of the denture reduces the strength of the guide. To avoid weakening of the guide, drillings are made through the acrylic teeth to indicate the planned position and inclination of the implants (***Fig. 2.46)***. Mandibular guides have reduced stability and should be held by the surgeon or the assistant during implantation. They are also difficult to use if extended flaps are necessary. Due to these reasons, they are usually used for the initial pilot drill and the check of implant position after insertion (***Figs. 2.47 and 2.48***).

Fig. 2.45

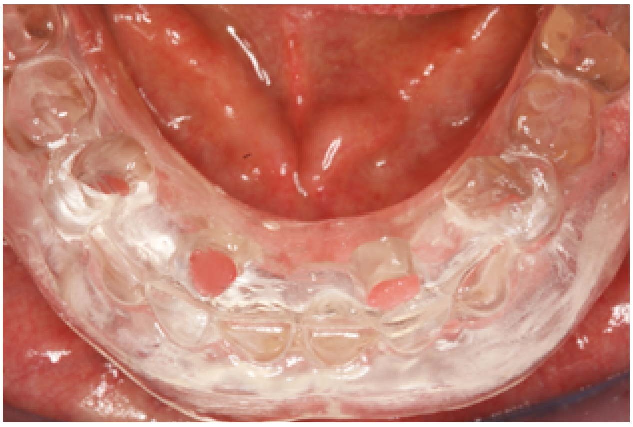
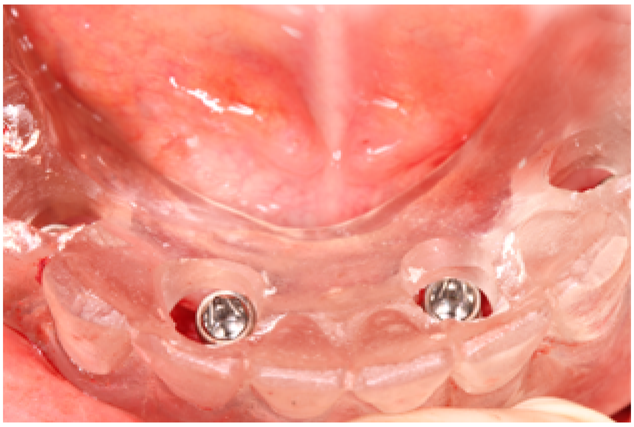


Fig. 2.46

Fig. 2.45: *Surgical guide for edentulous patient in the mandible as a duplicate of the existing denture.*

Fig 2.46: *The surgical guide with drillings indicating the planned positions and inclinations of the implants.*



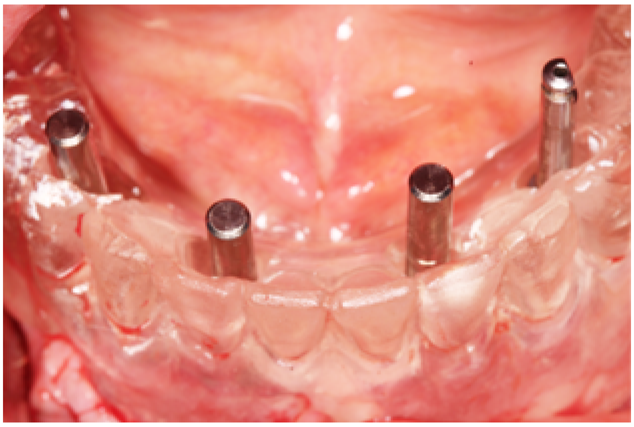


Fig. 2.47 **Fig. 2.48**

Figs. 2.47 and 2.48 *Intraoperative control of the implant positions and inclinations with the surgical guide (Surgery Prof. P. Madianos).*

The surgical guides may be contaminated during fabrication in the dental laboratory and are then used in surgical procedures. Therefore, it is crucial that they should be cleaned and disinfected prior to implant surgery (**Török et al., 2020**). If sterilization is not possible due to the possible deformation of the acrylic resin, disinfection in 70-80% alcohol solution for 15 min offers clinically acceptable safety (**Sennhenn-Kirchner et al., 2008; Smith et al., 2011**).

Surgical guides fabricated from 3D printing using other polymers than PMMA have been shown as more resistant to the commonly used steam autoclaving procedure without showing any deformation after sterilization (**Marei et al., 2019; Török et al., 2020*).***

2.9 Prosthetically driven implantation for a single tooth (Case D, Figs. 2.49-2.54)

In this case, the patient missed the maxillary right canine congenitally. After measuring the mesial-distal available space on the study cast, a full-contour diagnostic wax-up was made (***Figs. 2.49 and 2.50***). The radiographic examination revealed adequate bone substrate in height and width. A surgical guide was fabricated with a thin thermoplastic sheet from the duplicate cast of the wax-up (***Fig. 2.51***). The surgical guide facilitated the exact positioning of the implant in the edentulous space (***Fig. 2.52***). The patient was restored with a cement-retained implant-supported crown on a customized UCLA abutment (***Figs. 2.53 and 2.54***).

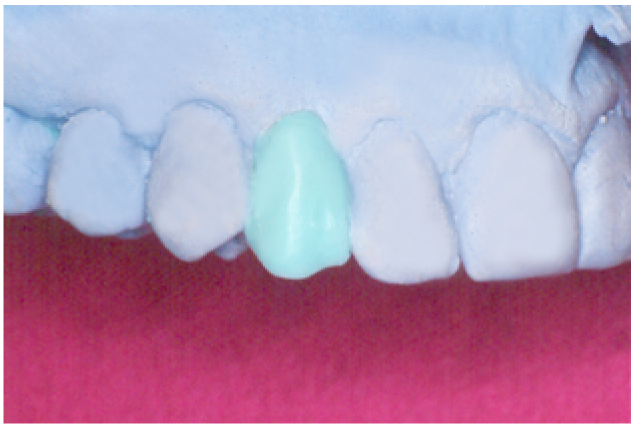


Fig. 2.49 **Fig. 2.50**

Fig. 2.49 *Case D, measurement of the available space on the study cast.*
Fig. 2.50 *Full-contour wax-up of the missing canine.*

Fig. 2.51

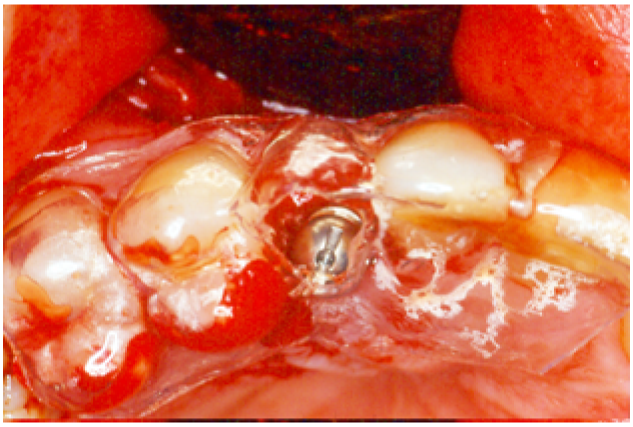


Fig. 2.52

Fig. 2.51 *Surgical guide fabricated from a thin thermoplastic sheet.*
Fig. 2.52 *Exact positioning of the implant with the surgical guide.*

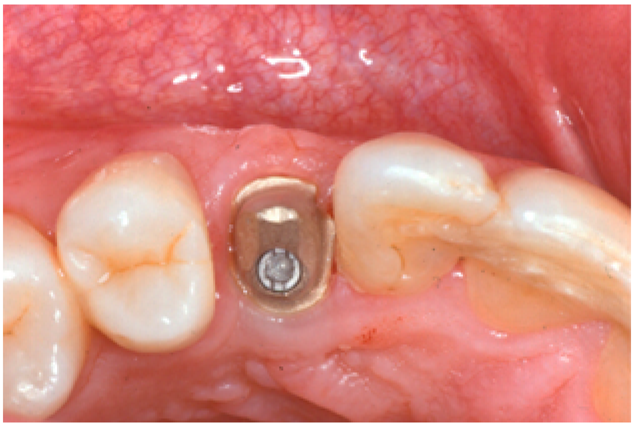


Fig. 2.53

Fig. 2.54

Figs. 2.53 and 2.54 *Customized UCLA abutment for a cement-retained crown and the final restoration.*

2.10 Prosthetically driven implantation for a partially edentulous patient (Case E, Figs. 2.55-2.62)

In this clinical case, all the anterior mandibular teeth were missing ***(Fig. 2.55***). On the study cast a full contour wax-up was done for a six-unit Fixed Dental Prosthesis supported by two implants in the mandibular canine region bilaterally (***Figs. 2.56-2.58)***.

Fig. 2.55

Fig. 2.56

Fig. 2.55 *Case E, initial clinical situation.*
Fig. 2.56 *Mandibular study cast.*

Fig. 2.57

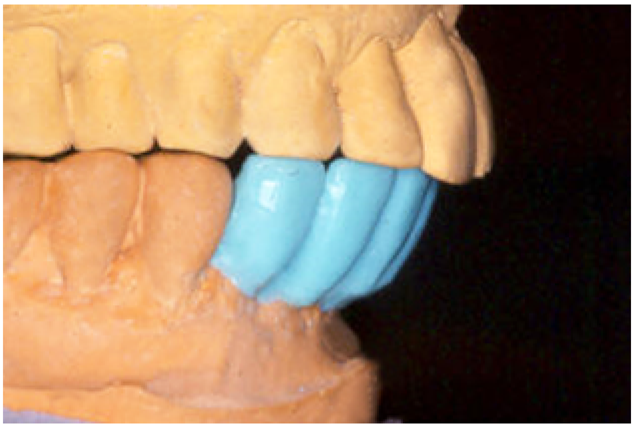


Fig. 2.58

Figs. 2.57 and 2.58 *Mounted study casts and wax-up in full-contour.*

It was important to mark accurately the regions of the canines and have a prosthetically favorable inclination of the implants. If the implant is not inserted precisely in the planned position, it may compromise the final esthetic outcome as the implant may be positioned in the interdental space of two teeth in the restoration. The inclination of an implant can be compensated by using an angulated abutment, but an unfavorable position cannot be corrected later. From the wax-up a surgical guide was fabricated from a thin thermoplastic sheet (***Fig. 2.59***).

This type of guide facilitated its use during the whole surgical procedure—from the initial drilling to the final insertion—and allowed visualization of the restoration contour during the implantation procedure (***Fig. 2.60***). In this way, minor corrections of the implant axis could be done during surgery to facilitate the prosthetic restoration. The implants were inserted in the planned positions and the implant abutments were within the planned contour of the restoration (***Fig. 2.61***). The patient was restored with a fixed implant-supported restoration on two prefabricated straight abutments (***Fig. 2.62***).

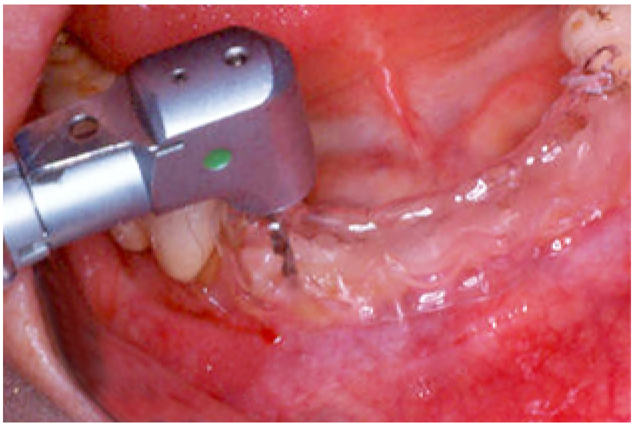


Fig. 2.59 Fig. 2.60

Fig. 2.59 *Surgical guide as a duplicate from the wax-up.*
Fig. 2.60 *Initial drilling through the surgical guide.*

Fig. 2.61 Fig. 2.62

Fig. 2.61 *The implant abutments are in the planned positions within the contour of the restoration.*
Fig. 2.62 *Case E, the final implant restoration.*

2.11 Clinical relevance

Radiographic and surgical guides are valuable means for accurate treatment planning in implant restorations. They offer the possibility of "visualization" of the planned restoration from the early step of radiographic examination. Any needed modifications to implant positioning or inclination can and should be made prior to surgery. In cases where the anatomic situation does not allow implant placement or Guided Tissue Regeneration is needed, the treatment plan should be altered accordingly. The surgical guide allows the transfer of all gathered information on the surgical field, so that the possibly needed corrections are made taking into consideration the final result.

Digital technology offers nowadays increased possibilities for a thoroughly digital presurgical evaluation and guided implant placement. This technology, however, is also based on the principles established by the conventional techniques that have been used successfully for decades. For this reason, it remains essential for the clinician to understand the diagnostic value of the radiographic and surgical guides as well as their contribution to a treatment with predictable final results.

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CHAPTER 3

Implant Overdentures

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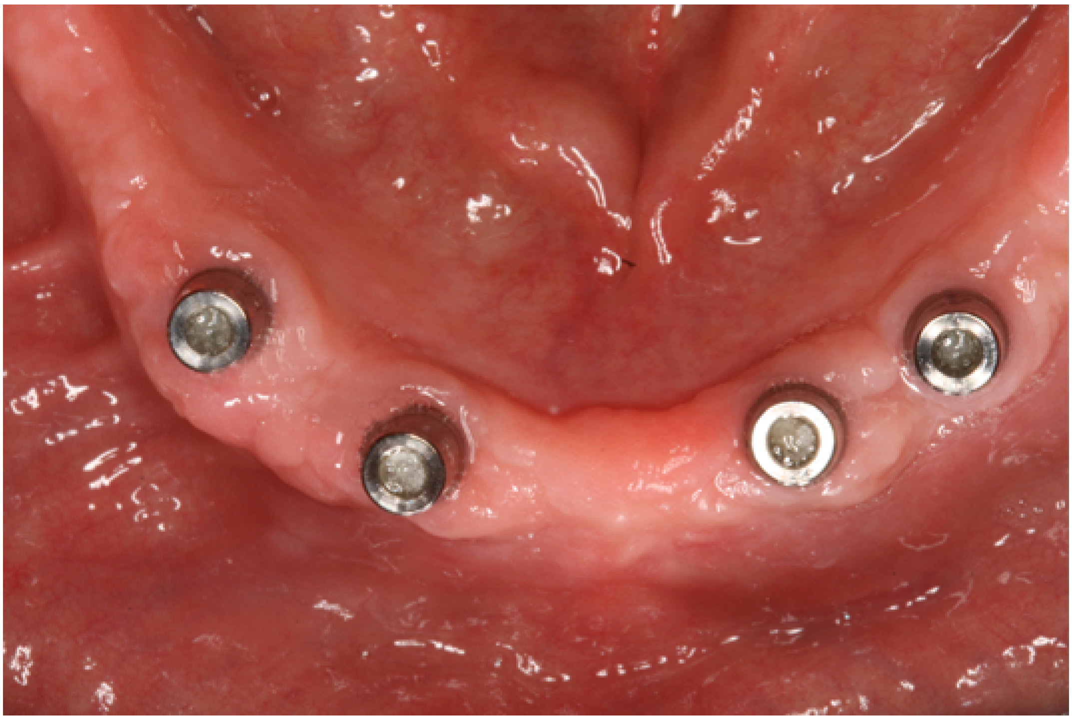


Abstract

Implant overdentures have been used for decades for the restoration of completely edentulous patients. Various types of implant overdentures have been introduced and used in clinical practice, supported by various numbers of implants and with a variety of retentive mechanisms. The purpose of this chapter is to classify the implant overdentures, to present and compare the various retention elements that are currently used and discuss the advantages and disadvantages of the different clinical options based on the existing literature data. The points of attention for the selection and fabrication of each type of overdentures are also presented and discussed with clinical examples.

Knowledge background

To understand the content of this chapter, the reader must know the basic principles and technique for conventional complete dentures.

3.1 Introduction

Complete dentures have been the traditional standard of care in the rehabilitation of edentulous patients for more than a century (**Feine and Carlsson, 2003**). Although the majority of patients using maxillary dentures are satisfied—as far as speech, esthetic, mastication and retention are concerned—in many cases the retention of mandibular dentures is not adequate, since more than 20% of patients report none or little satisfaction and decreased quality of life (**Redford et al., 1996; Thalji et al., 2016**).

Furthermore, as the expectations and demands of the patients are rising nowadays, patients are seeking comfort and improved function at a higher standard than offered by conventional mandibular dentures. To overcome the problems of mandibular dentures, implant-retained overdentures have been proposed because of their significantly improved retention, stability, and patient satisfaction (**Burns et al., 1995; Redford et al., 1996; Feine et al., 2002**).

3.2 Aim

The aim of this chapter is to analyze the principles for the restoration of completely edentulous patients with implant-supported overdentures. The various types of overdentures and retention elements are presented with clinical examples.

3.3 Definition and indications for implant overdentures

An implant overdenture is defined as any removable dental prosthesis that covers and rests on dental implants, or a dental prosthesis that covers and is partially supported by dental implants (**Glossary of Prosthodontic Terms, The Academy of Prosthodontics, 2017**). An implant overdenture can be used for the treatment of edentulous jaws—mainly in the mandible—for patients encountering problems with complete dentures, and in cases where the alveolar bone preservation is desired (**Mericske-Stern et al., 2000; Hobkirk et al., 2003**).

The major indication for implant overdentures compared to fixed restorations is the reduced number of implants, 2 for the mandible and 4 for the maxilla. There are also clinical cases where an overdenture offers advantages over a fixed restoration, even if multiple implants have been placed. These cases include patients with the need for maintaining effective oral hygiene, support of the soft peri-oral tissues or implants with doubtful prognosis.

3.4 Classification of implant overdentures

Implant overdentures can be classified as tissue-supported/implant-retained, tissue-and-implant supported and solely implant-supported.

3.4.1 Tissue-supported overdentures

Tissue-supported overdentures are supported by two implants and their design follows the same principles as conventional dentures. They are retained on implants using a retentive mechanism (attachment), as for example ball-attachments, Locators® or magnets. Tissue-supported overdentures are mainly used for the treatment of edentulous mandibles, as it is difficult to achieve retention and support from only 2 implants.

3.4.2 Tissue and implant-supported overdentures

These overdentures are retained by a superstructure fixed on two or more implants, usually positioned in the anterior area of the mandible or maxilla. This type of restoration is supported both from soft tissues and implants. The supporting and retentive mechanism is usually a bar connecting the implants with clips integrated in the base of the restoration. Alternatively, other types of retentive mechanism (ball attachments or Locators®) can be used if direct splinting of the implants is not considered necessary.

It must be underlined, however, that the support of implant overdentures is not dependent only on the number of implants, but it is also significantly affected by the retention elements. Resilient attachments and bars constructed with a spacer underneath the clip allow micro-movement of the denture towards the mucosa.

3.4.3 Implant-supported overdentures

Overdentures of this type are supported only by the implants, either via a superstructure rigidly connected to them or directly with telescoping crowns. The minimum number of needed implants for the mandible is 4, while for the maxilla 4-6 implants are necessary. The number of needed implants is also depended on the width of the edentulous arch and the extension of the occlusal table that is planned. Occlusal forces during mastication are mainly absorbed by the implants, so the mucosa is minimally loaded (**Block et al., 1997; Krenmair et al., 2012; Zou et al., 2015**).

3.5 Treatment strategy and number of implants

The selection of the type of restoration in each case depends on various parameters, such as the number of implants, the pain or discomfort caused by the existing denture, the quality and quantity of the alveolar bone, the patient's demands, and expectations, the interarch relation, the ability of the patient to maintain effective oral hygiene and also cost. When designing an implant overdenture, the clinician must decide on the number of necessary implants for the fabrication of a long-lasting prosthesis that can fulfill the patient's demands.

3.5.1 Edentulous mandible

According to the McGill consensus statement, an overdenture on two implants should be the treatment of choice for the edentulous mandible (**Feine et al., 2002**). According to **Hobkirk et al.,** (**2003**), two implants provide sufficient retention and stability, but support is provided by the underlying soft tissue. The long-term success and survival, as well as patient satisfaction and oral function, can be achieved with two-implant mandibular overdentures, as stated in an extended systematic review (**Thomason et al., 2012**). Although such a restoration is the most popular clinical choice, even a single implant in the midline of the mandible can improve function and aesthetics, if cost is a pressing factor (**Padmanabhan et al., 2020**). Furthermore, according to another literature review, this type of overdenture seems a sound and more affordable treatment (**Carlsson, 2014**). Nevertheless, other clinical variables, e.g. efficient mastication, bite force, retention and stability should also be taken into consideration. **Bhat et al., (2016**) in an in-vivo study reported that the masticatory efficiency of a single midline implant mandibular overdenture was better compared to a conventional denture. Another systematic review by **Kern et al.,** (**2016**) compared implant failure between one-implant and two-implant overdentures in the mandible and showed higher implant loss rates for the former rather than the latter type.

3.5.2 Edentulous maxilla

For the construction of a maxillary overdenture minimum 4 implants are necessary. According to **Hobkirk et al., (2003**), 4 implants evenly distributed can provide adequate support and avoid coverage of the palate. In a systematic review, the annual survival rate of implants was compared in restorations of 6 implants and a bar overdenture, 4 implants and a bar overdenture and 4 implants and a ball-attachment overdenture (**Kern et al., 2016**). According to the results, a maxillary overdenture supported by 6 implants connected with a bar showed the highest survival rates, both for the implants and the restoration. The second best was the 4-implant bar overdenture. The lowest success rate was reported for 4 or fewer implants and a ball attachment system.

According to an extended literature review (**Carlson, 2014**), 4-6 implant bar-splinted overdentures present sound results regarding function. In another study (**Raghoebar et al., 2014**), high survival rates both for the implants and the overdentures were reported in cases of implant-supported maxillary overdentures. All cases were restored with a minimum of 4 splinted implants. These results were confirmed by a systematic review by **Kern et al., (2016**) reporting that higher failure rates were noted for maxillary overdentures supported by fewer than four implants compared to cases with four or more implants.

In an in-vivo study (**Raghoebar et al., 2014**), it was concluded that 6-implant supported maxillary overdentures retained by a bar offered higher satisfaction among patients compared to cases with the same type of restoration on four implants. On the other hand, it is not possible to evaluate patients' satisfaction for 4 or 6 implants in the same subjects, as in most studies each patient receives and uses one of the two types, making it thus impossible to compare it with the other type. The economic factor also has an important impact on the treatment planning and plays a significant role in the decision regarding the number of implants (**Listl et al., 2014**).

3.6 Guidelines for mandibular overdentures

The basic prerequisites for a mandibular implant overdenture are 2 interforaminal implants—at least 8mm long—with a distance 15 to 25mm in order to allow adequate space for the retentive elements. The implants may be single with attachments or splinted with a bar. The bar should be parallel to the horizontal level (***Figs. 3.1 and 3.2***) and to the hinge axis of the condyles (**Spiekermann, 1995; Laurito et al., 2012**). The bar can be either round-shaped or "egg-shaped" (Dolder bar) in cross-section to allow rotation of the overdenture (resilient retention) in cases of tissue-supported or implant-and-tissue supported overdentures (***Figs. 3.3 and 3.4***). "U-shaped" bars (rigid retention) should be avoided if an implant-and-tissue supported overdenture is planned, as they do not allow any rotational freedom for the overdenture, thus transmitting all created stresses on the implants (**Spiekermann, 1995**). Though, they can be used in cases where multiple implants are splinted for an overdenture supported only by implants (***Fig. 3.5***).

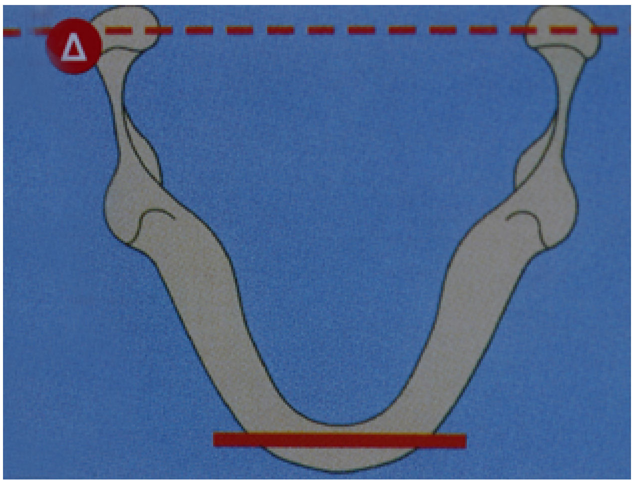


Fig. 3.1

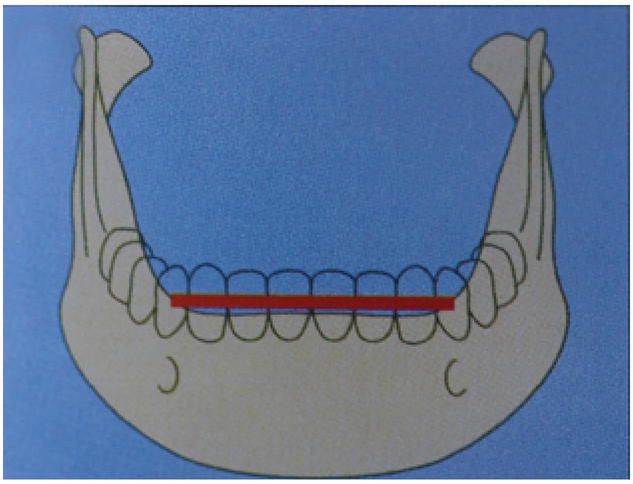
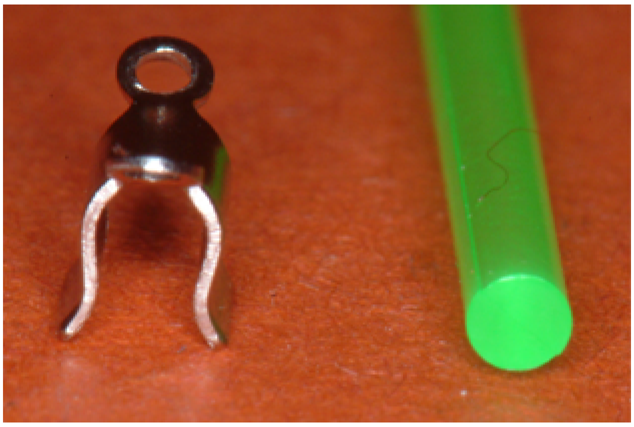


Fig. 3.2

Figs. 3.1 and 3.2 *The bar should be parallel to the hinge axis of the patient and to the horizontal level (from Preci-Line Laboratory manual, Alphadent Co, Belgium).*



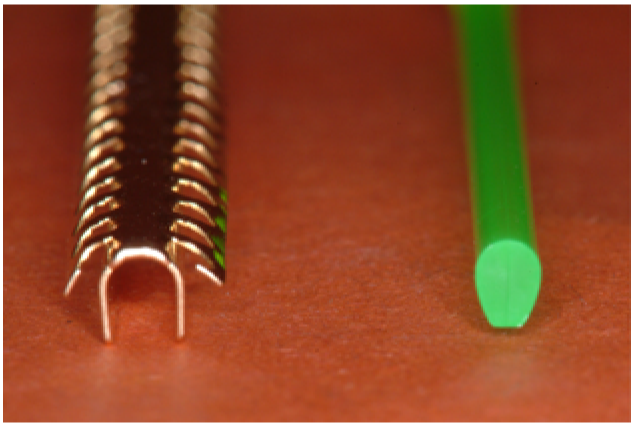


Fig. 3.3 **Fig. 3.4**

Fig. 3.3 *Plastic castable round bar with corresponding metal clip.*
Fig. 3.4 *Plastic castable "egg-shaped" bar with the corresponding metal clip.*

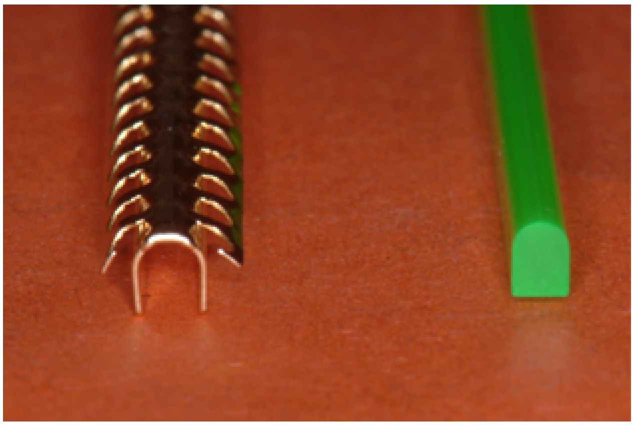


Fig. 3.5

Fig. 3.5 *Plastic "U-shaped" bar with the corresponding metal clip.*

The bar should connect the implants with straight parts avoiding any curve. The space underneath the bar should allow effective oral hygiene with interproximal brushes or special toothbrushes (***Case A, Figs. 3.6 and 3.7***). Adequate space should remain around the fixtures of the bar on the implants to avoid any interference or contact of the denture base on the implants.

The bar can be fabricated by casting from gold or base metal alloys. Alternatively, it may be constructed by soldering of prefabricated metal parts, usually from gold alloys. The retaining clips are made of gold alloy or plastic and are embedded directly in the base of the denture or are fitted in a prefabricated "housing" fixed in the base material.

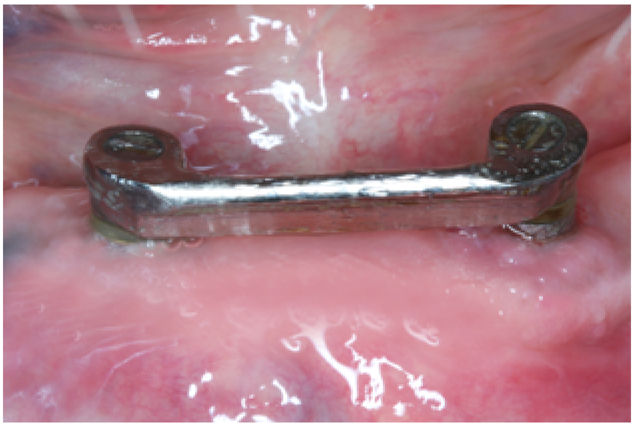


Fig. 3.6

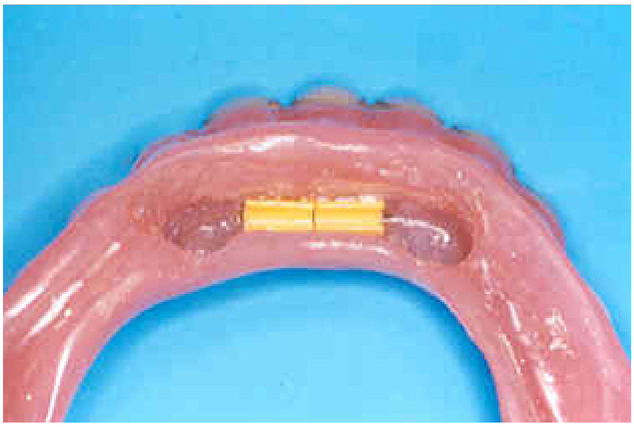


Fig. 3.7

Figs. 3.6 and 3.7 *Case A, Dolder bar and the corresponding prefabricated plastic retaining clips in the base of the denture.*

Single retentive elements are fixed on the implants (usually called the "male" component) and the retention is achieved by the integration of the "female" component in the denture base. The older retention elements were the ball-attachments that are still in use (***Case B, Figs. 3.8 and 3.9***). In this type of attachment, the part fixed on the implant is usually fabricated from titanium and the retention part is fabricated from gold alloy or has plastic rings allowing a certain freedom of insertion.

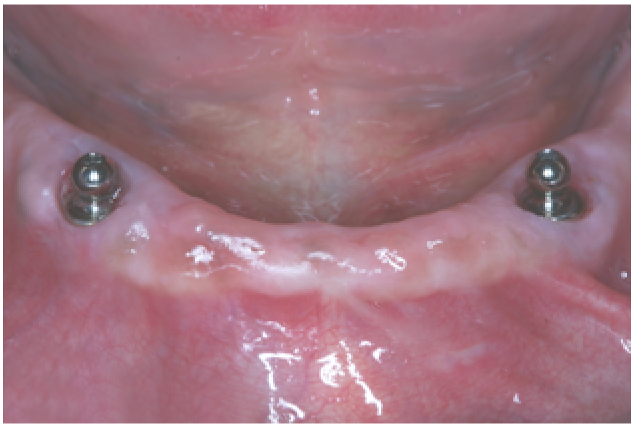


Fig. 3.8

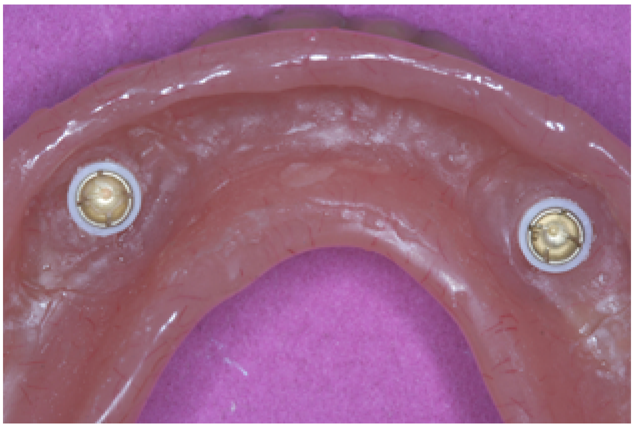


Fig. 3.9

Figs. 3.8 and 3.9 *Case B, Ball-attachments on two implants and the corresponding female parts in the base of the denture. The male parts are fabricated from titanium and the retaining parts from gold alloy. The white elastic ring around the female parts allows elastic deformation of the gold retentive components.*

The Locator® attachments were later introduced for clinical use and have some clinical advantages compared to ball attachments. In this type of attachment, the retention is achieved by a plastic ring that fits both into and around the metal (male) part which is fixed on the implant (***Case C, Figs. 3.10 and 3.11***). Single retention elements, however, should be used on implants without severe axis diversion. In these cases, a bar can be useful when the implants diverge severely from each other (**Spiekermann, 1995**).

Fig. 3.10

Fig. 3.11

Figs. 3.10 and 3.11 *Case C, Locator® attachments and the corresponding retaining female parts in the base of the denture. The plastic retaining parts in the housing are available in different retention forces and color-coded.*

If the space between the implants is limited, single retention elements (for example, ball-attachments) can be used to ensure adequate retention (***Case D, Figs. 3.12 and 3.1***3). In cases of V-shaped alveolar ridges—for example, in the anterior part of the mandible—the direct connection with a bar might restrict the space available for the tongue, and single retentive mechanisms are preferred (**Renouard and Rangert, 1999**).

Fig. 3.12

Fig. 3.13

Figs. 3.12 and 3.13 *Case D, Mandibular overdenture on 4 ball attachments.*

The use of telescoping crowns may combine the advantages of both retaining types (bar and ball attachments) and offer a clinical solution to certain clinical cases. Primary abutments—analogous to the primary telescoping crowns on teeth—are formed by milling of solid titanium abutments fixed on the implants. Secondary crowns are fabricated by casting with precious or non-precious alloys, rigidly connected to the metal framework of the superstructure. Telescoping crowns can compensate for divergent implants that are splinted, not directly through a bar, but through the superstructure.

All types of mandibular implant overdentures should be reinforced either with a cast metal framework or at least with a bar within the lingual surface of the denture to reduce the risk of fracture.

3.7 Guidelines for maxillary overdentures

At least 4 implants evenly distributed along the anterior region are necessary for a maxillary overdenture. If connection with a bar is planned, the segmented straight parts between the implants should follow the curve of the alveolar ridge without restricting the palatal space (***Case E, Figs. 3.14 and 3.15***). Each implant should be at least 10mm long and, if the host bone sites are resorbed and do not allow placement of long implants, several shorter ones should be inserted.

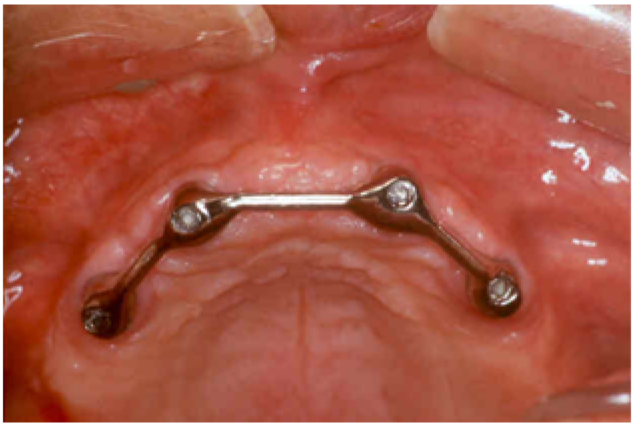


Fig. 3.14

Fig. 3.15

Figs. 3.14 and 3.15 *Case E, maxillary overdenture with cast bar and the corresponding retaining clips fixed in the metal framework.*

Labial inclination of the maxillary alveolar crest—especially in the anterior region—often leads to the need for a bar to allow a single insertion path for the overdenture. Single retentive mechanisms may also be used, but the thick mucosa and the intense inclination of implants often restrict their clinical application and efficacy. Although single retention elements allow easier cleaning from the patient, in cases of poor oral hygiene hyperplasia around the implants cannot be avoided (***Case F, Figs. 3.16 and 3.17***).

Fig. 3.16

Fig. 3.17

Figs. 3.16 and 3.17 *Case F, maxillary overdenture on 4 ball attachments at the 1-year recall. Although the patient performs oral hygiene both on implants and the overdenture, hyperplasia of the soft peri-implant tissues is evident in reducing the retention.*

Locator® attachments can also be used in cases where the implant axis shows slight diversion, as by selecting the proper plastic part an insertion path can be achieved. Locator® attachments allow easy oral hygiene and due to their design, hyperplasia of the peri-implant tissues can be avoided (***Case G, Figs. 3.18 and 3.19***).

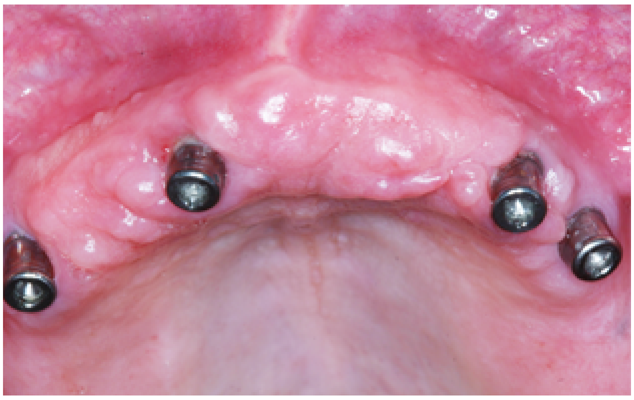


Fig. 3.18

Fig. 3.19

Figs. 3.18 and 3.19 *Case G, maxillary overdenture on 4 Locator® attachments at the 1-year recall.*

Telescopic crowns are another attractive clinical option offering retention and ensuring indirect splinting of implants (***Case H, Figs. 3.20-3.22***). In the maxilla, where most implants show intense diversion and labial inclination, telescoping crowns may compensate for the divergent axes without reducing the retention force. In these cases, the palatal coverage can be avoided. Reinforcement of the denture base is mandatory and should include a cast metal framework supporting the restoration to all extent. As reported in a 5-to-8-year retrospective study, maxillary implant-supported telescopic crowns or bar overdentures are a sound and predictable treatment option for patients with edentulous maxilla (**Burns, 2004**). Reinforcement of the denture base is also necessary and should include a cast metal framework supporting the restoration throughout its extent.

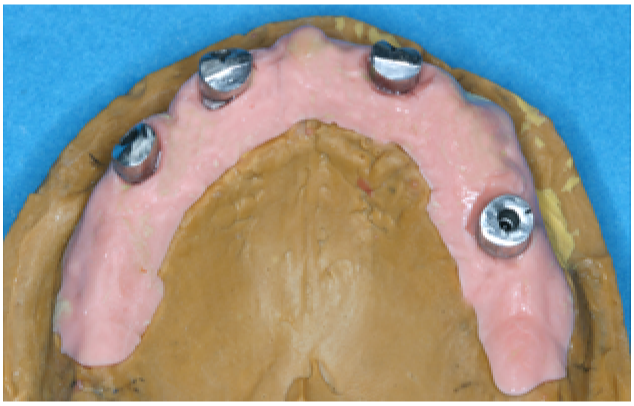


Fig. 3.20

Fig. 3.21

Figs. 3.20 and 3.21 *Case H, primary titanium abutments milled from prefabricated solid abutments for a maxillary overdenture.*

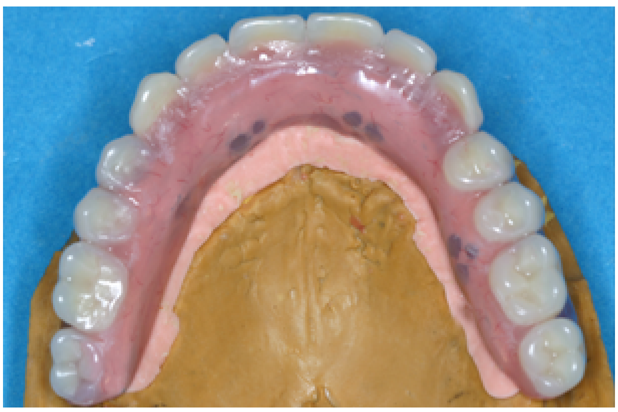


Fig. 3.22

Fig. 3.22 *The corresponding maxillary overdenture without palatal coverage.*

3.8 Advantages and disadvantages of implant overdentures

Patients accept implant overdentures more readily and their adaptation to the prostheses is easier compared to conventional dentures. Furthermore, increased retention and stability ensure improved function of the whole stomatognathic system in every aspect. Implant overdentures can significantly improve the aesthetic result, as the length of prosthetic teeth is not influenced by the alveolar crest resorption, which is compensated by the polymer material of the flange.

Improved aesthetics can also be achieved due to better support of facial soft tissues, while the remaining alveolar bone is also effectively preserved. In addition, soft tissue coverage may be reduced when an implant overdenture is used (**Zarb et al., 2004**). Regarding oral hygiene, a removable prosthesis requires less time and effort to maintain a proper level of plaque control. This is an important factor for elderly patients with reduced visual capacity and dexterity.

According to a 5-year study by **Hemmings et al.,** (**1994**), implant overdentures needed more frequent post-insertion adjustments than fixed prostheses in the first year of use. Later, fixed restorations showed more severe technical complications and needed higher maintenance than overdentures. On the other hand, the results of a systematic review by **Berglundh et al.,** (**2002**) revealed that incidence rates for technical complications due to implant components and superstructures were higher among overdentures than among fixed reconstructions. It must be underlined, however, that prosthetic complications of overdentures may be more frequent in general, but in most cases are of low severity and can be repaired with minimum effort and cost.

The main problem with implant overdentures arises from the patients' demands and expectations, e.g. that the prosthesis should be fixed—an expectation that this type of restoration cannot fulfill. On the other side, if more implants are used with the proper retention elements (for example, telescopic crowns), maximum stability and retention can be achieved, and the overdenture should only be removed for purposes of oral hygiene.

Implant overdentures require increased care and cost, compared to conventional dentures. Retentive mechanisms are sometimes difficult for patients with reduced dexterity. Beside the abovementioned, prosthetic complications are more frequent than those of conventional dentures, and a regular recall system is necessary.

3.9 Retention elements

A variety of retention elements has been used for implant overdentures, which are mainly classified into single attachments, splinted anchorage systems (bars) and telescopic crowns (**Misch et al., 2005**). Single retention elements and telescopic crowns are attached independently to each implant, for example, ball, magnets, and Locators®. Splinted anchorage systems are clips fitting on a bar that may be round, egg-shaped (Dolder Bar) or U-shaped. Round and egg-shaped bars allow rotation of the superstructure and provide a relative stress breaking effect. U-shaped bars offer increased retention, require more accurate fit, and result in rigid fixation of the superstructure (**Spiekermann, 1995**).

3.9.1 Single attachments

Single attachments are easier to use, require no additional laboratory steps (e.g. casting), and entail lower cost compared to clips on bars. They are often preferred when the patient's existing overdenture is to be transformed to an implant overdenture. This clinical option facilitates elderly denture-wearing patients—usually with limited dexterity—to use and maintain their existing dentures more easily. These overdentures can also be used as interim prostheses during the post-surgical healing phase, prior to the insertion of the definite prosthetic restoration, which is demanding regarding time and laboratory stages.

Single attachments are also an attractive solution in cases of limited vertical space, as they require shorter height within the base of the dentures than the bar and the retaining clip with its housing. Single retention elements are also used in cases of unfavorable distribution of the implants, where the space between them may not allow adequate length of the bar (***Case I, Figs. 3.23 and 3.24***). Another indication for attachments is in cases where an implant may be lost during osseointegration, and the patient denies re-implantation (***Case J, Figs. 3.25 and 3.26***).

Fig. 3.23

Fig. 3.24

Figs. 3.23 and 3.24 *Case I, mandibular implant overdenture on four implants. Ball-attachments were selected as the distribution of the implants was not favorable for the construction of a bar.*

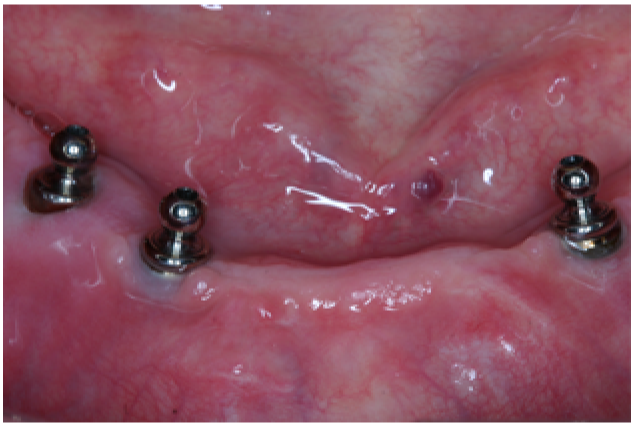


Fig. 3.25

Fig. 3.26

Figs. 3.25 and 3.26 *Case J, mandibular implant overdenture on three implants. Ball attachments were selected due to the distribution of the implants. The patient had received four implants but one failed during osseointegration and the patient denied re-implantation.*

3.9.2 Splinted implants (bars)

When single attachments are used, patients often complain of inadequate retention. Bars and clips provide increased retention when compared to single attachments if proper fit of the clips can be ensured. Bars can also compensate for unfavorable inclination of implants and diverted axes. In cases of short implants, splinting by a bar may contribute to increased stability and more even distribution of occlusal forces to the implants and the surrounding bone (**Kleis et al., 2010**).

The prefabricated retentive clips for the bar can be either metallic or plastic. Metallic clips (usually gold alloy) offer increased longevity as they are more wear-resistant than plastic. On the other hand, the thin "wings" of metal clips may be easily deformed, if the overdenture is not carefully inserted by the patient. In these cases, replacement of the retaining clips is mandatory.

The bar may be cast individually from gold or base metal alloy. Some manufacturers also offer the possibility to avoid casting and construct the bar by soldering of prefabricated pieces. As gold alloys increase cost, there is a tendency for the use of base metal alloys. The prefabricated metal retaining clips are usually made from gold alloy, as they show reduced wear resistance compared to other alloys. The main reason is that the expected wear during the clinical use should be mainly done on the retaining clips that are more easily replaced, leaving the bar intact. The clips are usually available in predetermined length and can be adjusted to the clinical dimensions by cutting. If the length between the implants is adequate, a single clip is preferred. If the length is limited, two shorter separate clips may be used (***3.27 3.31***).

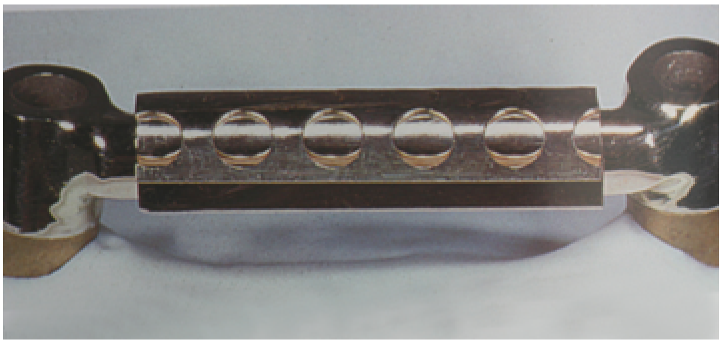
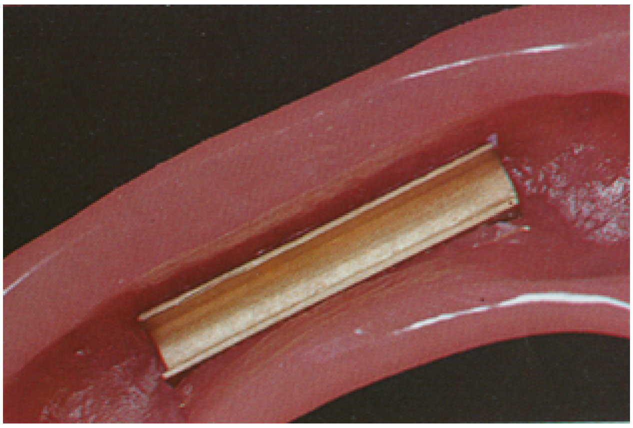
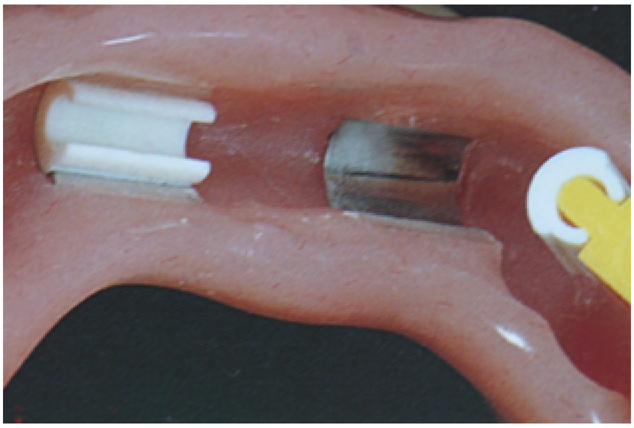


Fig. 3.27 *A gold bar with a single retaining clip on the working cast. Before integration in the denture base, the space underneath should be isolated (from Preci-Line Laboratory manual, Alphadent Co., Belgium).*



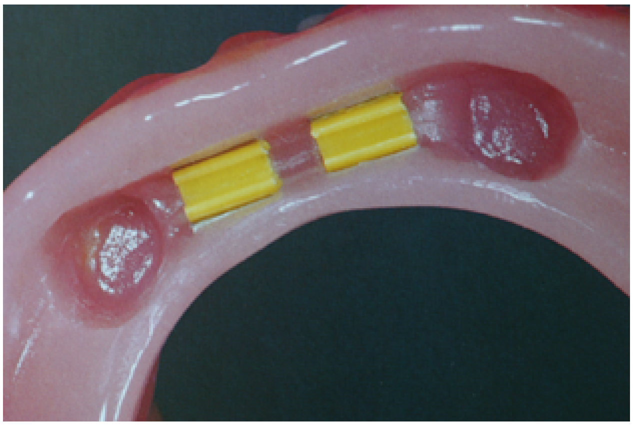
Figs. 3.28



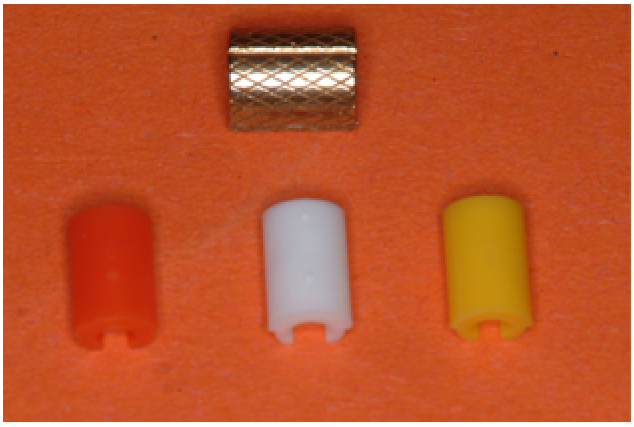
Figs. 3.29

Fig. 3.28 *The overdenture base with a single long metal clip (from Preci-Line Laboratory manual, Alphadent Co., Belgium).*

Fig. 3.29 *The overdenture base with two shorter plastic clips (from Preci-Line Laboratory manual, Alphadent Co., Belgium).*



Figs. 3.30



Figs. 3.31

Fig. 3.30 *Insertion of the plastic clip in the metal housing by a special instrument (from Preci-Line Laboratory manual, Alphadent Co, Belgium).*

Fig. 3.31 *Color-coded plastic clips with different retention force.*

The integration of the clip in the base of the denture can be done either in the laboratory or chairside by using auto-polymerizing resin. When using a single long clip, procession in the laboratory is preferred. Chairside integration of the clips prerequisite extreme caution, as no resin should flow underneath the bar, which would result in difficulty to remove the denture after polymerization. In case of two short clips, the procedure can be accomplished in the dental office through a "window" in the lingual side of the denture, but isolation of the space under the bar is mandatory.

Plastic clips are an attractive alternative to metal clips. They have lower cost, but they should be replaced more often, as the retention force decreases by clinical use. They are available in different hardness according to the intended retention force and are usually color coded. The plastic clip is easily inserted by slight pressure of a special tool in a metal housing, solidly integrated in the denture base. In this way, their replacement is easy and time effective.

If the horizontal space available between implants is too short to allow construction of a bar with adequate length, additional stability may be contributed by integrating precision attachments on the bar. Alternatively, short distal extensions may be added to the bar to allow placement of additional retaining clips (**Priescel, 1996; McCartney, 1992**), and in these cases, the overdenture is only implant-supported (***Case K, Figs. 3.32 and 3.33***).

Fig. 3.32

Fig. 3.32 *Case K, a cast bar on four implants with distal extensions.*

Fig. 3.33

Fig. 3.33 *The corresponding overdenture with metal framework and five retaining clips.*

Increased loading of most distal implants, when distal cantilevers were used, has been reported but bone resorption has not been confirmed by other in-vitro and in-vivo studies (**White et al., 1994; Elsyad et al., 2013**). Furthermore, neither the length of the cantilever can be predictably determined, nor can extensions (cantilevers) be used without considering the restrictions they impose on rotational freedom (**Sadowsky et al., 2004; Semper et al., 2010; Ebadian et al., 2016**).

Bars connecting three implants have also been suggested, but the angulation of two connective parts prohibits denture rotation, probably leading to unfavorable loading of implants. In these cases, it is impossible to form the bar parallel to the hinge axis of the patient. Although such a design has been described and presented, there is not sufficient clinical documentation on the longevity of these restorations.

Bars have been generally considered as a standard for maxillary overdentures, mostly in cases with 4 implants (**Hobkirk, 2003**). The main reasons for preferring a bar for the maxillary overdenture are the curve of the alveolar ridge, the palatal inclination of implants with (usually) divergent axes and the increased thickness of the mucosa. Ball attachments or Locators® may also be used, but maximum divergence between implants should be 10° and 40°. For this reason, the use of telescopic copings as retentive and supporting elements also shows clinical advantages (**Meriske-Stern et al., 2000**).

3.9.3 Telescopic copings

Telescopic copings provide stable and accurate retention and support to overdentures by friction of the primary coping to the secondary crown. The primary coping is formed by milling of a prefabricated solid titanium abutment retained by screw directly on the implant. The inclination of the axial walls varies from 2°-6°, depending on the number of implants and the friction planned. The secondary crown is cast—as in conventional telescopic crowns on natural teeth—and is connected to the frame of the overdenture. Gold alloys are most suitable for the casting of secondary crowns, as they offer biocompatibility, accurate casting and the needed friction, but they entail increased cost. Base metal alloys can also be used for this purpose, but they should be cast with extreme caution to achieve the necessary friction. CAD/CAM systems for fabrication of telescopic crowns on implants have recently been introduced, but there is not yet sufficient clinical data to compare the conventional casting procedure with the newly introduced technology (**Bergler et al., 2008**).

Telescopic copings offer excellent stability, allow for easy oral hygiene, and can be used even in severely divergent implants. They also offer a solution in cases of limited vertical space where a bar cannot be properly formed. Another indication for telescopic copings is to support overdentures on natural teeth and implants (***Case L, Figs. 3.34 and 3.35***). In these cases, remaining teeth with good or doubtful prognosis can serve as supporting elements along with implants placed in strategic positions. If a tooth fails and must be extracted, the overdenture can remain in function on remaining teeth or implants with minimum repair. The use of teeth and implants with telescoping crowns in the same restoration has been reported with very good results concerning implant survival and patient satisfaction (**Krennmair et al., 2007; Bernhart et al., 2012; Fobbe et al., 2019**).

Fig. 3.34

Fig. 3.35

Figs. 3.34 and 3.35 *Case L, a clinical case for an overdenture supported by telescoping crowns on natural teeth and implants inserted in strategic positions.*

On the other hand, for telescoping copings a technique-sensitive procedure must be followed, which requires skill and experience from the dental laboratory. Cost also rises, due to the technical complexity, the need for prefabricated abutments (requiring precision milling) and the casting of secondary crowns.

Prefabricated titanium abutments of different inclinations (4°-6°) and various gingival heights are also available for some implant systems, for example, Syncone Abutments for Ankylos implants (Sirona/Dentsply Co., Germany). These abutments can be parallelized and fixed intraorally, ensuring a single insertion path for the overdenture. They are combined with prefabricated telescoping gold copings that fit accurately on the abutments. The whole procedure of integrating the copings to the base of the overdenture can be accomplished chairside, eliminating the need for laboratory procedures.

This treatment option combines increased stability and retention, reduced laboratory cost and minimal maintenance care (***Case M, Figs. 3.36-3.38***). The same patient was restored in the maxilla with a bar-retained overdenture with additional precision attachments to increase stability and retention (***Fig. 3.39***).

Fig. 3.36

Fig. 3.37

Figs. 3.36 and 3.37 *Case M, a clinical case restored with prefabricated titanium primary telescopic copings (Ankylos Syncone Abutments) in the mandible at the 1-year recall.*

Fig. 3.38

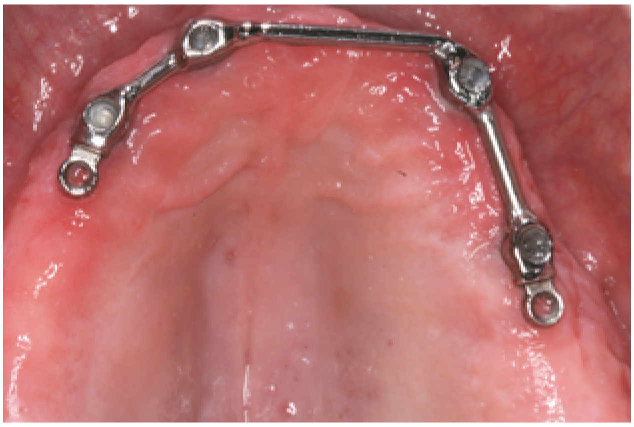


Fig. 3.39

Fig 3.38 *Prefabricated gold secondary telescopic copings welded to the metal framework of the overdenture at the 1-year recall.*

Fig 3.39 *The same patient (Case M) restored in the maxilla with a bar-retained overdenture at the 1-year recall.*

Compared to bars, telescoping crowns have also a major advantage concerning the peri-implant soft tissues, as they allow easier and more effective oral hygiene. In ***Fig. 3.40***, the same patient (***Case M***) as in ***Figs. 3.36 and 3.37*** is presented at the 7-year recall. As it can be noted, there is inflammation on the peri-implant tissue surrounding the bar anchors and a light hyperplasia underneath the bar. In contrast, the condition of the soft tissues around the telescopic copings is significantly healthier. The ability of the patient to maintain efficient oral hygiene is also reflected on the basis of the two types of overdentures of the same patient (***Figs. 3.41-3.44***).

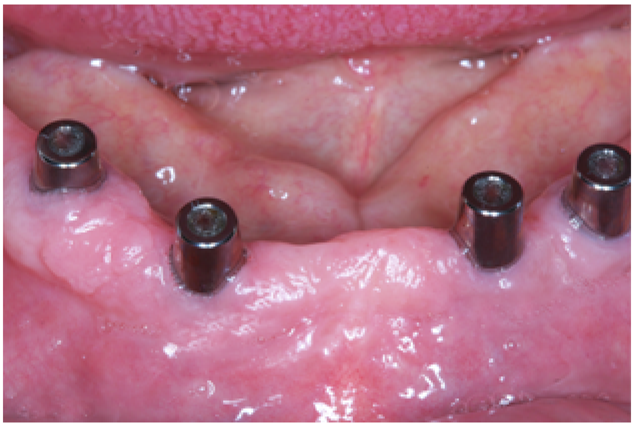


Fig. 3.40 Fig. 3.41

Fig. 3.40 *The same patient (Case M) at the 7-year recall.*
Fig. 3.41 *Soft tissue condition around the mandibular telescopic copings at the 7-years recall.*

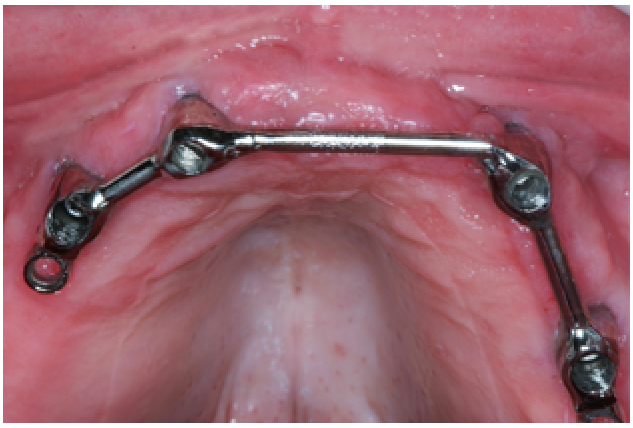


Fig. 3.42 Fig. 3.43

Figs. 3.42 and 3.43 *Soft tissue condition around the maxillary bar copings at the 7-year recall.*

Fig. 3.44

Fig. 3.44 *The maxillary and mandibular overdentures (Case M) at the 7-year recall.*

The restoration of edentulous patients in the mandible with implant-supported overdentures and telescoping crowns has been reported in a clinical trial even with immediate loading (**Kourtis et al., 2018**). The survival rate of the implants was 100% during the 8-year follow-up and the prosthetic complications were lower compared to other similar clinical trials. The bone resorption around the implants was investigated in another study focused on this treatment option and similar levels of bone resorption were noted both for the immediately loaded and the late loaded implants (**Andrikopoulou et al., 2019**). Similar results have also been reported in previous clinical trials with implant supported telescoping restorations both for the maxilla and the mandible (**Eccellente et al., 2010; Eccellente et al., 2011**).

3.10 Selection of retention elements

The selection of retention elements depends on the following: type of overdenture, condition and shape of the residual alveolar ridge, implant length and distribution on the ridge, patient's dexterity and demands from the final prosthesis and finally the cost entailed. Another factor impacting this choice is, of course, the clinician's personal preference depending on experience and training (**Kim et al., 2012**).

In cases of extended bone resorption, the retention elements should ensure horizontal stability, like bars and telescopic copings. On the other hand, when alveolar bone resorption is minimal, magnets may be considered as an alternative solution, despite their inherent disadvantages. Ball attachments are suitable for patients with a narrow alveolar crest, as bars may require space (vertical and horizontal) and restrict tongue comfort (**Shafie, 2007**).

Telescopic copings offer excellent retention and stability to the overdenture but require a technique-sensitive laboratory and clinical procedure. As in these cases the splinting of implants is achieved only indirectly, high stresses may be transferred on single implants, which can lead to marginal bone resorption or mechanical complications. Cost and time are two additional factors to be taken into consideration. Telescopic copings are the most expensive retention system followed by cast bars. Magnets, ball-attachments, and Locators need minimum additional laboratory stages, and their maintenance is simpler and easier to accomplish chairside (**Shafie, 2007**).

Magnet attachments for implant overdentures are available from certain manufacturers. The use of magnets is simple for the patient and easy oral hygiene may be performed. On the other side, magnet attachments have been associated with increased bone resorption, show displacement during clinical use and have lower satisfaction among patients, as reported in an extended systematic review with meta-analysis (**Chaware and Thakkar, 2020**). For these reasons their use in clinical practice has nearly stopped.

3.11 Comparison of retention elements

When comparing retaining mechanisms, the following factors should be taken into consideration: longevity, retention, patient satisfaction, quality of life and technical complications.

3.11.1 Longevity

A randomized prospective study (**Gotfredsen et al., 2000**) revealed a 100% survival rate over 5 years for implant-supported mandibular overdentures of 2 implants with a bar or ball-attachment. In another retrospective study, the cumulative survival rate for implant-supported, bar-retained, and ball-retained overdentures over a period of 72 months was evaluated; the authors reported an overall survival rate of 90% (**Närhi et al., 2001**). Another clinical trial with a 3-year follow-up reported survival rates of 90%, 88% and 75% for the Locator® group, the Southern plastic attachment (Southern Implants, South Africa), and the Straumann (Straumann Co., Switzerland) gold attachment respectively (**Mackie et al., 2011**). According to another 5-8-year retrospective study, no differences were found between telescopic crown and bar overdenture groups, during follow up, regarding survival and success rates of implants, average bone resorption and patients' subjective satisfaction scores (**Zou et al., 2013**). Therefore, implant-supported overdentures seem to be a safe and predictable treatment option with any type of retentive element.

3.11.2 Retention

A 5-year follow-up clinical trial studied comparative prosthetic outcomes and patients' satisfaction when ball, bar and magnet overdentures were used (**Naert et al., 1999**). Results revealed higher retention capacity in the bar group than in magnet and ball-attachments. Patients reported they would choose the same treatment again, but most of those in the magnet group would choose a better retentive solution to improve their denture stability.

According to the conclusions of a systematic review, in 2-implant overdentures most attachment systems lose their retentive force after clinical use (**Alsabeeha et al., 2009**). The cause for retention loss was wear, but there has been insufficient research into the specific mechanisms involved in this technical problem. Relevant literature implicates various parameters influencing both the retention force produced by the attachment system used and the characteristics of its wear. There is still, however, no conclusive data confirming the precise role of the process of wear.

An in-vitro study (**Türk et al., 2014**) compared in vitro the retentive force between ball and Locator® attachments. They reported decreased retention for both systems after 5,000 insertion-separation cycles. It should be noted, however, that Locators® showed higher retention compared to ball-attachments at the end of the fatigue test. Contrary results were reported in a later study, where Locators® showed lower retentive force compared both to ball attachment and bars (**Shastry et al., 2016**).

The systematic review and meta-analysis by **Sutariya et al.,** (**2021**) designed to compare different attachment systems used in mandibular implant-supported overdentures revealed that bar attachment provided the most superior retention among ball, magnet and locator attachments.

3.11.3 Patient satisfaction

In a clinical trial with an observation period of 5 years (**Naert et al., 1999**), it was reported that despite the lower retention forces noted in the magnet group—compared to bar and ball groups—all patients reported similar levels of satisfaction from their restorations. On the other hand, a clinical trial by **Ellis et al.,** (**1999**) concluded that the overall satisfaction of patients treated with ball-retained overdentures exceeded that of patients with magnets. Patients' satisfaction level with either implant overdenture type was significantly higher compared to conventional dentures.

The long-term follow-up study by **Kuoppala et al.,** (**2009**) presented excellent treatment results for implant-supported mandibular overdentures with a bar or a ball connection. Whichever type of attachment was used led to patients' satisfaction. Practical aspects that must be considered are the following: removable overdentures are easier to clean outside the oral cavity, while fixed restorations in an edentulous mandible demand significantly more time, effort, and dexterity for proper oral hygiene. For this reason, implant overdentures should be preferred for geriatric patients, due to their limited capacity for maintaining proper hygiene.

The 5-year prospective study conducted by **Krennmair et al.,** (**2011**) reported that, when the mandible was atrophic, either ball attachments or telescopic crowns on single implants could be a viable treatment for implant-supported overdentures, as there were no implant failures, and peri-implant conditions and overall patient satisfaction were good.

Another clinical trial by **Krennmair et al.,** (**2012**) demonstrated improved satisfaction among patients with ball or locator attachment compared to patients' baseline (i.e. their old dentures) for all parameters. Nevertheless, there was no significant preference among patients or differences concerning ball or locator attachments regarding any of the satisfaction criteria evaluated. As the systematic literature review by **Boven et al.,** (**2012**) revealed, the treatment of patients already using complete dentures with implant(s) support enhances their mastication capacity and increases bite force providing a definite improvement of their overall satisfaction.

3.11.4 Oral health-related quality of life (OHRQoL)

Oral health-related quality of life (OHRQoL) and satisfaction are used to assess some treatment modalities implemented to restore partial or complete edentulism. The influence of an implant overdenture on the oral health-related quality of life has been studied by many researchers. A systematic review (**Thomason et al., 2007**) compared quality of life between complete denture wearers and maxillary implant overdenture users and found that there were no significant higher overall ratings for maxillary implant prostheses compared to new conventional maxillary prostheses.

A meta-analysis of randomized-clinical trials (**Emamai et al., 2009**) revealed that mandibular implant overdentures increase the quality of life compared to new conventional complete dentures. Another prospective study (**Yunus et al., 2016**) comparing OHRQoL of patients wearing complete dentures and of the same patients after the insertion of implant mandibular overdenture reported increased OHRQoL following the placement of the implant mandibular overdenture. Furthermore, a systematic review and meta-analysis of randomized controlled studies comparing implant supported mandibular overdentures and conventional dentures regarding quality of life showed that the former perform better than the latter in improving various aspects of the quality of life of edentulous patients (**Sivaramakrishnan et al., 2016**).

3.11.5 Technical complications

Implant overdentures require a technique-sensitive procedure and both biological and technical complications may occur. The term "*technical complications*" covers any kind of mechanical damage caused to the implant, to implant components or to the superstructure. Therefore, technical complications that may arise during clinical use should be taken into consideration for the selection of a retention element. When bars were compared with single retention elements, there was controversy as to which of the two systems requires less maintenance.

According to **Naert et al.,** (**1999**), after a 5-year observation period, magnets and ball groups presented the highest incidence of prosthetic complications as compared to the bar group. Another report (**Walton, 2003**) presented the three-year follow up of bar-clip and ball attachment dentures and found that the latter needed to be repaired five times more frequently; namely there were 324 repairs compared to 72 needed for the former. In addition, according to another clinical trial (**MacEntee et al., 2005**) after a 3-year follow up period, the ball-attachment system needed significantly more repairs compared to the bar-and-clip system.

Furthermore, an in vivo study (**Rentsch-Kollar et al., 2010**) reported that ball anchors required significantly more prosthetic service and a higher average number of incidents than systems with bars. Retention device complications mainly entailed mounting new female retainers, bar repairing and ball anchor changing. On the other side, the results of a 5-year randomized prospective clinical study that focused on mandibular 2-implant overdentures showed that technical complications and repairs per patient were more frequent in bars than in ball attachments (**Gotfredsen et al., 2000**).

Locator® and ball attachment systems were compared in a one-year report, which revealed that the former showed higher maintenance needs than the latter (**Kleis et al., 2010**). **Krennmair et al.,** (**2011**) also reported that locator attachment systems demanded higher post-insertion care (activation of retention) than ball anchors, even though overall prosthodontic maintenance incidence rates showed no significant difference between the two retention modalities. The need for maintenance for Locators® attachments has also been reported in a clinical trial and associated with economic cost (**Patodia et al., 2021**). Contrary to the abovementioned, **Cakarer et al.,** (**2011**) reported lower frequency of mechanical complications with Locators® than with ball-attachments or bars.

Ball-attachments and telescopic crowns were compared in a 5-year prospective study (**Krennmair et al., 2012**). They reported that frequency of technical complications was higher with the use of the former rather than with the use of the latter system in the first years of the study, but similar rates of maintenance could well be expected from both retention modalities. According to a 5-8 year retrospective study (**Zou et al., 2015**) in both groups, implants found a healthy peri-implant structure with overdentures. Telescoping crowns have also shown good survival rates with a minimum number of complications, as reported in an extended systematic review (**Verma et al., 2013**).

In a long-term retrospective study (**Kourtis, 2010**) of more than 4,000 implants and a follow-up of 19 years, the survival of implants under various types of restorations was investigated along with the prosthetic complications that appeared (***Fig. 3.45***). Significantly more complications occurred under bars (23,4%) compared to the mean rate of complications with all types of restorations (7,7%) and to overdentures with single ball attachments (8,3%).

A recent extended systematic review based on six studies with austere inclusion criteria concluded that there was not sufficient evidence to determine a preferred attachment system both for maxillary or mandibular implant overdentures (**Payne et al., 2018**).

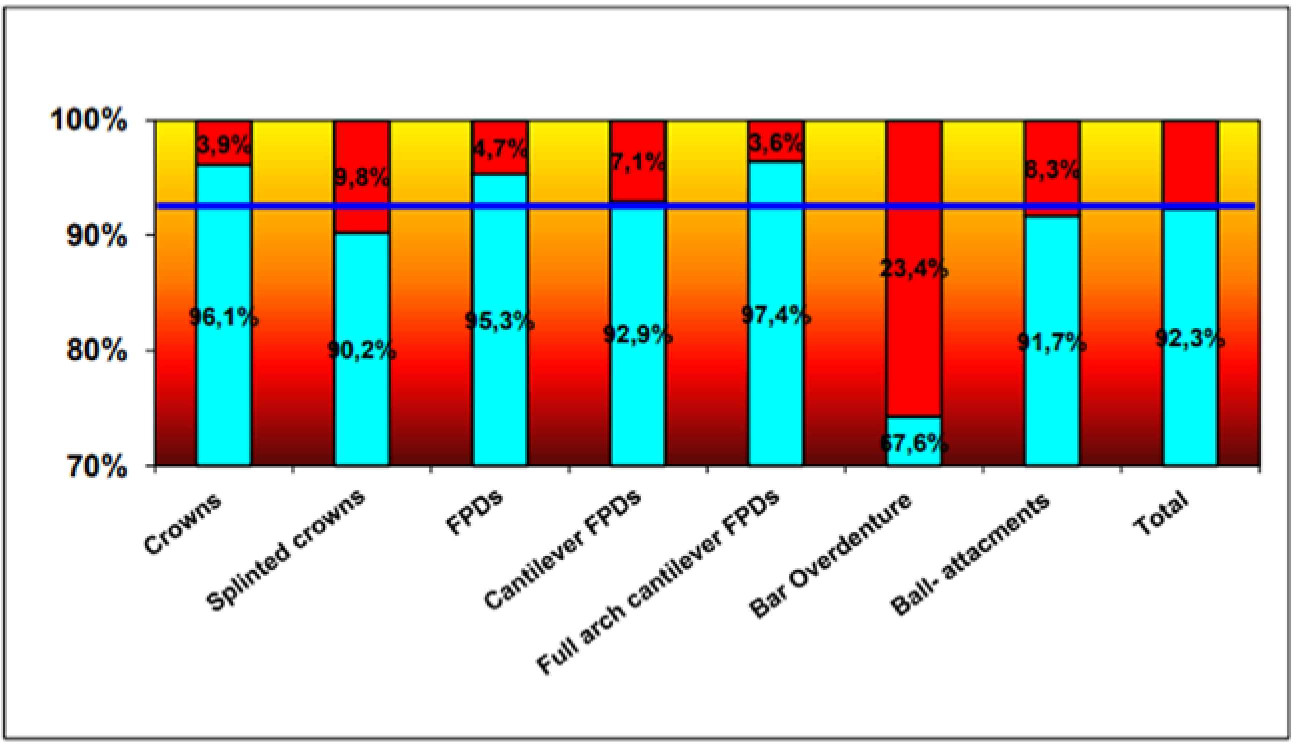


Fig. 3.45 *Prosthetic complications of implants in various types of restorations (from Kourtis 2010).*

3.12 Clinical relevance

Concluding, implant overdentures can offer great comfort and satisfaction to edentulous patients using a reduced number of implants and at a lower cost, as compared to fixed restorations. There are limitations and points of attention that must be evaluated for the treatment planning. The number of implants and the type of retention significantly affect the outcome, and the treatment plan should be made according to the specific characteristics of each clinical case. The patient's demands and expectations should be taken into consideration along with the ability of the patient to maintain oral hygiene and adapt to the restoration planned.

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CHAPTER 4

Impression techniques for implant restorations

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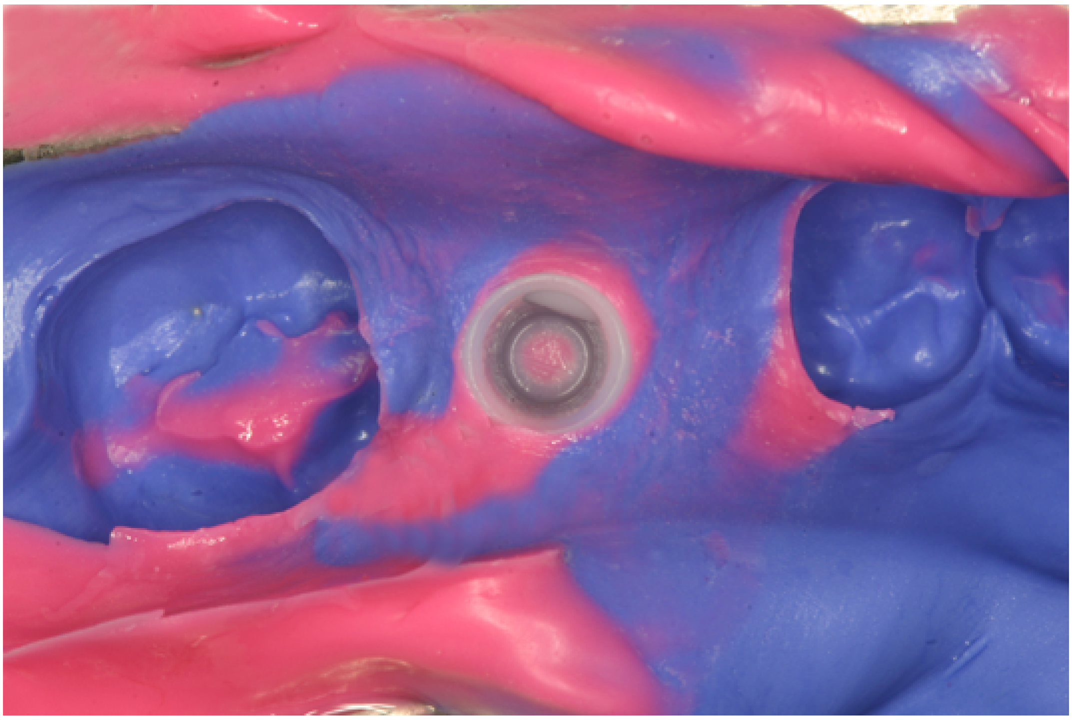

Abstract

Implant restorations are an established treatment for edentulous or partially edentulous patients. One of the most crucial factors for the long-term success of implant-supported prostheses is the accuracy of the impression procedure to obtain the passive fit of the restoration on the implants. In this chapter the impression materials and techniques that are nowadays used in implant-supported restorations are presented through clinical examples.

Knowledge background

To understand the content of this Chapter the reader must be familiar with the conventional impression techniques that are used for the natural teeth.

4.1 Introduction

The accurate transfer of the clinical situation to the dental laboratory by means of the impression is an important stage in implant-supported restorations, concerning the position, the inclination, the geometry of the prosthetic platform of the implants, as well as the condition of the peri-implant tissues (**Herbst et al., 2000; Chee et al., 2006**). The impression procedure in implant cases present certain differences compared to natural teeth, as implants are mechanical devices that are rigidly connected with the prosthetic components. In contrast to natural teeth, implants and their components have no micro-movement that could possibly compensate for minor inaccuracy of fit (**Sahin et al., 2001**).

4.2 Aim

The aim of this chapter is to present the impression materials and techniques that are nowadays used in implant-supported restorations with examples through a series of clinical cases.

4.3 Impression Materials

The term "impression" is used to describe a negative "copy" of the hard and soft tissues of the oral cavity, including teeth, implants, gingival margin, alveolar ridge and the covering mucosa. The goal is the fabrication of a life-size positive "copy" of the abovementioned tissues, in the form of a cast (**Stewardson, 2005**).

For implant impressions, addition-type silicones (or poly-vinyl-siloxane) and polyether are currently considered the materials of choice. Comparative studies have been published, investigating the accuracy and clinical efficiency of both elastomeric impression materials (**Wassell et al., 1991; Fenske, 2000; Taylor and Agar, 2002; Donovan et al., 2004**).

Most researchers agree that there is no significant difference in the accuracy of implant impression between poly-vinyl-siloxane and polyether (**Barrett et al., 1993; Vigolo et al., 2000; Petrie et al., 2003; Lee et al., 2008**). In an in-vitro study focusing on the influence of impression materials on the accuracy of the working casts, addition-type silicones showed increased accuracy compared to polyether (**Stefos et al., 2018**). Furthermore, **Wenz et al.,** (**2008**) compared the different impression techniques using only addition-type silicone, and concluded that the single-step (single mixing) impression technique resulted in more accurate impressions.

Regarding the viscosity of the impression material, the use of medium-viscosity offers certain advantages in clinical practice. Medium-viscosity or monophase materials can flow around the impression posts without exerting pressure. Due to their increased hardness after polymerization, an accurate impression can be obtained. Their use, however, should be combined with a custom tray that allows even thickness of the impression material around the implants. Medium-viscosity materials can be used alone or combined with high-flow materials to achieve maximum detail reproduction and allow the material to flow/penetrate even in small gaps around the impression posts. Some manufacturers have introduced addition-type silicones in medium-viscosity that have been evolved especially for implant restorations (e.g. Hydrorize Implant, Zhermack Co, Italy). The use of these materials certainly facilitate the clinical procedure as they combine high flow before polymerization and increased hardness after polymerization.

Putty or high-viscosity impression materials offer rigidity and can also be used, but their flow is limited compared to medium-viscosity. For this reason, putty or low-flowing (high-viscosity) materials should be used in combination with high-flowing (low-viscosity) materials to achieve detailed reproduction.

In daily clinical practice, the most important factor in implant impressions seems to be the practitioner's compliance with the manufacturer's specifications and guidelines, since no significant difference has been shown between the accuracy offered by polyether versus addition-type silicone.

4.4 Impression techniques for implant restorations

The choice of the impression technique and the accuracy of the resulting impression affects directly the passive fit of the implant-supported restoration, which is an important goal in the restorative procedure. An inaccurate impression may result in a metal framework fitting non-passively, which can possibly cause mechanical complications, such as screw loosening or fracture, and/or abutment fracture. The most widely used impression techniques for implants in clinical practice are the open tray technique and the closed tray technique.

4.4.1 Open tray technique

The open-tray (or pick-up) technique involves the embedding of the impression posts (also referred to as impression copings) within the mass of the impression material during the final impression and their removal from the mouth in the tray after setting the material. The impression tray can be either a modified prefabricated plastic tray or a custom tray fabricated from auto- or photo-polymerizing resin on a study cast. For the open tray technique, metal trays with removable parts are also available, which allow access to the screws of the impression posts through the impression material, as some occlusal parts of the metal tray can be removed prior to impression (***Fig. 4.1***).

For the open tray technique, it is necessary to use either long impression posts or long retention screws that pass through the impression material and are retrievable through the tray's openings (***Fig. 4.2***). After complete polymerization of the impression material, the retention screws are completely removed from the impression posts and the implants. The posts remain embedded within the impression material and are simultaneously removed from the mouth. The impression posts for the open tray technique have outer surfaces with undercuts that allow the engagements of the posts in the mass of the material. For this reason, impression materials with increased hardness are recommended.

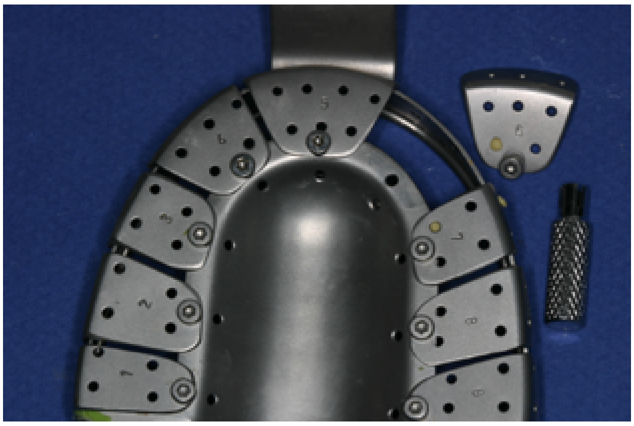

Fig. 4.1

Fig. 4.2

Fig. 4.1 *Prefabricated metal impression tray with removable parts to be used with the open tray technique.*

Fig. 4.2 *Impression posts with long screws for the open tray technique.*

For the fabrication of the working cast, the laboratory implant analogs are connected to the base of the impression posts protruding from the impression material and the retaining screw is fixed from the external side of the impression. On the working cast, a gingival mask is formed with a special addition-silicone material (usually pink in color) mimicking the peri-implant soft tissues.

The open tray technique was the standard procedure during the first years of use of dental implants, when the external hexagon was the most widely used implant type. As the main task was to transfer the exact position of the external hexagon for the fabrication of the master cast, the open tray technique facilitated the detachment of the impression posts from the top of the implants. For the same reason, it is also widely used for impressions on transgingival abutments (also referred to as multi-purpose abutments), where the connection mechanism (hexagon) is located above the soft tissues.

In cases of impressions in implant level for internal connection implants, it is not always easy to detach simultaneously multiple impression posts from the interior of the implants, especially if their axes are divergent. In this condition, the closed tray technique with an impression material of medium hardness may be of advantage.

In some clinical cases, splinting of the impression posts is performed before the impression procedure. Splinting offers the advantage of complete rigidity of the posts as a solid piece upon removal of the impression from the mouth. On the other side, splinting requires additional time for the clinician, and the patient has to stay with an open mouth for more time. The splinting of the impression posts is recommended in cases of implants in proximity, where it is difficult for the impression material to penetrate between the implants. Splinting allows secure removal of the posts in the mass of the polymerized material.

The most widely used technique for splinting of the impression posts is the creation of a scaffold with dental floss around and between the implants, which is covered with autopolymerizing resin to form a solid mass. A free space should be kept under the implants to allow penetration of the impression material over the mucosa and ensure removal of the solid block (Case C). Alternatively, a metal ring can be fabricated in the laboratory by casting on a study cast. The metal ring is fitted around the impression posts intraorally and the posts are fixed on the ring using autopolymerizing resin. Adequate space should be left under the block of the resin to allow the flow of the impression material. The posts and the metal ring are embedded in the mass of the impression material and are removed as a block with the open tray technique.

Advantages of the open tray technique

- Easier impression of implants with unfavorable inclination. The impression posts remain embedded in the impression material and do not require repositioning; therefore, possible errors due to incorrect handling can be avoided.
- Less strain is induced in the impression material during its removal from the mouth since it does not need to be detached around the impression posts.
- Easier impression of implants with converging axes, or in great proximity to each other.

Disadvantages of the open tray technique

- Necessity of a custom tray, or a modified prefabricated tray.
- Necessity to find and expose the protruding screws of the impression posts before setting of the impression the material
- Difficulty to apply in the posterior regions due to the increased height of the screws.
- Longer working time is needed intraorally, as all screws must be loosened before removing the impression.

4.4.2 Closed tray technique

In the closed tray (or repositioning technique), the impression tray (custom or prefabricated) has no opening over the implant area. During the impression procedure, the impression posts remain attached to the implants (***Case A***). After the setting of the material, the impression is detached from the mouth, while the impression posts remain fixed on the implants in the same way as the prepared natural teeth. For that reason, the impression posts are shorter than those used in the open tray technique, and they are equipped with shorter screws that do not protrude from the posts (***Fig. 4.3***). The shape of the posts is also rounded to allow removal of the polymerized impression material around the posts without exerting increased strain.

Subsequently, the impression posts are loosened and sent separately to the dental laboratory. For the fabrication of the working cast, the impression post is fixed on an implant analog and the pair is placed in their respective spaces (indentations) in the impression material. To ensure a more accurate placement of the posts, most manufacturers offer and recommend the use of a special plastic transfer cap. The cap is fitted on the top of the impression post and remains embedded in the impression material (***Fig. 4.4***).

The repositioning of the posts is thus performed with greater accuracy as only a single position of the impression post in the embedded transfer cap is possible without sinking or rotation of the post in the mass of the impression material. The design of the impression posts varies among manufacturers. It is important, however, that the manufacturer of the implant to be restored offers the option between the open and the closed tray technique.

Fig. 4.3

Fig. 4.4

Fig. 4.3 *Impression posts for the closed tray technique.*

Fig. 4.4 *Impression posts for the closed tray technique with plastic transfer cap for accurate repositioning in the impression.*

Advantages of the closed tray technique

- Simpler procedure, presenting great similarities with the usual impression techniques used for natural teeth.
- Easier clinical application in all areas without need for excessive mouth opening.
- Possibility of simultaneous impressions for teeth and implants.
- The use of a custom tray or a modified prefabricated tray is not necessary.
- The intraoral working time is reduced compared to the open tray technique.

Disadvantages of the closed tray technique

- The repositioning of the impression posts in the impression material may lead to inaccuracy of the working cast, especially if plastic transfer caps have not been used.
- Increased strain in the mass of the impression material may be induced upon impression removal.
- Difficulty in removing the impression from implants with unfavorable or diverting inclination.
- Doubtful accuracy in cases of implants in proximity.

4.5 Closed tray technique, single implant (Case A, Figs. 4.5-4.9)

In cases of single implants that have adequate distance to the adjacent teeth and favorable inclination, both the open tray and the closed tray technique can be applied. Addition-type silicone can be used in putty consistency combined with high-flow material in a prefabricated metal tray, as used for natural teeth (***Figs. 4.5-4.8***). In cases with putty material and closed tray technique, it is strongly advisable, however, to use impression posts with a plastic transfer cup that facilitates the repositioning of the post in the mass of polymerized impression material minimizing inaccuracy. Alternatively, a medium-viscosity material combined with high-flow could also have been used. The patient was restored with a screw-retained implant crown (***Fig. 4.9***).

Fig. 4.5

Fig. 4.6

Fig. 4.5 *Case A, Initial clinical situation with impression post for closed tray.*
Fig. 4.6 *Plastic transfer caps for repositioning fitted on the impression post.*

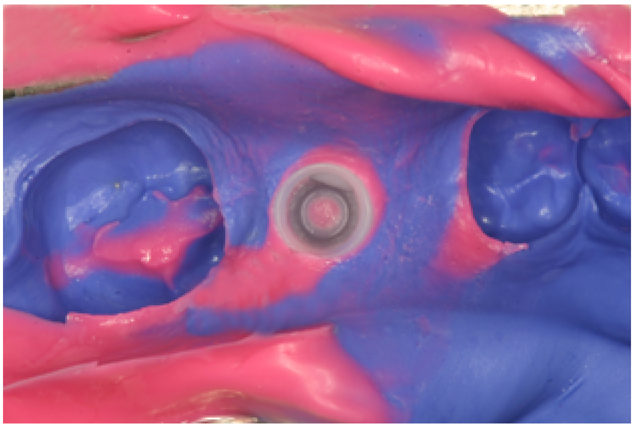

Fig. 4.7

Fig. 4.8

Fig. 4.7 *Closed tray impression, double mixing technique.*
Fig. 4.8 *The working cast.*

Fig. 4.9 *Case A, the final implant-supported crown.*

4.6 Closed tray technique, two implants (Case B, Figs. 4.10-4.15)

In the presented case (**Case B**), two internal connection implants in the mandibular right side (regions #44 and 46) were to be restored. As the position and the inclination of the implants were favorable and the distance to adjacent tooth adequate (***Fig. 4.10***), the closed-tray technique (repositioning technique) was applied. On the impression posts, the plastic caps for the repositioning were fitted (***Fig. 4.11***).

Addition-type silicone was used in heavy-body and light-body consistency with a prefabricated metal tray, and an accurate working cast was fabricated (***Figs. 4.12 and 4.13***). The implants were restored with an implant-supported screw-retained Fixed Dental Prosthesis (FDP) that fitted accurately (***Figs. 4.14 and 4.15***).

Fig. 4.10

Fig. 4.11

Fig. 4.10 *Case B, Initial clinical situation with impression posts for closed tray.*
Fig. 4.11 *Plastic transfer caps fitted on the impression posts.*

Fig. 4.12

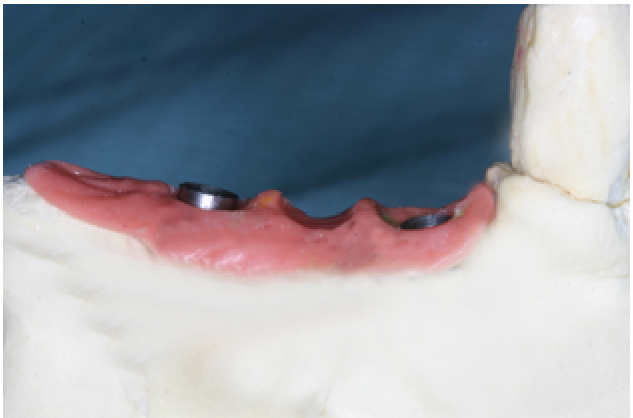

Fig. 4.13

Figs. 4.12 and 4.13 *Closed tray impression, double mixing technique and the working cast.*

Fig. 4.14 *The restoration of the working cast.*

Fig. 4.15 *Case B, the final screw-retained restoration.*

4.7 Open tray technique, partially edentulous patient (Case C, Figs. 4.16-4.21)

In Case C, two adjacent implants in the maxillary right region (#15, 16) and tooth #14 had to be restored (***Figs. 4.16 and 4.17***). Due to the proximity and the unfavorable inclination of the implants, the open tray technique was selected. The thickness of the peri-implant tissues also increased the difficulty for proper insertion of the transfer (repositioning) caps over the impression posts. A custom tray from light-curing resin was fabricated on a study cast made from an initial alginate impression. The height of the tray was checked to verify the access to the impression posts (***Fig. 4.18***).

An addition-type silicone was used in medium and high-flow consistency, both for the implants and the tooth and an accurate working cast could be fabricated (***Figs. 4.19 and 4.20***). The use of medium and high-flow silicone was advantageous in this case, as the space between the implants was narrow and a heavy-body or putty material probably would not embrace the impression posts. The patient was restored with two splinted screw-retained crowns on the implants and a metal ceramic crown on the tooth (***Fig. 4.21***).

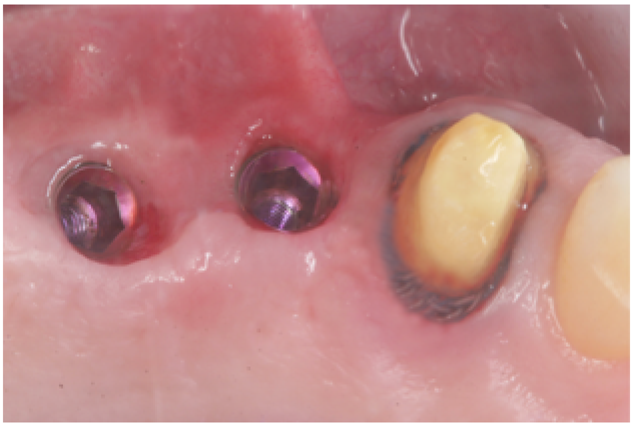

Fig. 4.16

Fig. 4.17

Fig. 4.16 *Case C, initial clinical situation.*
Fig. 4.17 *Impression posts for the open tray technique.*

Fig. 4.18

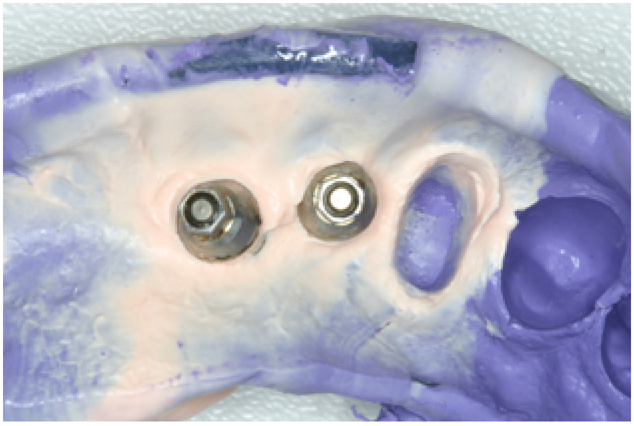

Fig. 4.19

Fig. 4.18 *Custom tray with openings for the impression posts with adequate height.*
Fig. 4.19 *Open tray impression, double mixing technique.*

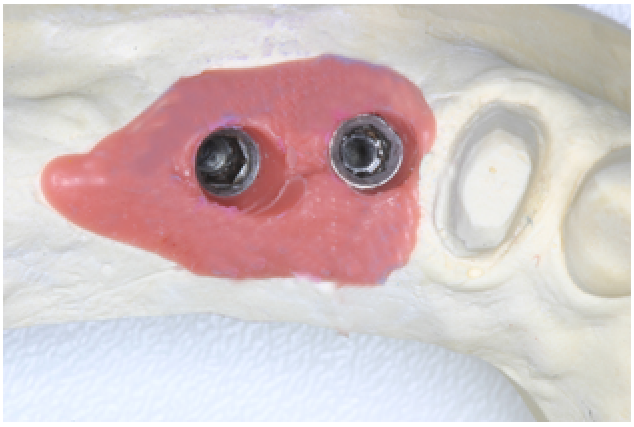

Fig. 4.20

Fig. 4.21

Fig. 4.20 *The working cast.*
Fig. 4.21 *Case C, the final restoration.*

4.8 Open tray technique, partially edentulous patient (Case D, Figs. 4.22-4.27)

In Case D, three adjacent implants were to be restored in the mandibular left side in regions #34, 35, 36 (***Fig. 4.22***). The implants were not parallel with unfavorable inclinations. Additionally, the anterior implant was placed deep subgingivally and for these reasons the open tray technique was selected. As the patient was on a heavy schedule and it was not possible to make a custom tray in the dental laboratory, a prefabricated plastic tray was modified with openings for the impression posts. To achieve maximum accuracy of the impression, the impression posts were splinted with autopolymerizing resin (Pattern Resin, GC Co., Japan) which was added on a scaffold created with dental floss around and between the implants (***Fig. 4.23***).

An addition-type silicone was used with a single mixing technique. The medium viscosity of the material allowed the flow under the splinting, and the increased hardness after polymerization contributed to the secure removal of the splinted impression posts in the material (***Figs. 4.24 and 4.25***). An accurate working cast was fabricated, and the patient was restored with splinted screw-retained crowns (***Figs. 4.26 and 4.27***).

Fig. 4.22

Fig. 4.23

Fig. 4.22 *Case D, initial clinical situation.*
Fig. 4.23 *Splinted impression posts.*

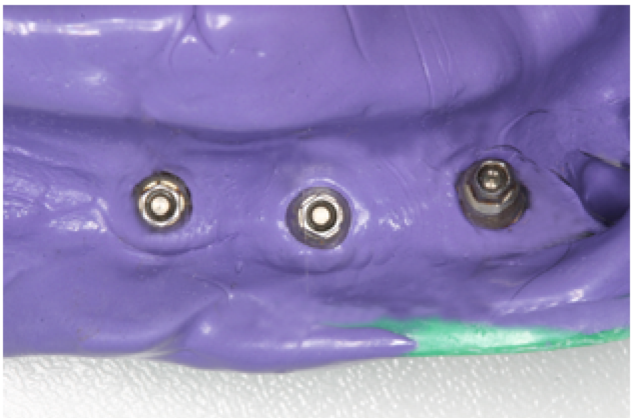

Fig. 4.24

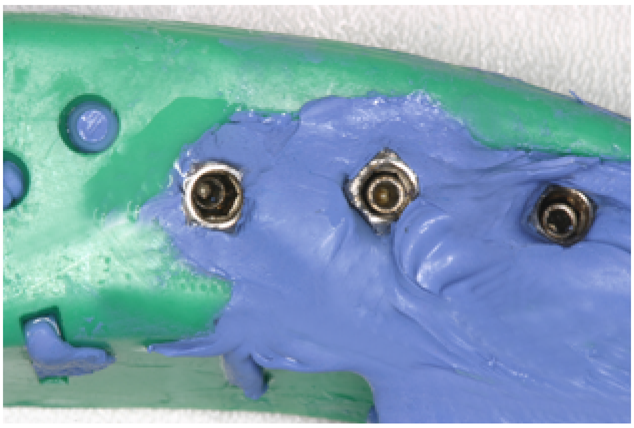

Fig. 4.25

Figs. 4.24 and 4.25 *Open tray impression, single mixing technique.*

Fig. 4.26

Fig. 4.27

Fig. 4.26 *The working cast.*
Fig. 4.27 *Case D, the final screw-retained restoration.*

4.9 Open tray technique without splinting, edentulous maxilla (Case E, Figs. 4.28-4.35)

In Case E, four implants were inserted in the edentulous maxilla according to the shortened dental arch principle (***Fig. 4.28***). The implants were parallel with favorable inclination with the exception of the implant #23 that had a severely divergent axis (***Fig. 4.29***). As the distance between the implants was adequate, it was decided to use the open tray technique without splinting of the impression posts. A custom tray was fabricated on a study cast in the dental laboratory using light-polymerizing resin (***Fig. 4.30***).

The tray was tried intraorally with the impression posts fixed on the implants to verify an undisturbed insertion path. It is important to verify the correct path of insertion before loading the impression material as the tray may need modification to allow proper placement (***Figs. 4.31 and 4.32***). The impression was taken using medium-viscosity material (***Figs. 4.33-4.35***). The patient was restored with an implant-retained fixed restoration (***Fig. 4.36***).

Fig. 4.28

Fig. 4.29

Fig. 4.28 *Case E, initial clinical situation.*
Fig. 4.29 *Long impression posts for open tray.*

Fig. 4.30

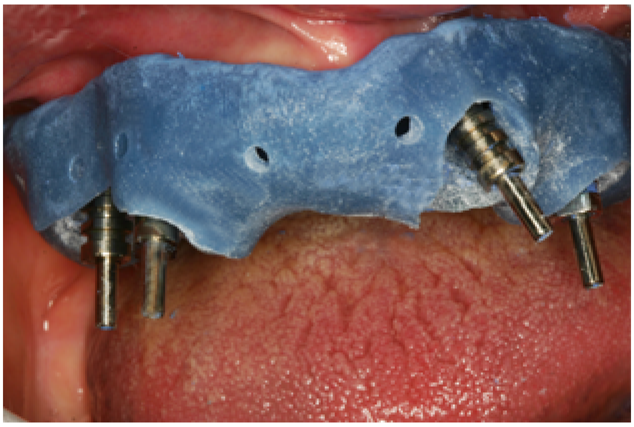

Fig. 4.31

Fig. 4.30 *The custom tray on the study cast.*
Fig. 4.31 *The custom tray tried for the correct path of insertion.*

Fig. 4.32 *Modification of the custom tray to allow insertion.*

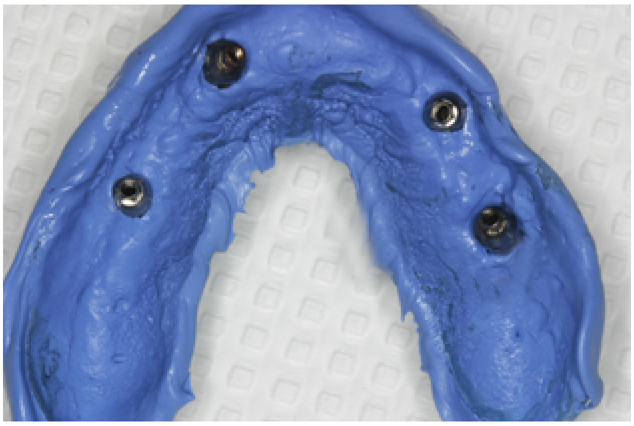

Fig. 4.33

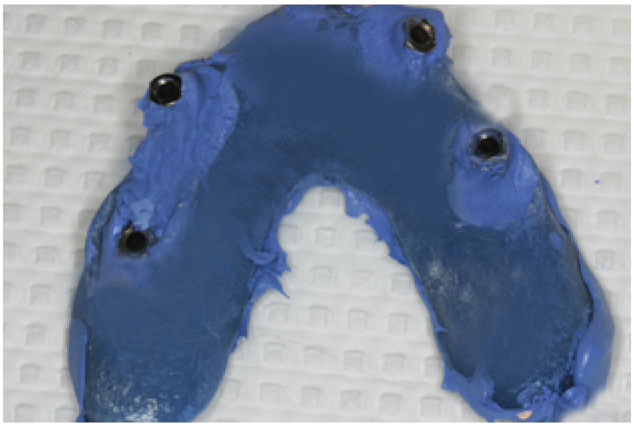

Fig. 4.34

Figs. 4.33 and 4.34 *Impression with open tray, single mixing technique.*

Fig. 4.35

Fig. 4.36

Fig. 4.35 *The working cast.*
Fig. 4.36 *Case E, the final restoration.*

4.10 Open tray technique, edentulous mandible (Case F, Figs. 4.37-4.43)

In Case F, four implants were inserted in the anterior region of the mandible for a screw-retained fixed restoration according to the short dental arch principle (***Fig. 4.37***). The restoration would be fitted directly in the implants, and for this reason the impression should be taken at implant level. For the open tray technique, a custom tray was fabricated on a study cast without a handle in the anterior region, as it would cause difficulties to remove the retaining screws of the post (***Fig. 4.38***).

The impression posts for the open tray in this implant system were short and their embedment and retention in the impression material was doubtful. The impression posts were splinted with dental floss forming a scaffold on which autopolymerizing resin was added intraorally to create a block (***Figs. 4.39 and 4.40***). The impression was taken using medium-viscosity addition-type silicone both under the impression posts and in the tray (***Fig. 4.41 and 4.42***). The patient was restored with a screw-retained hybrid fixed restoration (***Fig. 4.43***).

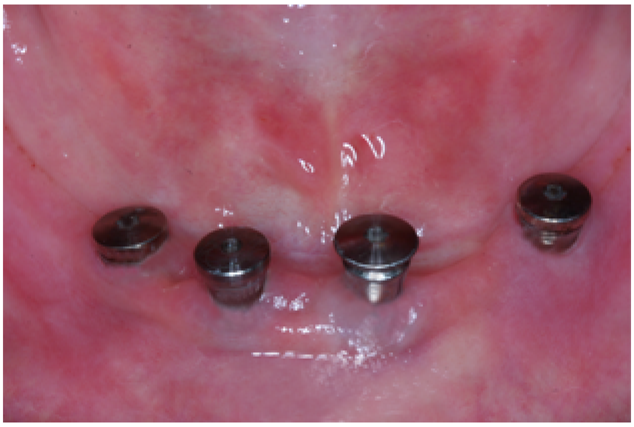

Fig. 4.37

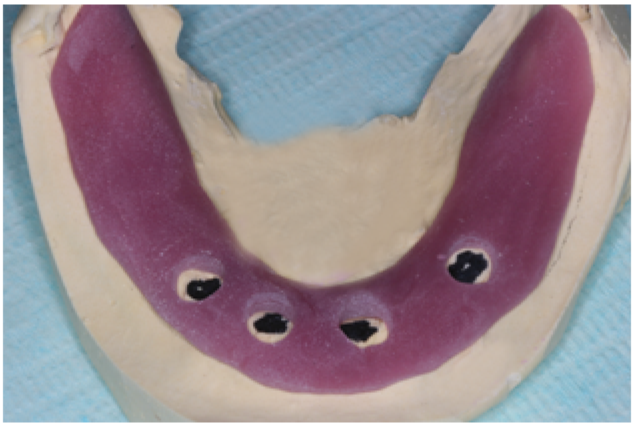

Fig. 4.38

Fig. 4.37 *Case F, initial clinical situation.*
Fig. 4.38 *Custom tray without handle fabricated on a study cast.*

Fig. 4.39

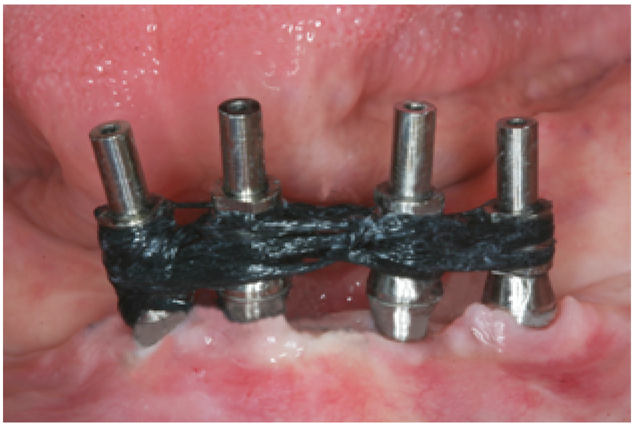

Fig. 4.40

Fig. 4.39 *The impression posts.*
Fig. 4.40 *Splinting of the impression posts with dental floss and autopolymerizing resin.*

Fig. 4.41

Fig. 4.42

Figs. 4.41 and 4.42 *Impression with open tray and single mixing technique.*

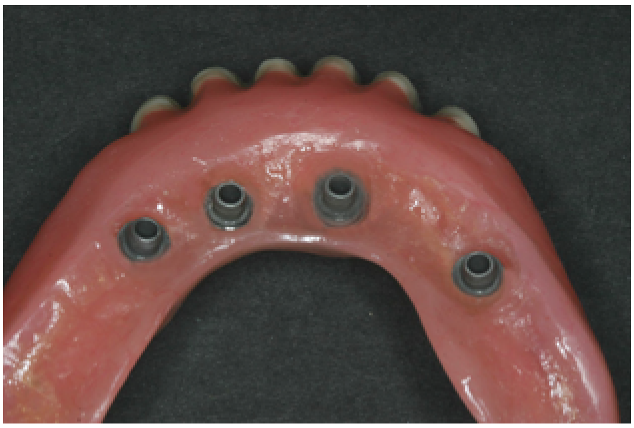

Fig. 4.43 *Case F, the final restoration.*

4.11 Open tray technique with splinting in adjacent implants with proximity (Case G, Figs. 4.44-4.51)

In this case (**Case G**), two adjacent implants were placed in the maxillary left region for the replacement of missing teeth #24 and 25. The implants were in proximity, and it was not possible to insert the impression posts simultaneously (***Fig. 4.44***). The possible clinical options for this case were either the modification of the posts by grinding the opposing sides or the impression of each implant separately. Instead of using the impression posts, the implant carriers were fitted on the implants and were used as impression posts. The carriers have the same diameter as the implants on the base and fit exactly to the internal hexagon of the implant but they are narrower than impression posts in the body. The main problem of using the carriers as impression posts is that due to their design the repositioning in the impression material is not accurate. Additionally, the carriers are provided with short screws and cannot be used as impression posts for the open tray technique.

Taking into consideration the above-mentioned limitations, it was decided to use the carriers with an open custom tray by splinting. The custom tray was fabricated with reduced height to allow access to the top of the carriers, as the screws were short and were not protruding from the tray. The carriers were fixed on the implants and were splinted using autopolymerizing resin covering the whole edentulous space (***Figs. 4.45 and 4.46***).

Before taking the impression, the unobstructed removal of the block of resin was checked. The impression was taken using heavy body addition-type silicone for the tray that had the proper stiffness to engage the resin block surrounding the posts and remove it (***Fig. 4.47***). Low-viscosity silicone was injected under the block for detailed reproduction. Alternatively, medium viscosity combined with low-viscosity material could also have been used.

This impression technique resulted in a working cast with the needed precision and detail that allowed the construction of two splinted screw-retained crowns fitting accurately (***Figs. 4.48-4.51***). The inter-implant space was checked carefully to allow the use of a thin interdental brush for oral hygiene.

Fig. 4.44 *Case G, initial clinical situation with the carriers fitted on the implants.*

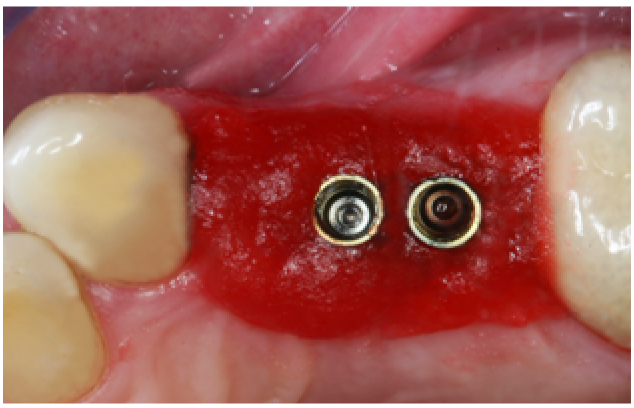

Fig. 4.45

Fig. 4.46

Figs. 4.45 and 4.46 *The implant carriers splinted with autopolymerizing resin.*

Fig. 4.47 *The final impression with double mixing technique.*

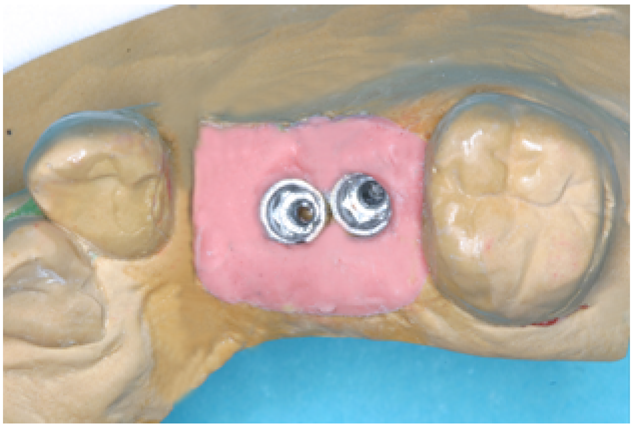

Fig. 4.48

Fig. 4.49

Fig. 4.48 *The working cast.*
Fig. 4.49 *Screw-retained splinted crowns.*

Fig. 4.39

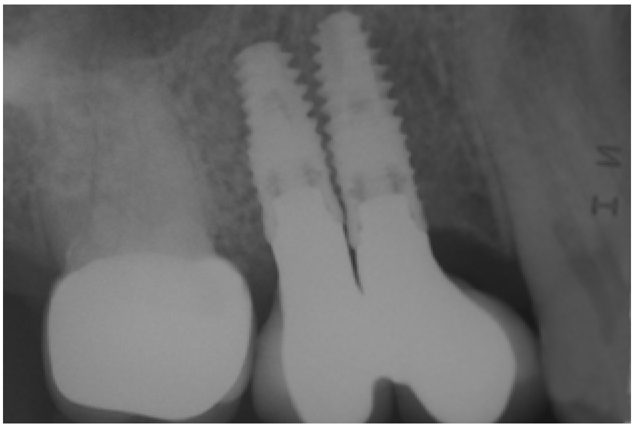

Fig. 4.40

Fig. 4.50 *The final restoration in the mouth.*
Fig. 4.51 *Case G, radiographic control of the fit of the restoration.*

4.12 Open tray technique in reduced space, single implant, (Case H, Figs. 4.52-4.60)

In this case (**Case H**), an implant was inserted in the region of the right mandibular lateral incisor, but the restoration of the implant was delayed due to the heavy schedule of the patient involving multiple long-term trips abroad. As a result, the available space was severely reduced because of migration/inclination of the adjacent teeth (***Fig. 4.52***). The remaining space did not allow the use of the regular impression post that is wider in diameter than the implant.

As in the previous case, it was decided to use an implant carrier of the corresponding diameter for the impression. In this clinical situation, there was no possibility of splinting the implant carrier and it was decided to use a modified prefabricated plastic tray for the open tray technique. An additional clinical difficulty was the fact that carriers are provided with short screws, and the access to the retaining screw should be kept uncovered during the impression (***Fig. 4.53***). The carrier was fitted on the implant and the shaft of an implant screwdriver was fitted on the retaining screw to keep the access open through the impression material (***Fig. 4.54***).

A prefabricated plastic tray was used that was modified to allow the protrusion of the shaft of the screwdriver. The hole on the top of the impression tray was covered with paper tape to avoid overflow of the impression material (***Fig. 4.55***). A medium-viscosity addition-type silicone was used for the impression combined with the corresponding high-flow material that was injected around the implant carrier for detail reproduction (***Fig. 4.56***).

After setting the impression material, the handle of the screwdriver was fitted on the protruding top of the shaft and loosened the retaining screw (***Fig. 4.57***). An accurate impression could be obtained as the stiffness of the impression material allowed the removal of the implant carrier from the implant (***Figs. 4.58 and 4.59***). The patient was restored with a screw-retained crown (***Fig. 4.60***).

Fig. 4.52 *Case H, initial clinical situation.*

Fig. 4.53 *An impression post for an open tray (left) with a long screw compared to an implant carrier for the same implant (right).*

Fig. 4.54 *The implant carrier on the implant with the screwdriver shaft fitted on the retaining screw.*

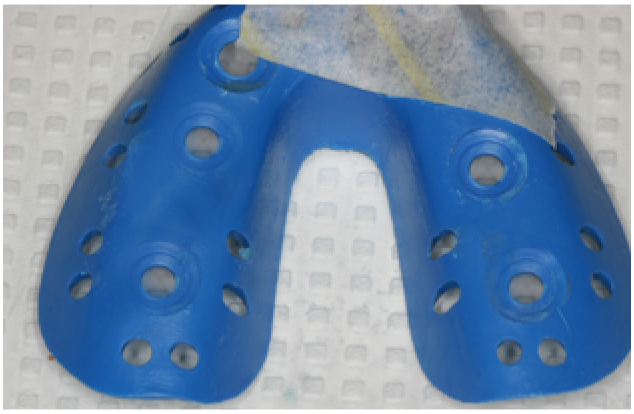

Fig 4.55 *The prefabricated plastic tray modified for the open tray technique.*

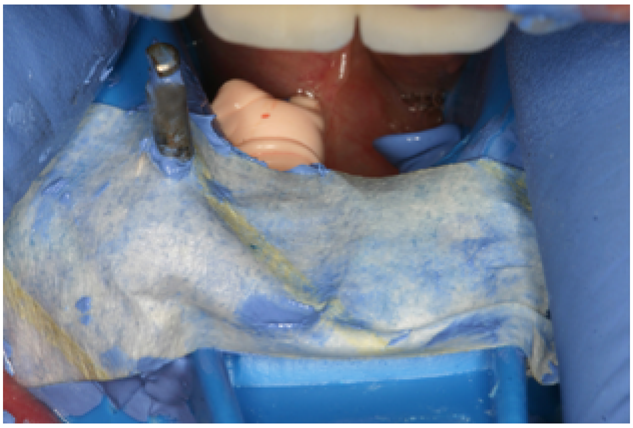

Fig. 4.56

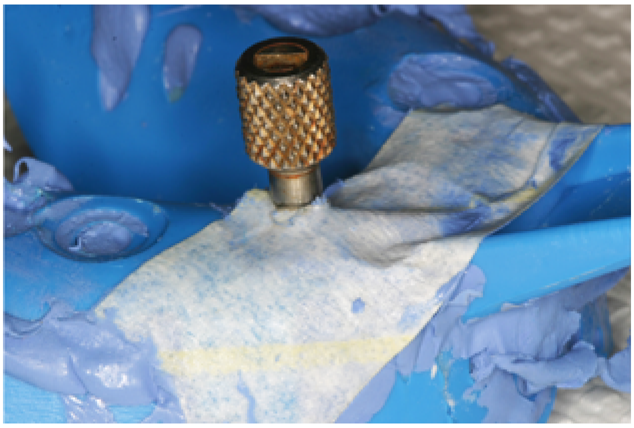

Fig. 4.57

Fig. 4.56 *Impression with the shaft protruding through the impression material.*
Fig. 4.57 *The handle of the screwdriver fitted on the shaft for loosening of the retaining screw.*

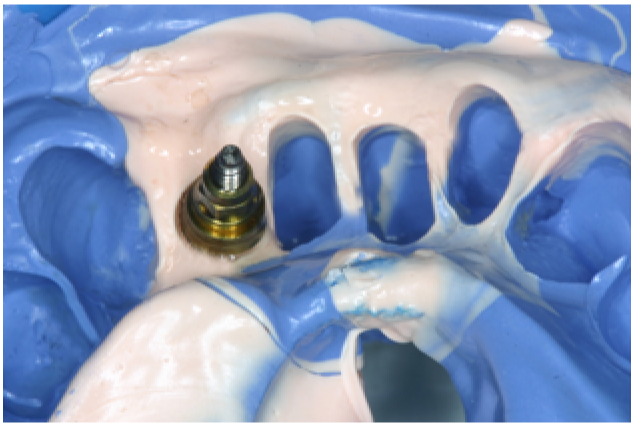

Fig. 4.58

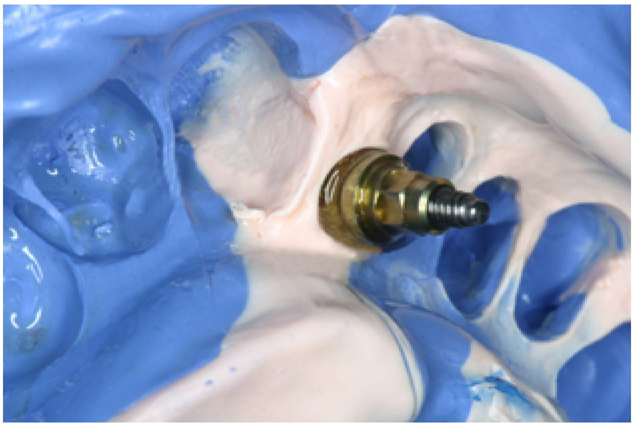

Fig. 4.59

Figs. 4.58 and 4.59 *The final impression with the double mixing technique.*

Fig. 4.60 *Case H, the final restoration.*

4.13 Open tray technique for the edentulous mandible with splinting of the impression posts (Case I, Figs. 4.61-4.70)

In this patient (**Case I**), six implants were placed for the rehabilitation of the edentulous mandible. The planned restoration for this case was a screw-retained fixed restoration on transmucosal (multi-purpose) abutments. For this reason, the final impression should be taken on the abutment level. An initial open-tray impression at the implant level was taken with long impression posts and a primary (initial) working cast was fabricated with a soft tissue mask (***Figs. 4.61 and 4.62***).

On the primary working cast, the initial selection of the transmucosal abutments (multi-purpose abutments) was done according to the height of the peri-implant soft tissues and the inclination of the implant. The definitive selection of the transmucosal abutments would be done intraorally with a verification from the surgical guide (***see also Chapter 7, Case E***). On the working cast, the impression posts for the transmucosal abutments were fitted and splinted with a scaffold from dental floss and autopolymerizing resin (***Figs. 4.63-4.64***). The splint was then cut between the implants and a new custom impression tray was fabricated (***Figs. 4.65 and 4.66***).

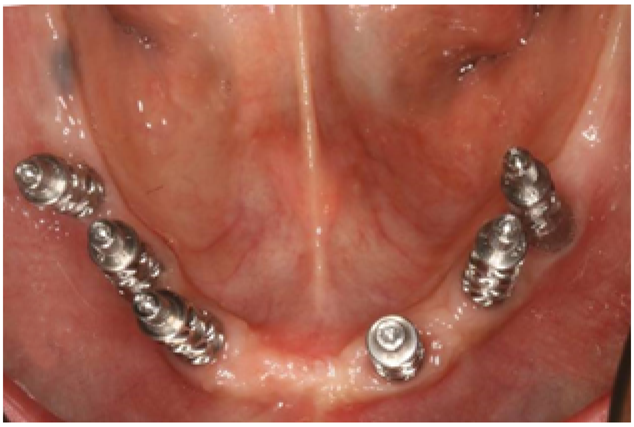

Fig. 4.61 **Fig. 4.62**

Fig. 4.61 *Case I (courtesy of Dr. E. Bachlava), initial impression at implant level.*
Fig. 4.62 *Initial working cast with impression posts for the transmucosal abutments.*

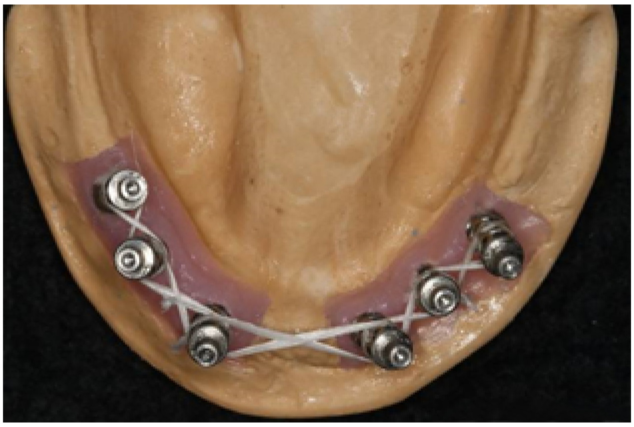

Fig. 4.63 **Fig. 4.64**

Figs. 4.63 and 4.64 *Splinting of the impression posts with dental floss and autopolymerizing resin.*

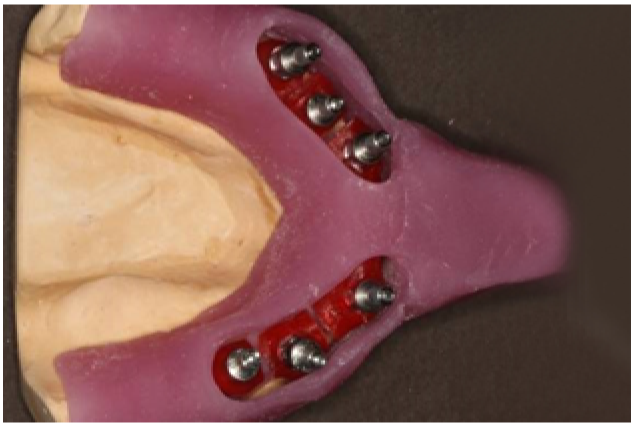

Fig. 4.65 **Fig. 4.66**

Fig. 4.65 *Separation of the splinting.*
Fig. 4.66 *Custom impression tray for the open tray technique.*

Following this procedure, the maximum possible accuracy for the final impression could be achieved, as the polymerization shrinkage of the resin could be minimized by reducing the quantity of the resin applied. On the other side, as the final fixing of the transmucosal abutments was done intraorally, the connection of the resin blocks after the final torque could compensate for small discrepancies.

The transmucosal abutments were finally selected intraorally and fixed with the recommended torque. The impression posts for the abutment level impression—each one embedded in a block of resin—were fixed on the abutments and connected with resin (***Figs. 4.67 and 4.68***). An open tray impression was taken with medium-viscosity addition-type silicone and a new working cast was fabricated with implant analogs corresponding to the transmucosal abutments (***Figs. 4.69 and 4.70***). The definitive intraoral selection of the abutments and the restoration of the patient is described in detail in ***Chapter 7: Screw-retained restorations as Case E.***

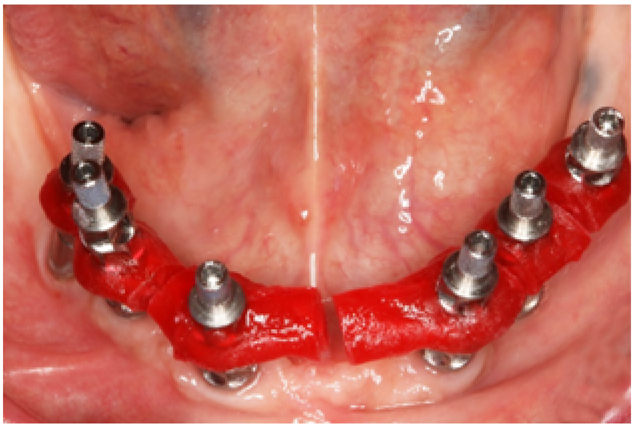

Fig. 4.67

Fig. 4.68

Fig. 4.67 *The impression posts for the final impression*

Fig. 4.68 *Final splinting of the impression posts.*

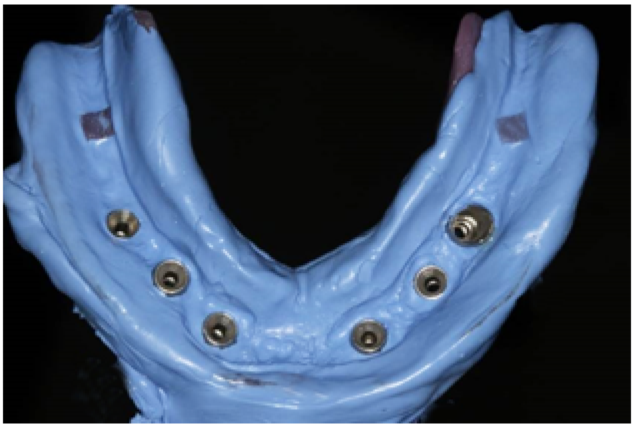

Fig. 4.69

Fig. 4.70

Fig. 4.69 *The final impression with the open tray.*

Fig. 4.70 *Case I, the definitive working cast with implant analogs corresponding to the transmucosal abutments.*

4.14 Comparative studies of the accuracy of different impression techniques

Concerning the accuracy of both different impression techniques (open or closed tray), several comparative studies have been published (**Humphries et al., 1990; Philips et al., 1994; De La Cruz et al., 2002; Assuncao et al., 2004; Del' Aqua et al., 2008; Herbst et al., 2000; Naconecy et al., 2004; Cabral and Guedes, 2007; Conrad et al., 2007; Mpikos et al., 2012**).

Most studies concluded to increased accuracy of the open tray technique (**Philips et al., 1994; Assuncao et al., 2004; Del' Aqua et al., 2008**), others found no significant differences (**Herbst et al., 2000; Naconecy et al., 2004; Conrad et al., 2007**), while in a limited number of studies the closed tray technique presented more accurate results (**Humpries et al., 1990; De La Cruz et al., 2002**). Other research studies also suggested that there is a correlation between the accuracy of the impression technique and the number of implants. In most studies with three or fewer implants, there was no difference (**Carr, 1992; Cabral et al., 2007; Conrad et al., 2007**) between open and closed tray techniques. Research papers in cases with more than four implants, (**Philips et al., 1994; Assuncao et al., 2004; Del' Aqua et al., 2008; Wentz et al., 2008; Mpikos et al., 2012**) suggested that the open tray technique had better results, while in some studies no significant differences were found (**Herbst et al., 2000; Naconecy et al., 2004**). For non-parallel implants, however, the open tray technique has been shown as more accurate (**Osman et al., 2019**).

In conclusion, it appears that for a limited number of implants (n <3) there was no significant difference between the two impression techniques, while for extended implant restorations (n> 3) the open tray technique seems to be advantageous. Finally, although there is no clear clinical guideline, most studies report that the splinting of the impression posts can improve the impression accuracy. Some authors, however, report potential problems during splinting, such as the deformation or shrinkage of acrylic material (**Spector et al., 1990; Burawi et al., 1997**).

Many studies have compared the open tray technique in the two variants, i.e., with splinted or unsplinted impression posts. Most of these papers argue that splinting leads to improved accuracy (**Assif et al., 1992; Assif et al., 1996; Burawi et al., 1997; Vigolo et al., 2003; Vigolo et al., 2004; Assuncao et al., 2004; Naconecy et al., 2004; Cabral et al., 2007**). In other studies, the non-splitting technique showed better accuracy (**Inturregui et al., 1993; Philips et al., 1994**), while in other studies (**Hsu et al., 1993; Assuncao et al., 2004; Choi et al., 2007; Wentz et al., 2008**), no significant differences were found in the accuracy between the two impression techniques. In an in-vitro study comparing the influence of the splinting of impression copings on the accuracy of the final cast, no difference was found in parallel implants. On the other hand, in non-parallel implants the splinting improved the accuracy of the impressions (**Kavadia et al., 2019**).

In an extended systematic review (1980-2013) based on numerous studies the influence of different factors affecting the accuracy of impression materials and techniques was investigated (**Papaspyridakos et al., 2014**). In 21 in-vitro studies addition-type silicone was compared to polyether but in 19 studies among them no significant difference was found.

4.15 Clinical relevance

The impression of implants has several differences compared to the impression of natural teeth and the clinician should take these differences into consideration. Careful selection of the proper impression material and technique according to the needs of each clinical case is of vital importance to achieve the construction of an accurate working cast.

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CHAPTER 5

Intra-Oral Scanning – Digital Impressions for Implant Restorations

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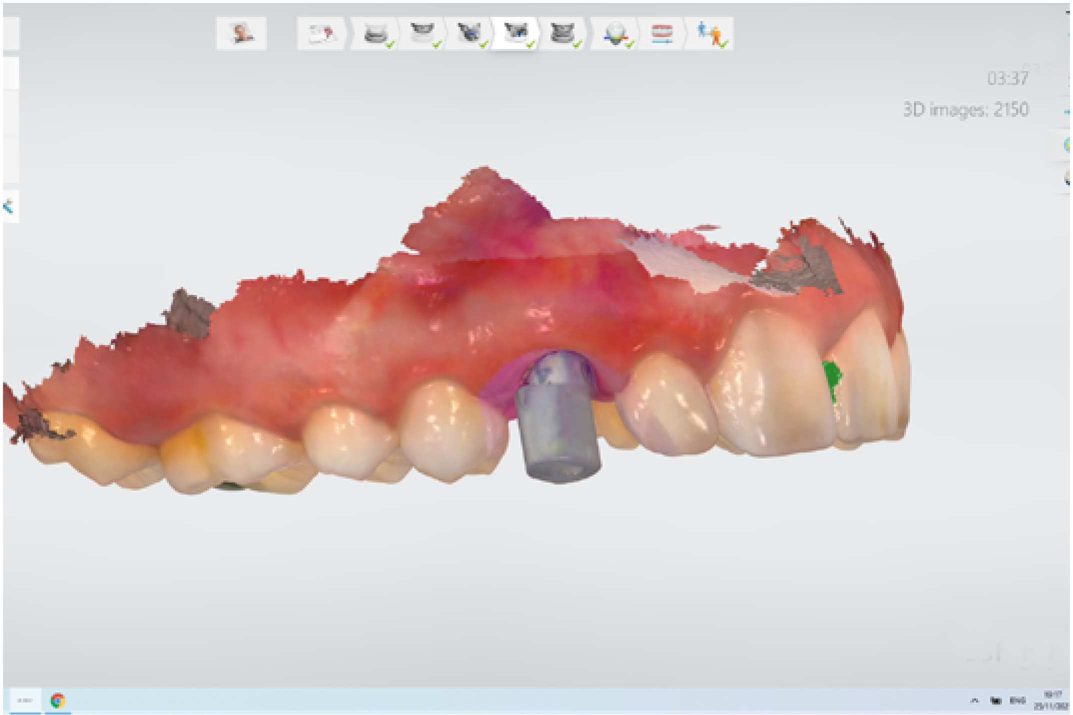
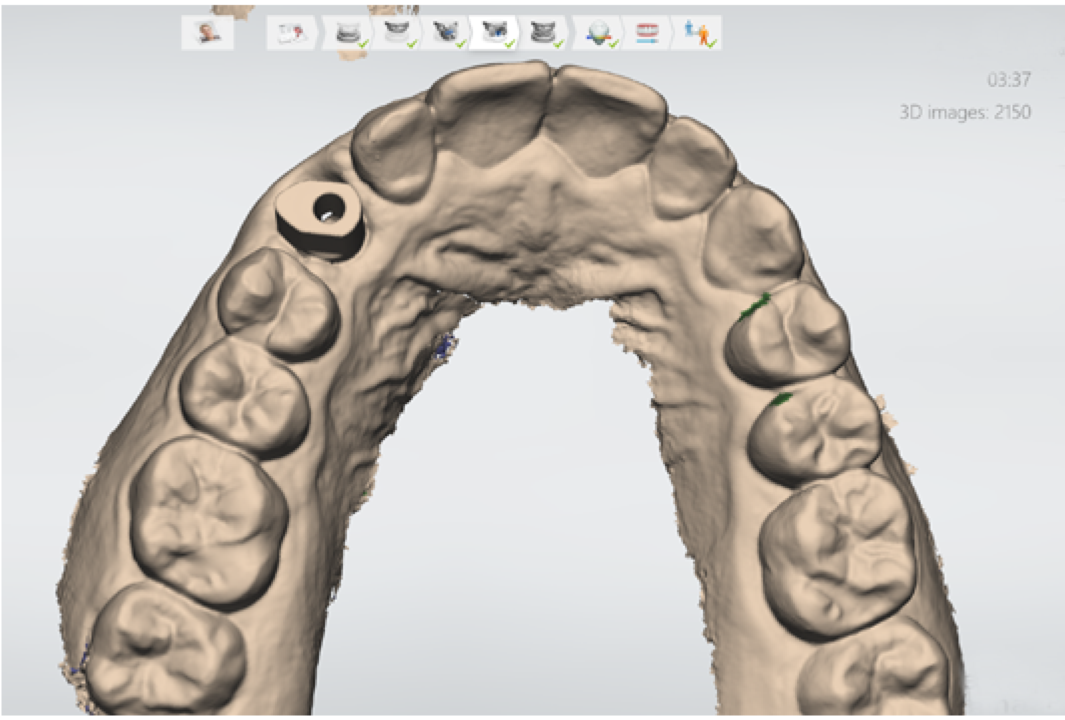




Abstract

The intra-oral scanning—also referred to as digital impression—is a newly introduced technique reducing some problems associated with the conventional techniques and impression materials. For intra-oral scanning, optical methods are used to record the positions of the teeth and/or implants and transfer them in a virtual digital model. The intra-oral scanning reduces the needed clinical time and offers comfort to the patient. It can also simplify the transfer of the acquired data to the laboratory, as only digital files are sent through the web. Archiving of the patients is easier, as all data can be saved digitally. On the other side, there are certain limitations, and the clinician should apply this new method carefully, as there is always a learning curve in every new technique.

Knowledge background

To understand the content of this Chapter, the reader must be familiar with the conventional impression techniques, as they are described in detail in Chapter 4: "Impression techniques for implant restorations."

5.1 Introduction

Intra-oral scanning—also referred to as digital impression—is a newly introduced technique in implant dentistry aiming for accurate transfer of the position and angulation of implants. This new technology can eliminate some problems associated with the conventional techniques and impression materials. For intra-oral scanning, optical methods are used to record the positions of the teeth and/or implants, and transfer them in a virtual digital model. Digital impressions have been used successfully for orthodontic purposes (**Goracci et al., 2016**).

In implant prosthodontics as well, their use is widely adopted by the clinicians. In the conventional impression technique, elastomeric material and impressions copings are used to transfer the implant positions to a stone cast with implant analogs reproducing the original implants (**Flügge et al., 2018**). The intra-oral scanning also reduces procedure time and improves patient comfort in implant dentistry as was concluded in a systematic review based on 17 studies (**Siqueira et al., 2021**).

5.2 Aim

The aim of this chapter is to present the basic principles, possibilities, and limitations of intra-oral scanning through clinical examples.

5.3 Intra-Oral Scanning

In the intra-oral scanning, the scope is to acquire a 3D digital image of the teeth and/or implants by the scanning device. Digitalization of the dentition was initially introduced using an indirect scan of the stone model in the dental laboratory and 3D-digital images could be obtained. The direct intra-oral scanning (IOS)—also referred to as digital impressioni—s becoming increasingly popular in conjunction with CAD/CAM technology. The electronic files are acquired by means of a high-precision camera and saved as Standard Tesselation Language (STL) files. These files are exported and can be digitally archived and sent to the dental laboratory, saving time, cost, and space. These fascinating advantages are quite useful in implant dentistry.

For digital impressions of implants with IOS devices, the impression trays, materials and also impression copings are not needed. Consequently, the patients can avoid opening their mouths widely for prolonged time during the impression procedure. Digital impressions of implants can be achieved by scanning of special components (scan bodies) that are fixed on the implants. Scan bodies are available in different shapes and are fabricated from different materials from various implant manufacturers (***Figs. 5.1-5.6***).

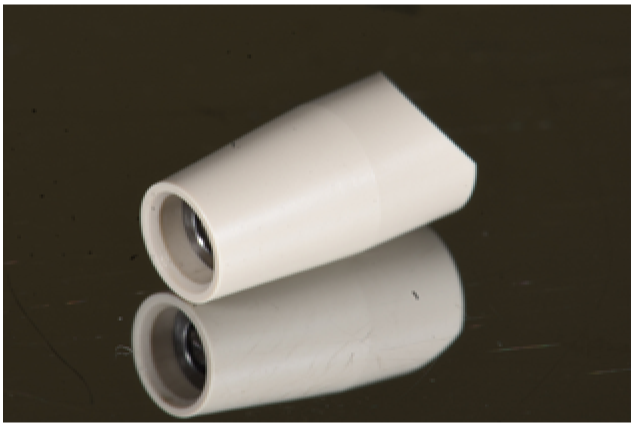


Fig. 5.1

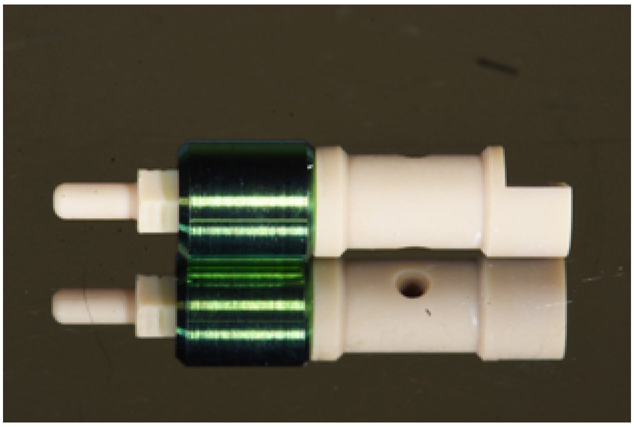


Fig. 5.2

Fig. 5.1 *Scanbody for external connection implant (Nobelbiocare Co.).*
Fig. 5.2 *Scanbody for internal connection implant without retaining screw (BIOHORIZON Co.).*

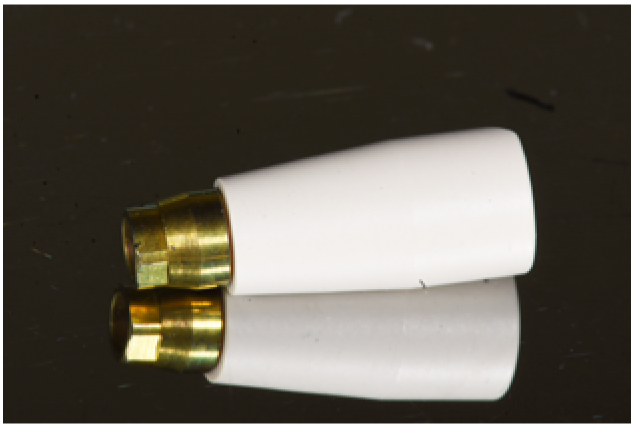


Fig. 5.3

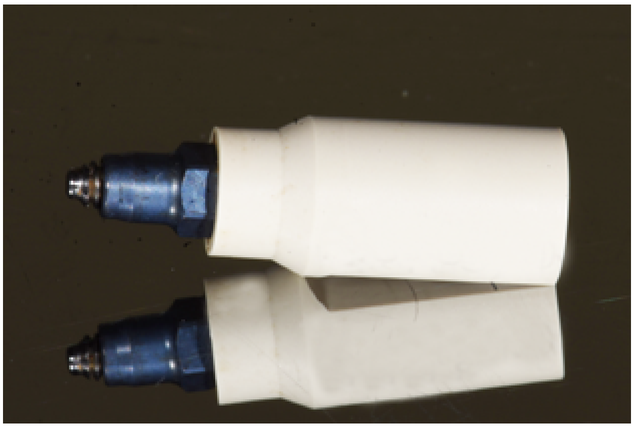


Fig. 5.4

Fig. 5.3 *Scanbody for internal connection implant with titanium base and PEEK body (XIVE implants, Dentsply/ Sirona Co.).*

Fig 5.4 *Scanbody for internal connection implant with titanium base and PEEK body (3i Certain implants, Biomet Co.).*

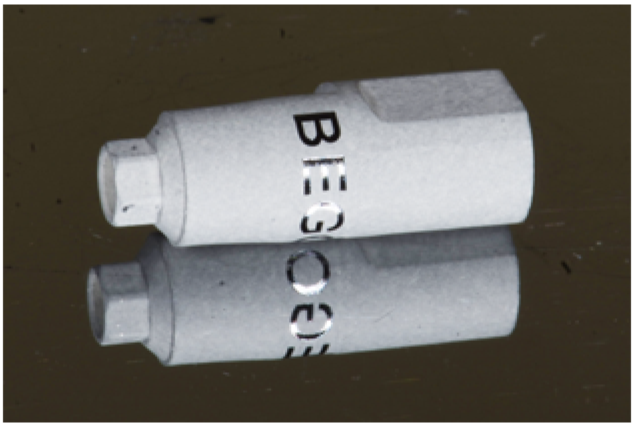


Fig. 5.5

Fig. 5.6

Fig. 5.5 *Scanbody from PEEK for internal connection implant (Bego Co., Germany).*
Fig. 5.6 *Scanbodies for transmucosal abutments (multi abutments, Bego Co., Germany).*

The intra-oral scanning with scanbodies is a simpler procedure compared to the conventional procedure, which includes tightening and loosening of screws for the impression copings, especially if the open tray technique is used (**Sawase and Kuroshima, 2020**). Obviously, a higher impression accuracy is needed for implant-supported prostheses compared to natural teeth, as beside the position and the inclination of the implants, the retention mechanism (internal or external hexagon) must also be recorded and transferred with precision (**Flügge et al., 2016**).

The intra-oral scanning technique for implants was first introduced in 2004, where the first scannable components for implants were presented in the dental market (**Wilk, 2015**). Nowadays, scanbodies (scannable impression posts) are available from most major implant manufacturers in various shapes, size and materials including titanium, polyetherketone (PEEK) and resins (**Mizumoto and Yilmaz, 2018**). The 3D digital image of the implants is combined in the laboratory with digital implant analogs available in digital libraries by means of the indicated software. In this way, a digital model is produced that contains the position, inclination, and geometry of the implant.

In the digital workflow, no stone cast is needed, but depending on the procedure, a physical model with the necessary accuracy requirements must be necessary. These models are mostly three-dimensionally printed using stereolithography apparatuses (SLA), and they feature clinically acceptable accuracy. The latest generation of video-based systems (IOS) seems to be more accurate, faster, and more efficient in clinical application than previously employed devices. They are also even suitable for less experienced practitioners, because of their simplified handling (**Sacher et al., 2021**). IOSs use suitable cameras for the optical detection of the denture that collect point clouds on a path proposed by the suppliers and determined by the dentist. The description of the obtained surface in the three-dimensional (3D) space happens in the Standard Tesselation Language (STL) format.

There are several intraoral scanning devices available in the market nowadays, each with its specific characteristics. The most popular devices are 3M True Definition (3M Co.), CS 3600 (Carestream Co.), Primescann and Omniscann (Dentsply/Sirona Co.), Trios 3 (3 Shape Co.), Emerald (Planmeca Co.), Heron (MIS Co.), Medit (Medit Co.) and several others that are introduced with constantly increased frequency.

5.4 Advantages and disadvantages of the intra-oral scanning

The main advantages of the digital impressions compared to the conventional technique can be summarized as following:

- Reduced patient discomfort and time saving as the scanning procedure lasts on average less time than the conventional procedure.
- Easier and less technique-sensitive procedure for the clinician.
- Simplified communication with the dental laboratory.
- Visualization of the result from the clinician and the patient.
- Avoidance of impression materials and elimination of the stone working casts.
- Immediate, simple, safe, and cost-effective transfer of the acquired data to the dental laboratory.
- Possibility of digital archiving of the data from each patient.
- Correction of the digital impression by local re-scanning if a region has not been scanned or depicted clearly.
- Easier integration of the digital images in the CAD/CAM fabrication of the prosthetic restoration.
- Integration of the digital impressions from the initial steps to a digital planning of the implant positioning and the fabrication of a surgical guide for guided implant insertion.

On the other side, for intra-oral scanning the purchase of an expensive device is needed, and the effectiveness is clearly associated with the necessary learning curve.

5.5 Accuracy of the digital impressions

Accuracy is defined as the "closeness of agreement between a measured quantity value and a true quantity value of a measurand." It is expressed by two factors ***"trueness"*** and ***"precision."*** Trueness represents the closeness of the measurement to the accepted reference value, whereas precision represents the closeness of repeated measurement of the same object (**Sawase and Kuroshima, 2020**). The precision of IOSs can be measured easily in vivo by repetitive captures of the object and assessment of their reproducibility, whereas the calculation of trueness is slightly difficult. A sophisticated scanner, such as an industrial coordinate measuring machine, is needed to obtain a reliable reference model.

The trueness of IOSs is calculated by the closeness of agreement between the measurement result and a true value (**Kurawase and Kuroshima, 2020**). Numerous studies have been published comparing the accuracy of digital and conventional impressions (**Chochlidakis et al., 2016; Mangano et al., 2016; Ajioka et al., 2016; Chew et al., 2017; Menini et al., 2017; Imburgia et al., 2017; Ribeiro et al., 2018; Ciocca et al., 2018; Gintaute et al., 2018; Mangano et al., 2019; Sawase and Kuroshima, 2020; Revilla-León et al., 2020; Mizumoto et al., 2020; Motel et al., 2020; Arcuri et al., 2020**).

The reported results in the above-mentioned studies are controversial, and due to different testing methods it is not possible to compare the studies directly. In systematic reviews also the inclusion and exclusion criteria differ, and it is not easy to reach a generalized conclusion. On the other side, most of the abovementioned studies were in vitro,and they tend to agree that the intra-oral scanning seems a reliable and promising technique for digital impressions in implant restorations (**Rutkūnas et al., 2017**). However, high levels of heterogeneity were found in a systematic review based on numerous (75) studies, and no clinical recommendation could be derived (***F*****lügge et al., 2017**).

There are some factors that may influence the accuracy of digital impressions and they still require further investigation. For instance, many authors support the accuracy of digital impressions for the rehabilitation of single implants; however, the extension of the edentulous space and the increased number of implants are major obstacles to a full digital workflow in implant dentistry (**Marques et al., 2021**). The accuracy of digital and silicone impressions for single-tooth implants and short span FDPs was comparable, as concluded an in-vitro study (**Nagata et al., 2021**). In full arch restorations, however, the accuracy of intra-oral scanning compared to the conventional technique was shown as doubtful (**Sawase and Kuroshima, 2020**).

An in-vitro study that focused on the influence of inter-implant distance on the accuracy of two intra-oral scanners concluded that increased distance affected negatively the precision of digital impressions (**Thanasrisuebwong et al., 2021**). Most studies agree that the inaccuracy of the impressions increase with the length of the edentulous area (**Mangano et al., 2017**). However, it remains unclear in the literature with which exact number of placed implants the decrease in accuracy becomes clinically significant (**Gimenez-Gonzales et al., 2016; Zimmermann et al., 2015; Imburgia et al., 2017; Marti et al., 2017; Mandeli et al., 2017; Mangano et al., 2017**).

Some other clinical parameters that may influence the accuracy of a digital impression are the angulation of the implants, the design of the used scanbodies, the depth of the implant, the scanning protocol, and the kind of the scanning device (**Abduo et al., 2018**). In another in-vitro study, significant differences were noted in the accuracy of three different devices for intra-oral scanning (**Vandeweghe et al., 2017**).

The shape and geometry of the scanbodies may also affect the accuracy of the intra-oral scanning (**Motel et al., 2020; Mizumuto et al., 2020**). The operator's experience and the size of the intra-oral device have also an influence on the accuracy of the acquired digital impressions by intra-oral scanning (**Resende et al., 2021**).

Various studies have compared the accuracy of intra-oral scanners in complete arch implant rehabilitation, but no concrete conclusion can be drawn. In some studies, the accuracy of intra-oral scanners was comparable to that of conventional impression techniques (***P*****apaspyridakos et al., 2016; Amin et al., 2017; Ribeiro et al., 2018; Menini et al., 2018**) whereas other studies have revealed that the conventional impression technique was more accurate than intraoral scanning in full-arch implant restorations (**Tan et al., 2019; Kim et al., 2019; Huang et al., 2020**). In an in-vitro study focused on the accuracy of intra-oral scanning compared to conventional impressions for full-arch implants, the conventional technique showed better results (**Revilla-Leon et al., 2021 A and B**). On the other hand, an in-vitro study comparing the accuracy of full-arch implant impressions showed better accuracy for the digital technique compared to the conventional (**Albayrak et al., 2021**).

The effect of additional reference objects on accuracy of five intra-oral scanners in partially edentulous arches was investigated in an in-vitro study. The authors concluded that artificial landmarks did not affect the accuracy of digital impressions. On the contrary, it significantly affected the accuracy of full-arch scanning (**Rutkūnas et al., 2021**).

An extended systematic review based on 30 studies (29 in-vitro and one clinical trial) concluded that full-arch digital implant impressions showed reduced accuracy compared to the conventional impression techniques

(**Zhang et al., 2021**). According to their results, the accuracy varied significantly with inter-implant distance, scan body type, scanner type and operator experience.

It must be underlined,however, that this controversy of results among different studies may be attributed to the heterogeneity in the research methodology. A recent extended systematic review could not conclude to a decisive statement regarding the trueness and precision of digital implant impressions (**Sanda et al., 2021**).

5.6 Partially edentulous mandible (Case A, Figs. 5.7-5.10)

In this patient, two internal connection implants were inserted in the mandibular right region. After the osseointegration period, transmucosal abutments were fixed on the implants with the torque recommended by the manufacturer (***Figs. 5.7 and 5.8***). An intra-oral scanning was performed at abutment level, and a digital model of the patient was created by the software. The patient was restored with a screw-retained Fixed Dental Prosthesis (FDP) fabricated using CAD/CAM technology on transmucosal abutments.

The final restoration was a monolithic zirconia FDP cemented on prefabricated titanium copings that were fitted in the implants (***Figs. 5.9 and 5.10***). The emergence profile of the crowns was shaped according to the soft tissue profile and the use of prefabricated components (transmucosal abutments and copings) ensured the desired accuracy of fit.

Fig. 5.7

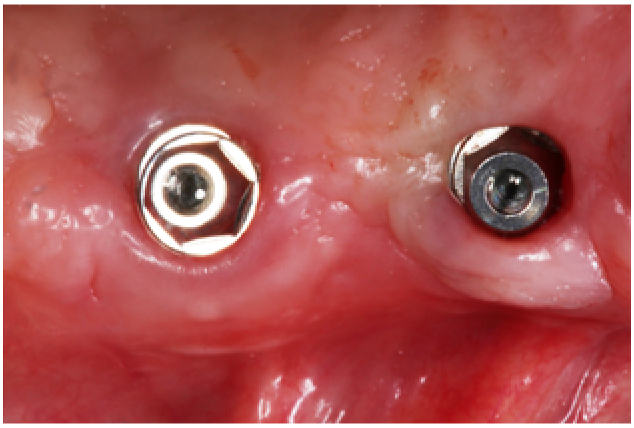


Fig. 5.8

Fig. 5.7 *Case A (Dr. V. Roussou), initial clinical situation.*
Fig. 5.8 *Transmucosal abutments fixed on the implants.*

Fig. 5.9

Fig. 5.10

Fig. 5.9: *The digital model of the patient created from the intra-oral scanning.*
Fig. 5.10: *The screw-retained implant restoration.*

5.7 Completely edentulous maxilla (Case B, Figs. 5.11-5.20)

The patient presented for treatment of his maxillary teeth. From the initial and radiological examination all teeth showed poor prognosis (***Figs. 5.11 and 5.12***). The treatment plan included the extraction of all maxillary teeth and the insertion of 5 internal connection implants (Bego Co., Germany) (***Fig. 5.13***). All implants had adequate primary stability, and therefore immediate loading with a provisional restoration was decided.

Following the implant insertion, an intra-oral scanning at implant level was performed with scanbodies—after suturing of the flaps—and a digital model was created (***Fig. 5.14***). The intra-oral scanning could be easily accomplished even with an open flap, and this facilitated the procedure. The conventional impression with elastomeric material would not be possible during surgery and would be difficult even after suturing.

On the digital model a screw-retained provisional restoration was designed and fabricated by milling from PMMA for immediate loading of the implants (***Figs. 5.14 and 5.15***). The provisional restoration was screw-retained using titanium copings fitting in the implants and was delivered within 24 hours from surgery (***Fig. 5.16***).

Fig. 5.11

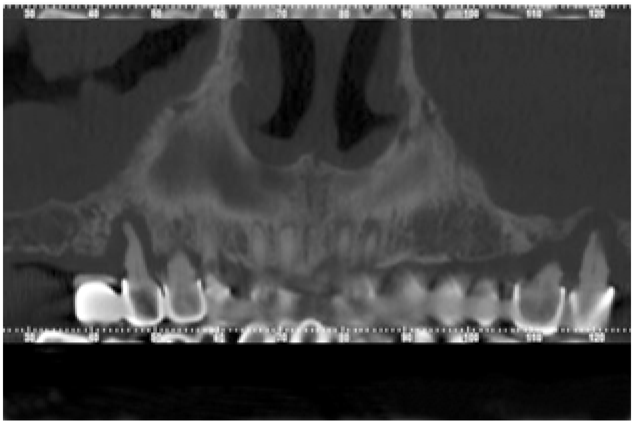


Fig. 5.12

Fig. 5.11 *Case B (Dr. V. Roussou), initial clinical situation.*

Fig. 5.12 *Panoramic view from the CBCT of the maxillary teeth.*

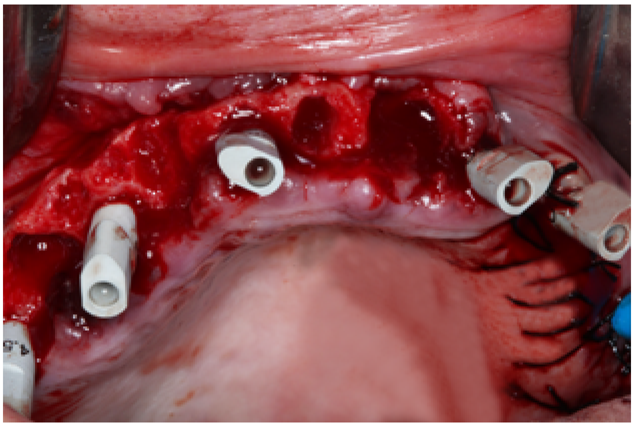


Fig. 5.13

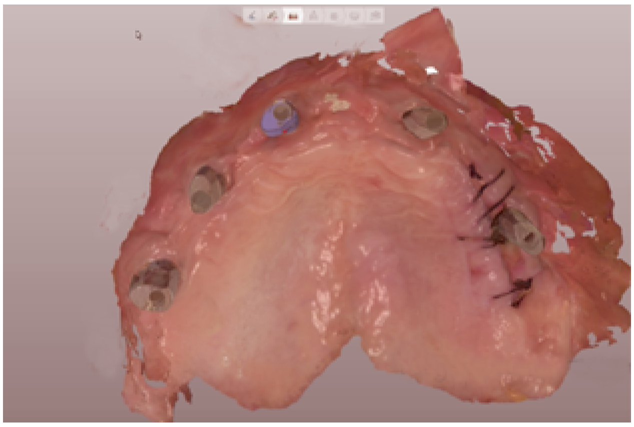


Fig. 5.14

Fig. 5.13 *Intra-oral scanning after implant insertion.*

Fig. 5.14 *Digital image from the intra-oral scanning.*

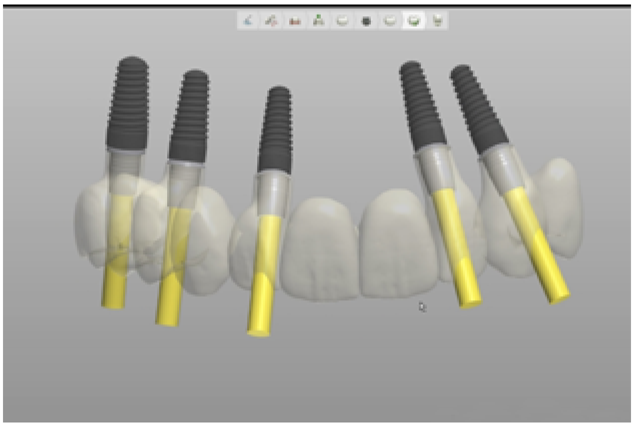
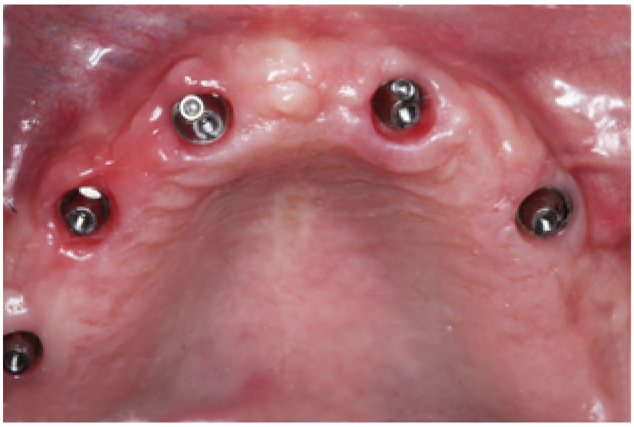


Fig. 5.15 **Fig. 5.16**

Fig. 5.15 *Digital design of the provisional restoration.*
Fig. 5.16 *Implant-supported provisional restoration.*

The osseointegration of the implants was uneventful. The final restoration was a screw-retained metal-ceramic FDP fabricated using CAD/CAM technology on transmucosal abutments (***Figs. 5.17-5.20***).



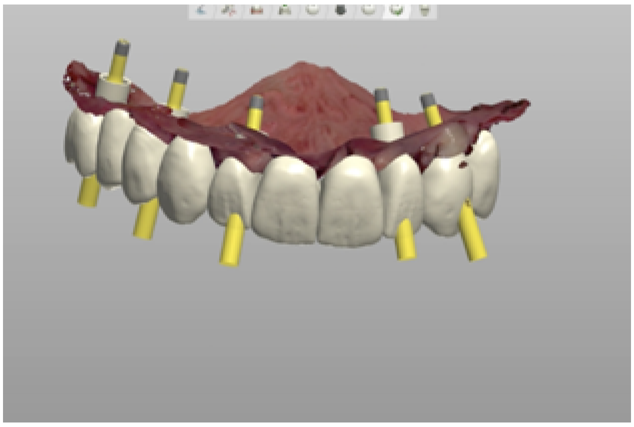


Fig. 5.17 **Fig. 5.18**

Fig. 5.17 *Transmucosal abutments after osseointegration.*
Fig. 5.18 *Digital design of the final restoration.*

Fig. 5.19 **Fig. 5.20**

Fig. 5.19 *Metal framework of the final restoration.*
Fig. 5.20 *Case B, the final restoration.*

5.8 Single missing tooth (Case C, Figs. 5.21-5.30)

In this patient, an internal connection implant had been inserted in the region of the missing left central incisor (#21). The osseointegration was uneventful with open healing. To create a favorable soft tissue profile around the implant, a provisional restoration on a ceramic abutment was planned. A scanbody was fixed in the implant and an intraoral scanning was performed (***Figs. 5.21 and 5.22***).

An additional scanning was performed without the scanbody to depict the soft tissue profile precisely (***Fig. 5.23***). The abutment and the provisional restoration was designed on the digital model and the whole procedure was accomplished without any working cast (***Fig. 5.24***). A customized ceramic abutment was fabricated on a prefabricated titanium base to support the soft tissue profile (***Figs. 5.25 and 5.26***).

Fig. 5.21

Fig. 5.22

Figs. 5.21 and 5.22 *Case C (Dr. V. Roussou), intra-oral scan of the clinical situation with scanbody.*

Fig. 5.23

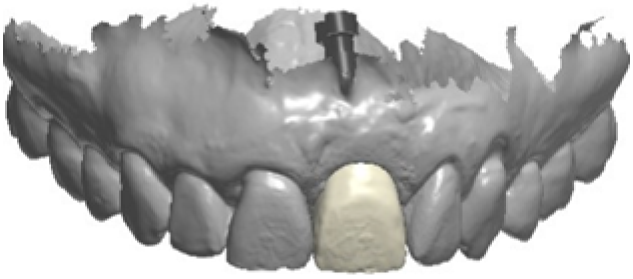


Fig. 5.24

Fig. 5.23 *Intra-oral scan without scanbody.*
Fig. 5.24 *Digital planning and design of the implant restoration.*

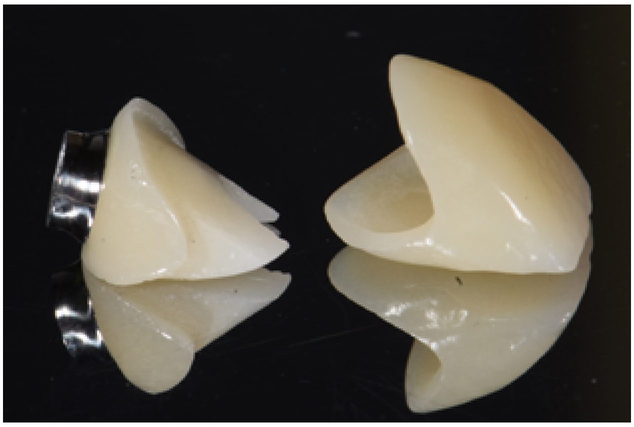


Fig. 5.25 **Fig. 5.26**

Fig. 5.25 *Customized ceramic abutment with prefabricated titanium base and provisional crown.*
Fig. 5.26 *The ceramic abutment in-situ.*

The contour of the provisional restoration was modified with light selective pressure and an esthetic emergence profile of the soft tissues was achieved (***Fig. 5.27***). The right maxillary incisor (#11) was prepared for a ceramic veneer to optimize its shape (***Fig. 5.28***). The final restoration was a cement-retained ceramic crown on a customized ceramic abutment with prefabricated titanium base, made by CAD-CAM technology (***Figs. 5.29 and 5.30***).

Fig. 5.27 **Fig. 5.28**

Fig. 5.27 *The provisional restoration.*
Fig. 5.28 *The right central incisor was prepared for a ceramic veneer.*

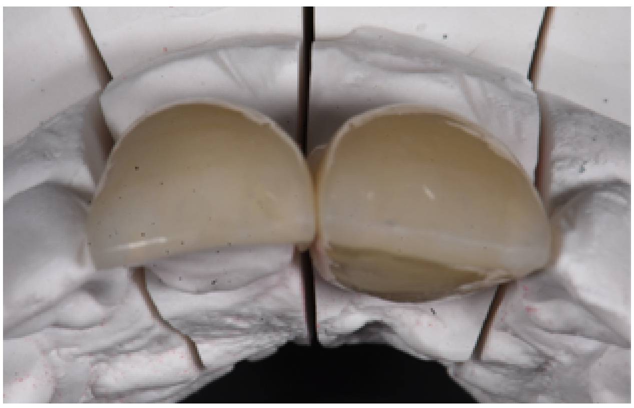


Fig. 5.29 **Fig. 5.30**

Figs. 5.29 and 5.30 *Case C, the final restorations.*

5.9 Single missing tooth (Case D, Figs. 5.31-5.58)

The patient in this case presented for treatment of the maxillary right canine, which was sensitive to palpation, showed pain upon pressure and intercuspation and also a deep periodontal pocket. The tooth had sustained an endodontic treatment some weeks ago and had a provisional crown. The symptoms of the teeth had started some days ago, after injury of the face and the maxillary teeth in a traffic accident. Suspicion of a crack along the tooth axis raised, as it was compatible with the existing symptoms.

An initial intra-oral scan was performed, and the patient was referred for a CBCT (***Figs. 5.31-5.33***). The radiographic examination revealed an enlarged peri-radicular space and a periapical lesion on the apex (***Fig. 5.34***). The treatment plan for this patient was the extraction of the canine and immediate placement of an implant. If adequate stability could be achieved, immediate restoration would be done by a screw-retained provisional restoration.

The presurgical plan was accomplished digitally by selecting an implant of the proper diameter and length on the CBCT images (***Figs. 5.35 and 5.36***). A surgical guide was fabricated by 3D printing to allow the drillings and the exact positioning of the implant with flapless procedure in the alveolar socket. As the tooth was in place, it was not possible to try the surgical guide intra-orally.

Fig. 5.31

Fig. 5.32

Figs. 5.31 and 5.32 *Case D (Dr. V. Roussou), initial intra-oral scan of the patient.*

Fig. 5.33

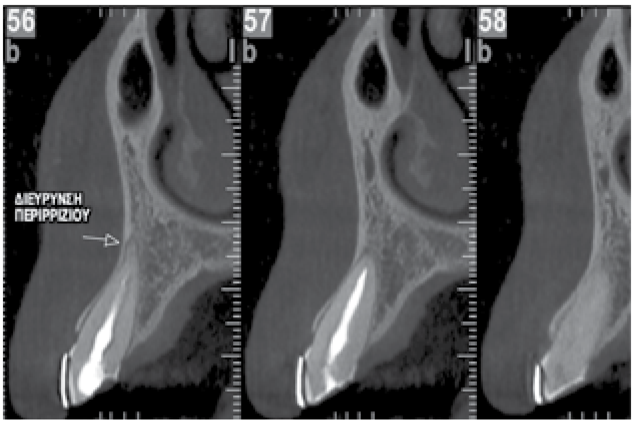
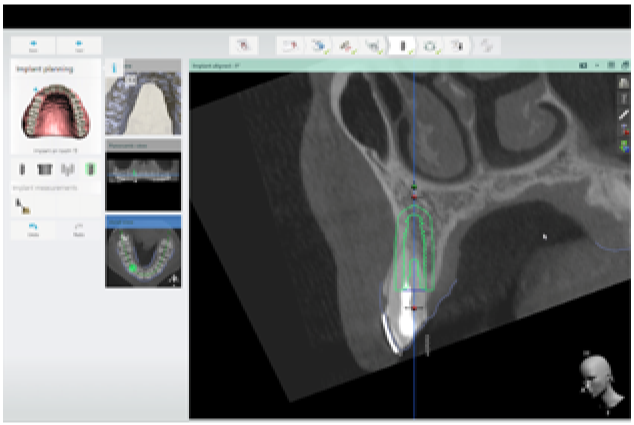


Fig. 5.34

Fig. 5.33 *Initial intra-oral scanning, occlusal view.*

Fig. 5.34 *CBCT examination.*



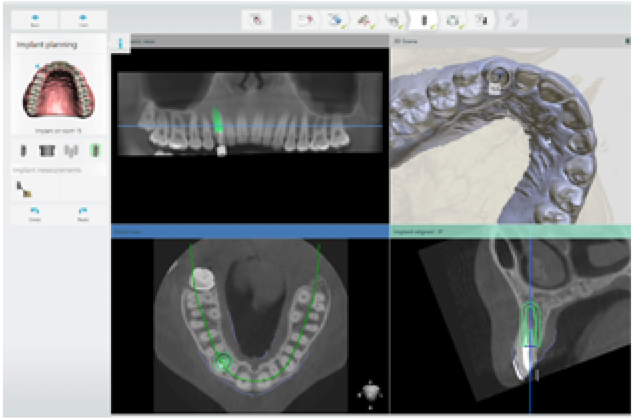


Fig. 5.35 **Fig. 5.36**

Figs. 5.35 and 5.36 *Preoperative digital planning for guided implant placement.*

A provisional restoration was also fabricated to be used if adequate initial stability of the implant could be achieved. The provisional restoration had a cylindrical opening where the titanium coping would be fitted with autopolymerizing resin after implant placement (***Figs. 5.37 and 5.38***). Alternatively, flow photopolymerizing resin can be used. On the mesial and distal surfaces of the provisional crown, two "wings" were formed to allow precise fit of the crown in the planned position, eliminating possible rotation.

The tooth was extracted, and the surgical guide was tried intra-orally (***Figs. 5.39 and 5.40***). A crack was obvious along the root of the extracted tooth, confirming the initial diagnosis. Immediately after tooth extraction and prior to the drillings an intra-oral scan was performed to depict the existing soft tissue contour for the emergence profile of the restoration (***Figs. 5.41 and 5.42***).

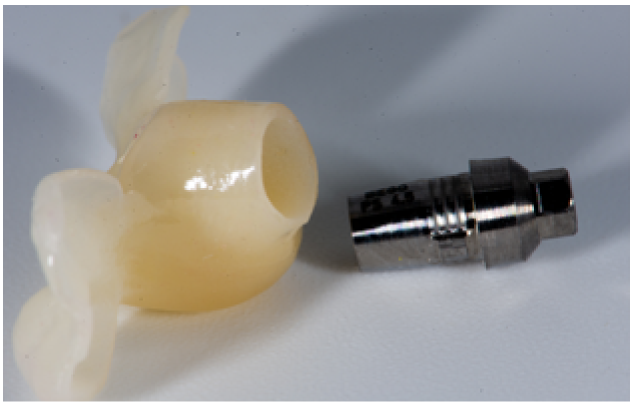


Fig. 5.37 **Fig. 5.38**

Figs. 5.37 and 5.38 *Provisional restoration and prefabricated titanium coping.*

Fig. 5.39 **Fig. 5.40**

Fig. 5.39 *The extracted tooth.* **Fig. 5.40** *The surgical guide fitted on the adjacent teeth.*

The drillings and implant insertion were performed through the sleeve of the surgical guide in the predetermined position and inclination (***Figs. 5.43 and 5.44***). As the initial stability was increased, the implant was immediately restored with the prefabricated screw-retained provisional restoration (***Figs. 5.45 and 5.46***). The implant crown was checked and had no occlusal contacts or interferences in the lateral movements.

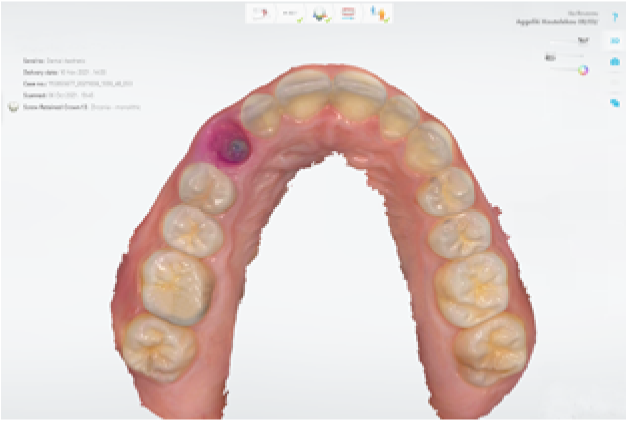


Fig. 5.41

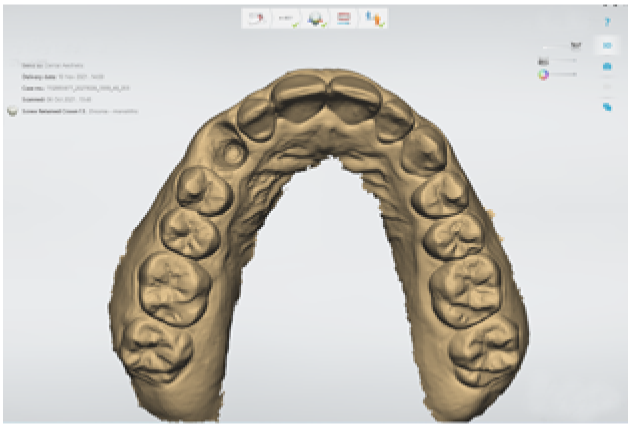


Fig. 5.42

Figs. 5.41 and 5.42 *Intra-oral scanning after tooth extraction.*

Fig. 5.43

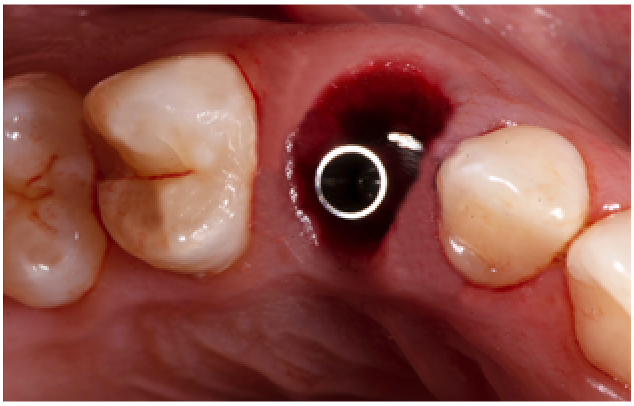


Fig. 5.44

Figs. 5.43 and 5.44 *Flapless implant placement through the surgical guide.*

Fig. 5.45

Fig. 5.46

Figs. 5.45 and 5.46 *Immediate provisional restoration.*

The healing period was uneventful and after four months the provisional crown was removed, and a new intra-oral scan was performed with a scanbody to create a digital model with the exact position and inclination of the implant (***Figs. 5.47 and 5.48***). Digital models were created depicting precisely the intra-oral condition (***Figs. 5.49 and 5.50***).

The soft tissue contour that was created was favorable (***Figs. 5.51 and 5.52***) and another intra-oral scanning was performed without the scanbody to depict the contour of the peri-implant soft tissues (***Figs. 5.53 and 5.54***). As the provisional restoration had a good esthetic result, an additional scanning was performed with the crown in-situ to be used as basis for the design of the final restoration (***Fig 5.55 and 5.56***).

The data from the intra-oral scanning were exported to a CAD/CAM software for the design and fabrication of the final prosthesis. The final restoration was a screw-retained ceramic crown on a prefabricated titanium abutment with customized emergence profile to support the soft tissue contour (***Figs. 5.57 and 5.58***).

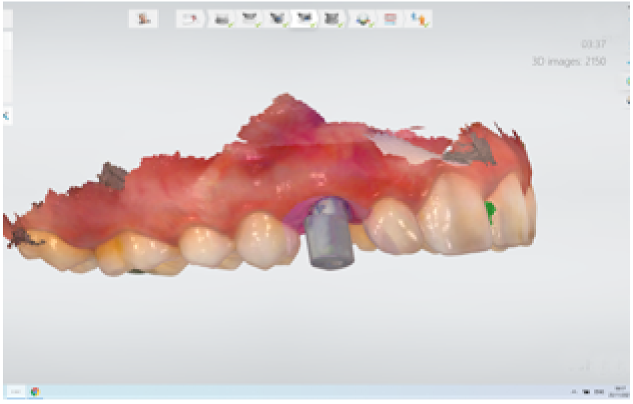


Fig. 5.47

Fig. 5.48

Figs. 5.47 and 5.48 *Intra-oral scanning with scanbody at the end of osseointegration.*

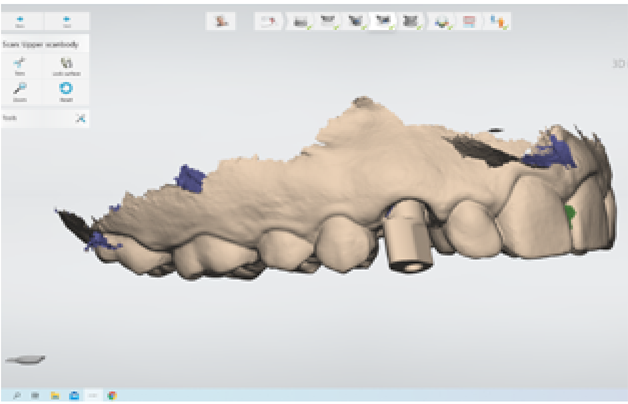


Fig. 5.49

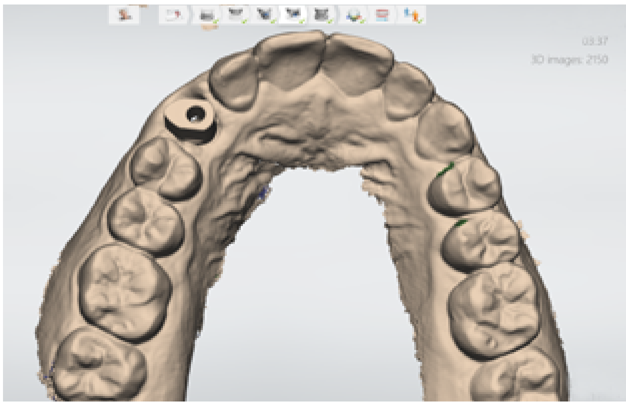


Fig. 5.50

Figs. 5.49 and 5.50 *Digital images of the intra-oral scanning.*

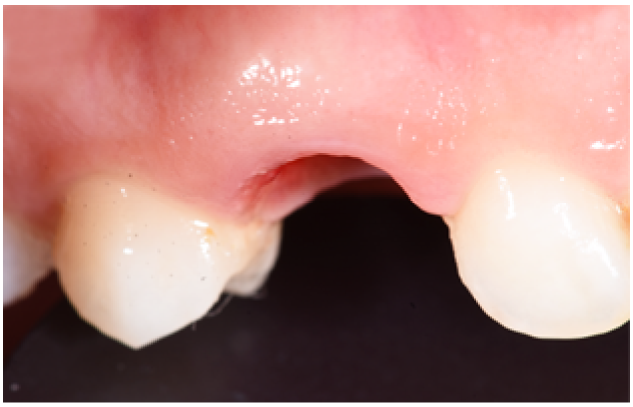


Fig. 5.51

Fig. 5.52

Figs. 5.51 and 5.52 *The soft tissue profile at the end of osseointegration.*

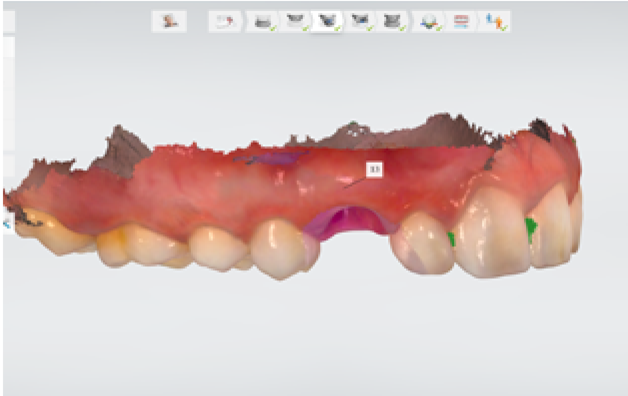


Fig. 5.53

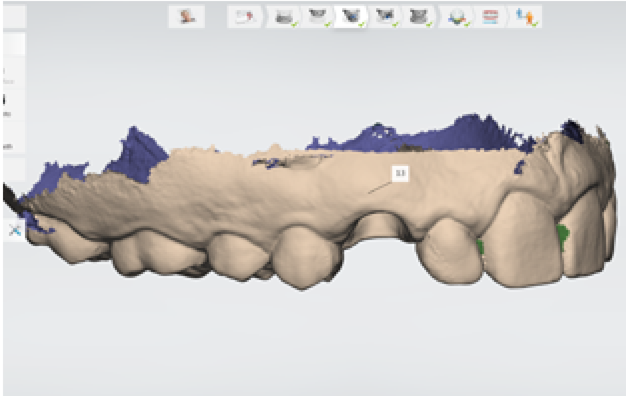


Fig. 5.54

Figs. 5.53 and 5.54 *Intra-oral scan of the peri-implant soft tissues.*

Fig. 5.55

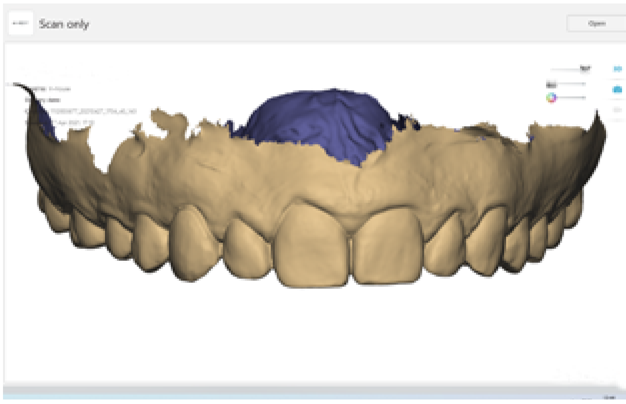


Fig. 5.56

Figs. 5.55 and 5.56 *Intra-oral scan of the provisional restorations.*

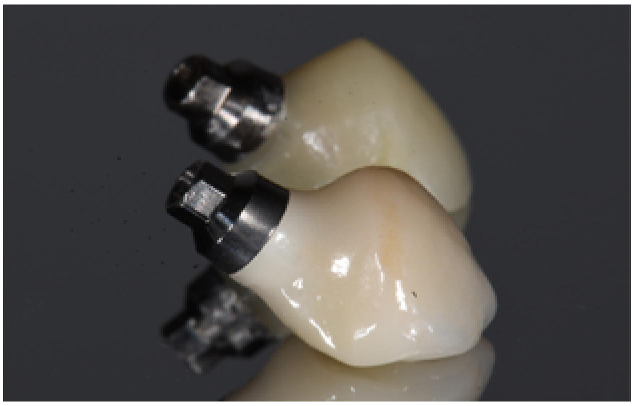


Fig. 5.57

Fig. 5.58

Figs. 5.57 and 5.58 *Case D, the final restoration.*

5.10 Intra-oral scanning compared to conventional impression and laboratory scanning

Laboratory scanners are considered in general more accurate than the intra-oral scanners, and for this reason they are used as points of reference in in-vitro studies that compare the accuracy of intra-oral scanners (**Renne et al., 2017**). There is still controversy about the accuracy of intra-oral scanning, laboratory scanning and conventional impressions. Some studies favor the increased accuracy of the conventional technique compared to laboratory scanning by photogrammetry (**Revilla-Leon et al., 2021A; Revilla-Leon et al., 2021B**). In another in-vitro study the laboratory scanning using the photogrammetry technique showed better accuracy compared to intra-oral scanning scanner and conventional impressions (**Tohme et al., 2021**).

An in-vitro study focused on the accuracy of full-arch implant impressions with conventional impression, intra-oral scanning and photogrammetry. The most accurate results were shown by the laboratory scanning followed by the conventional impression and last by the intra-oral scanning (**Ma et al., 2021**).

In impressions for full-arch implant restorations, several factors must be taken into consideration as they may affect the final accuracy: intra-oral scanner brand (**Di Fiore et al., 2019; Mangano et al., 2019**), ambient light (**Revilla-Leon et al., 2020A**), scanbody types (**Arcuri et al., 2020; Dental et al., 2019; Mizumoto et al., 2020**), inter-implant distance (**Tan et al., 2019; Thanasrisuebwong, 2021**), scanning range (**Flugge et al., 2018**), characteristics of the mucosa (**Marghalani et al., 2018**), movable mucosa (**Schaerer et al., 2016**) and scanning pattern (**Mueller et al., 2016**).

Summarizing, the following can be stated that is also the conclusion of an extended systematic review (**Aswani et al., 2020**): "Digital intra-oral impression systems continue to undergo rapid development. Due to the heterogeneity of the data, it was difficult to compare individual studies directly in order to arrive at a general conclusion regarding the accuracy of IOSs. Intra-oral scanning systems, in comparison to conventional impressions, can be reliably used for diagnostic purposes and short-span scanning. However, for whole arch scanning, the IOS is susceptible to more deviation. Although the accuracy of IOS systems appears to be promising and comparable to conventional methods, they are still vulnerable to inaccuracies" (**Aswani et al., 2020**). The abovementioned conclusions have also been confirmed by other systematic reviews (**Khraisi and Duane, 2016; Giachetti et al., 2020; Sawase and Kuroshima, 2020**).

5.11 Clinical relevance

Intra-oral scanning is a new technology, and its use is spreading in clinical practice. It can offer new possibilities for the clinician and increased comfort for the patient. In implant restorations, the use of scanbodies can simplify the impression procedure and minimize the needed time. The accuracy and precision of models from intra-oral scanning in short span restorations are comparable to models obtained with conventional impression techniques. In full-arch restorations, however, the published results still show some controversy. The clinician must familiarize with the new technology, recognize the limitations of the device, the technique and the software, and finally integrate this new method in clinical practice according to their learning curve.

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CHAPTER 6

Cement-retained Implant Restorations

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Abstract

Screw-retained prostheses were the first restorations used over implants. Later the cement-retained implant restorations were introduced and widely used in clinical practice. Each retention mode has advantages and disadvantages that should be evaluated according to the demands of each clinical case. The aim of this chapter is to present an overview of the cement-retained restorations with clinical cases and analyze the characteristics for this type of retention.

Knowledge background

To understand the content of this chapter, the reader should be familiar with the basic principles of fixed restorations on natural teeth and have the basic knowledge of implant restorations, as analyzed in the previous chapters.

6.1 Introduction

The first restorations used on implants by the Branemark group at the early years of osseointegration (going back to 1965) were the so-called "tissue integrated prostheses." These prostheses were strictly screw-retained, had a metal framework, and were veneered with acrylic resin that supported denture teeth. At that time, dental implants were used only for the restoration of the edentulous mandible and 5-6 implants were considered necessary for this prosthetic treatment. The prostheses were fixed on transmucosal (also called transgingival) abutments which were secured by screw on the implant (**Hobkirk et al., 2003**).

In the following years, the spectrum of restorations on implants was enlarged from total edentulism to partial edentulism and single tooth implants. The available materials for the fabrication of implant restorations nowadays include porcelain-fused-to-metal (which is the most widely used type of restoration), polymer-to-metal restoration and all-ceramic restorations. The techniques for their fabrication have also been improved and the use of CAD/CAM restorations deriving from intra-oral scanning or laboratory scanning expands rapidly. Despite the evolution of materials and techniques, there is always the issue of fixing the prosthesis on the dental implant. The two existing available options for implant-supported restorations remain the screw- or the cement-retention.

Cement-retained prostheses were introduced at the beginning of the 90s as fixed restorations. The first abutments were the UCLA -type that allowed fabrication of customized abutments by overcasting on a prefabricated gold alloy basis (**Lewis et al., 1988, 1992**). The prefabricated Titanium abutments were also introduced either as straight or angulated (inclined), and at that time a great change occurred in the field of implant restorations. Cement-retained restorations are supported by abutments fixed by screw in the implants and the axis of the crown can be different or divergent from the implant axis. Non-parallel or divergent implants can also be combined in the same restoration as the path of insertion for the Fixed Dental Prosthesis (FDP) is independent from the direction of the retention screws of the abutments. This characteristic offers great versatility in the fabrication of implant prostheses allowing the restorations of all implants, even with non-favorable inclinations. For these reasons, cement-retained restorations were immediately adopted by the clinicians. The use of angulated abutments made possible the fabrication of crowns without an access hole for the retaining screw and it offered a solution, especially in cases of anterior maxillary implants, where the implant inclination usually has severe diversion to the implant axis.

6.2 Aim

The aim of this chapter is to present an overview of the cement-retained restorations with clinical cases and analyze the advantages, disadvantages and characteristics for cement retention.

6.3 Screw- or Cement-retained?

A fixed implant restoration can be fabricated either by fixing the prosthetic directly to the implant head using a screw for retention or it can be achieved by cementing the final prosthetic onto an abutment, which, in turn is fixed by screw to the implant. There is also the possibility to secure a transmucosal abutment on the implant (also called "multi-purpose abutment") and then fix the prosthesis by a retention screw on the abutment. These abutments are prefabricated titanium abutments with diameter analogous to the implant diameter and available in different heights to fit the clinical demands of each case. Each method has specific advantages and disadvantages; thus, the retention mode should be selected individually after taking into consideration the characteristics of each clinical case.

6.4 Advantages, disadvantages and indications for cement - retention

Cement-retained restorations offer a better esthetic result and are often the clinical choice in anterior maxillary restorations, when the implant axis does not allow the placement of the access hole on the palatal surface. In some cases, however, it may be difficult to remove the excess cement from a deep sub-gingival abutment margin. If excess cement remains under the abutment margin, it may cause infection to peri-implant tissues. For this reason, the margin line of the cemented crown should be placed to an adequate depth from the soft tissue margin (2-3mm) so that the excess cement can be safely removed.

Screw-retained restorations offer easy retrievability which is important to allow repair and maintenance. Retrievability can be difficult in cement retention, even if temporary cement has been used. There is no clearly documented guideline about the type of cement that should be used. The loosening of the fixing screw in an abutment for a cemented implant crown—while the crown remains cemented on the abutment—is a common clinical problem and may lead to severe prosthetic complication (**Kourtis et al., 2017**).

In implant restorations, absolutely passive fit of the prosthesis on the implant or the transmucosal abutment is of crucial importance. In cement-retained restorations, the passive fit is considered easier to achieve, as the use of cement may be a compensating factor for minor misfits. On this issue, however, there are so far no published data to support scientifically this consideration.

The passive fit of the cement-retained restorations on the abutments should be checked carefully in the same way it is performed on natural teeth. In cases of implants with thick peri-implant tissues, radiographic control may be necessary.

The abutments for cemented restorations should be fixed by applying the final torque, as indicated by the manufacturer only prior to cementation of the prosthesis. The use of a torque measuring device is recommended to exert and control the tightening torque on the fixing screws upon final fixation. The recommended torque of more than 20Ncm—which is standard in most manufacturers—cannot be achieved by the majority of the clinicians with wet gloves. If the abutment screws are not fixed with the recommended torque, screw loosening may occur during clinical function resulting in prosthetic complications (**Kourtis et al., 2017**).

Cement-retained restorations have their main indication in esthetically demanding cases where the existence of the access hole on the labial surface may compromise the final esthetic result. They are also a clinical solution for implants with divergent axes in the same restoration or mall-aligned implants. In cases of implants where a fully customized abutment in the cervical area is needed, mostly in anterior maxillary implants, cement-retained restorations offer increased possibilities for the creation of the emergence profile on the abutment.

6.5 Materials for implant abutments

Various materials have been used over the last decades for the industrial fabrication of implant abutments including titanium, aluminum oxide, zirconium oxide, gold alloys and lately PEEK (Poly-Ether-Ether-Ketone). Titanium is still the most widely used material for prefabricated abutments (***Figs. 6.1 and 6.2***) either as commercially pure Titanium Grade 5 or as Titanium alloys (Ti-6Al-4V, Ti6Al4V or Ti-6-4). Titanium has adequate mechanical strength to withstand the forces applied on the abutment and has been used extensively by most implant manufacturers.

Fig. 6.1

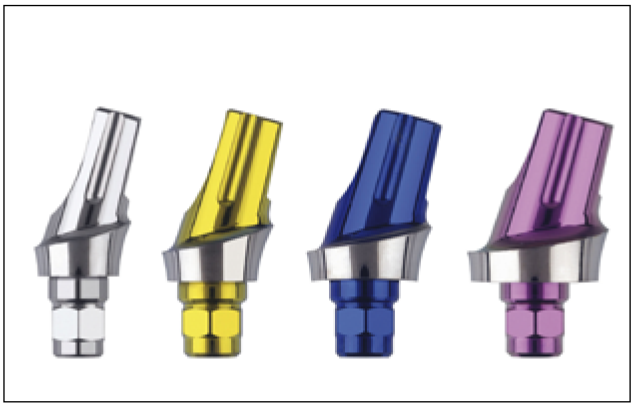

Fig. 6.2

Fig. 6.1 *Prefabricated titanium abutments (straight) for cement-retained restorations in different diameters (Xive implants, Dentsply/Sirona Co.).*

Fig. 6.2 *Prefabricated titanium abutments (angulated) for cement-retained restorations in different diameters (Xive implants, Dentsply/Sirona Co.).*

Gold alloys have been used for the fabrication of custom abutments on UCLA basis by overcasting (***Fig. 6.3***). This type of abutment allows complete customization directly from the implant head and can compensate for any unfavorable implant axis. Generally, a plastic UCLA abutment is waxed up and customized to shape and then overcast with alloy compatible to the prefabricated gold alloy base which fits the implant accurately (**Shafie and White, 2014**).

Aluminum oxide has been used in the past for prefabricated ceramic abutments, usually with a prefabricated titanium base (***Fig. 6.4***) due to its improved esthetic performance and was indicated mainly for anterior maxillary implants (**Anderson et al., 2003; Andrioteli et al., 2009**). Ceramic abutments nowadays are fabricated almost exclusively from Zirconium oxide (***Fig. 6.5***) that has similar esthetic properties and excellent biocompatibility combined with increased strength (**Myshin and Wiens, 2005; Butz et al., 2005; Manicone et al., 2007; Linkevicius et al., 2008; Koutouzis et al., 2011**). The PEEK abutments have been used mainly as temporary abutments and there are no published data concerning their use in final restorations (**Alexakou et al., 2019**).

Fig. 6.3

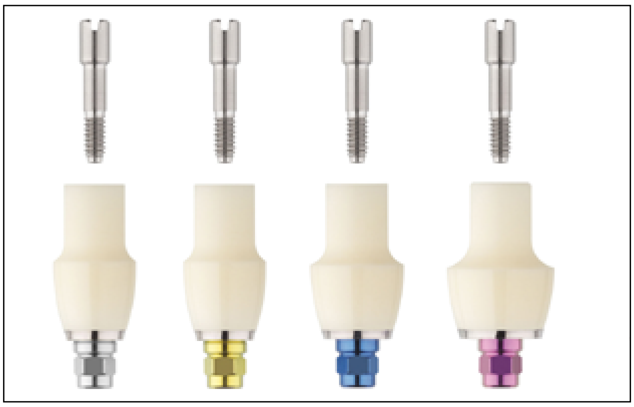

Fig. 6.4

Fig. 6.3 *UCLA type abutment (Aurobase abutments) with prefabricated gold alloy base for overcasting (Xive implants, Dentsply/Sirona Co.).*

Fig. 6.4 *Prefabricated aluminum oxide abutments with titanium base (Cerabase abutments, Xive implants, Dentsply/Sirona Co.). The cervical part can be modified individually.*

Beside the prefabricated abutments, many implant manufacturers offer the possibility of completely customized abutments fabricated on demand by CAD/CAM (Computer Aided Design/ Computer Aided Manufacturing) technology (***Fig. 6.6***) , as for example the Atlantis System (Dentsply/ Sirona Co.). Titanium and Zirkonium oxide are the most widely used materials nowadays. CAD/CAM abutments offer increased possibilities in cases of implants demanding an individually shaped emergence profile, or if increased angulation is needed. Ceramic materials have shown adequate mechanical strength to be considered as a safe option for implant restorations (**Silva et al., 2020**).

Fig. 6.5

Fig. 6.6

Fig. 6.5 *Prefabricated ceramic abutments (Cerkon abutments, Xive implants, Dentsply/Sirona Co.). The cervical area is designed to support the soft tissues and can be customized.*

Fig. 6.6 *Fully-customized abutments for cement-retained restorations (Atlantis, Dentsply/Sirona Co.).*

6.6 Luting cements for cement-retained restorations

The choice of the luting cement is an important factor to ensure adequate retention of the implant prosthesis with the feasibility of removal, and thereby improving the longevity of the restoration. Temporary luting cements are the most used means for the retention of implant prostheses. The factors that influence the retention of the cement-retained restorations are well-documented and are basically the same as those for natural teeth (**Hebel and Gajjar, 1997; Tarica et al., 2010**). Various authors have shown that the type of cement, the amount of cement space or internal relief, the occlusal forces, and the type of luting agent can also affect the retentiveness of final restorations. The ideal cement should be strong enough to retain the crown indefinitely, yet weak enough to allow the clinician to retrieve it if necessary (**Beranl et al., 2003; Garg et al., 2013; Kapoor et al., 2016**).

Methacrylic-based urethane cements and elastomeric resin-based zinc-oxide cements have also been used for the fixation of implant restoration, but their efficacy has not been documented with long-term clinical trials (**Sarfaraz et al., 2019**). The highest retention, however, is achieved with resin cements (**Gultekin et al., 2013**).

Ideally, adequate strength of the luting agent is required for the retention of prosthesis, yet it should allow professional removal of restorations by simple clinical procedure. However, literature regarding the ideal cement has revealed disagreements. Owing to varied cement, implants, components, and treatment protocols being used in different studies, a standardized cementation protocol was difficult to obtain. Most of the studies used zinc phosphate as definitive cement and zinc oxide-eugenol as temporary cement. Zinc phosphate luting agent can be advantageous as increased mechanical bonding of the cement and substructure can be achieved.

Zinc oxide eugenol, on the other hand, being a temporary luting agent, guarantees theoretically easy removal. It can thus be assumed that a cement that performs well as a temporary luting agent for tooth-supported restorations may or may not be a definitive luting agent for implant supported prosthesis. Hence, in these cases, easy removal remains a controversial issue (**Jatin et al., 2018**).

In all clinical cases, radio-opaque cement is of advantage as the excess of the cement can be detected by an oral radiography. The cement should be applied on a very thin layer in the inside of the implant crown while on the outer surfaces Vaseline should be applied to facilitate cement removal after setting (**Canullo et al., 2015**).

6.7 Fabrication of cement-retained restorations

For the fabrication of cement-retained crowns, it is essential to select an abutment with proper dimensions to support the final restoration. The important factors that must be taken into consideration are the implant diameter, the height of the transmucosal part (Gingival Height), the height of the abutment over the cervical area and the contour of the cervical area lying under the soft tissue level. The height of the abutment is important to ensure adequate mechanical retention to the prosthesis. The height of the transmucosal part and its contour are crucial for the support of the soft tissues and the depth of the marginal line of the prosthesis. In cases where angulated abutments are needed, the abutment with the right inclination should be selected to allow adequate thickness for the metal framework and the ceramic materials.

For all these reasons, a full wax-up of the planned restoration offers significant help before the abutment selection and has been suggested several years ago (**Kourtis, 2002**). Silicon partial impressions from the wax-up can be applied on the working cast and the selected abutment can be checked before the fabrication of the prosthesis. The wax-up can also be used as a guide for the individual modification of prefabricated abutments concerning the height or inclination. The wax-up (conventional, scanned or digitally designed) is also essential for the design of custom fabricated CAD/CAM abutments in order to achieve the needed form in all aspects (**Osorio and Kernstein, 2014**).

6.8 Maxillary Fixed Dental Prosthesis with cantilever on prefabricated titanium abutments (Case A, Figs. 6.7-6.14).

In this case, two internal hexagon implants (Xive implants, Densply/Sirona Co) were inserted in regions #13 and 14 (***Fig. 6.7***). The height of the alveolar crest under sinus floor did not allow the placement of additional implants distally, and the patient denied any surgical treatment involving the sinus. He wished for a simple and low-cost restoration. For these reasons, a cement-retained restoration was planned as the implants had severe diversion from the axis of the crowns (***Fig. 6.8***).

An impression was taken at implant level and prefabricated titanium abutments were selected that allowed the fabrication of the crowns to the planned shape (***Fig. 6.9***). Minimal modification was needed, and the abutments were tried intra-orally to verify that the margin was slightly under the soft tissue margin (***Fig. 6.10***).

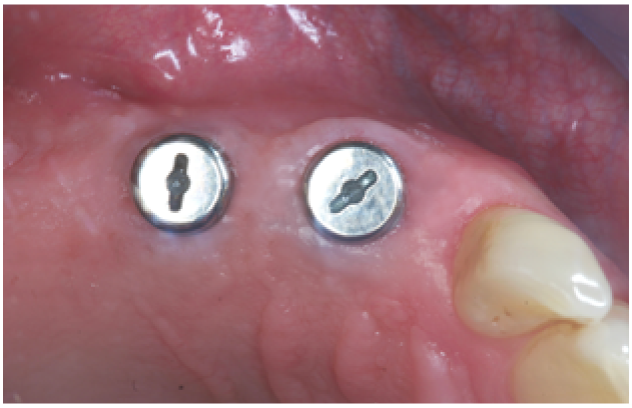

Fig. 6.7

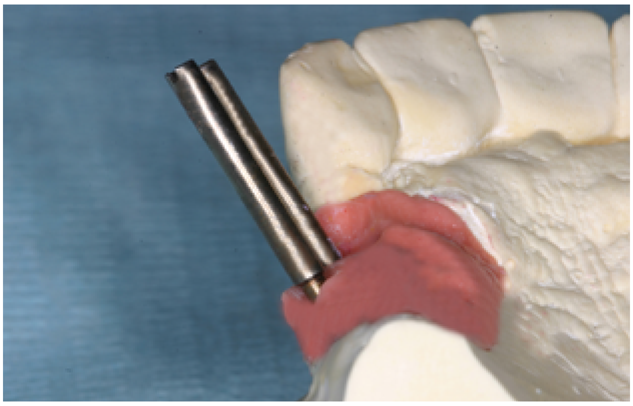

Fig. 6.8

Fig. 6.7 *Case A, initial clinical situation.*

Fig. 6.8 *The working cast with long screws in the implants indicating severe diversion of the implant axis to the prosthetic restoration.*

Fig. 6.9

Fig. 6.10

Fig. 6.9 *Prefabricated titanium abutments (angulated) for cement-retained restorations. The abutments can be modified individually.*

Fig 6.10 *Try-in of the abutments intraorally.*

The final restoration was a 3-unit FDP with a distal cantilever shaped as premolar (***Figs. 6.11-6.13***). Before the final cementation a radiographic control was necessary to verify the precision of fit (***Fig. 6.14***).

Fig. 6.11

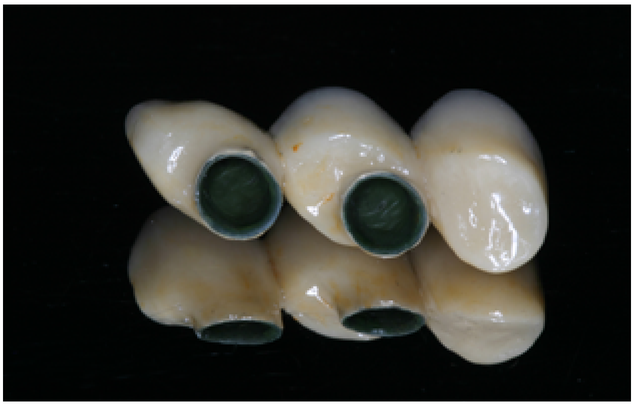

Fig. 6.12

Fig. 6.11 *The 3-unit cantilever FDP on the working cast.*

Fig. 6.12 *The restoration before cementation.*

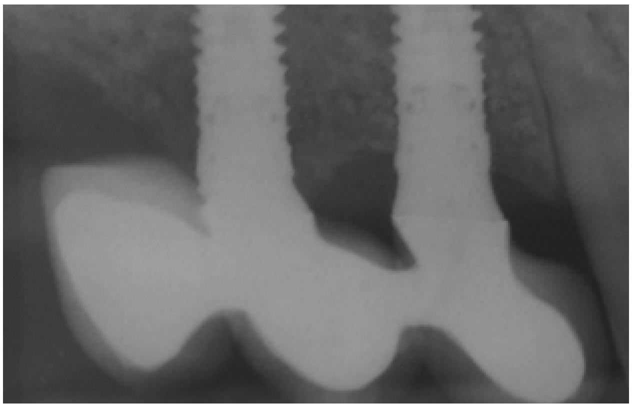

Fig. 6.13

Fig. 6.14

Fig. 6.13 *Radiographic control before cementation.*

Fig. 6.14 *Case A, the final clinical result.*

6.9 Mandibular Fixed Dental Prosthesis on prefabricated titanium abutments (Case B, Figs. 6.15-6.20)

Two implants (Astra implants, Densply/Sirona Co.) were inserted in regions #34 and 36 for the restoration of partial edentulism in the posterior left mandibular area (***Fig. 6.15***). The implants had slightly divergent axes and a screw-retained restoration with direct fixation on the implants would be difficult. There was adequate vertical space with the antagonist teeth and a cement-retained FDP was fabricated on prefabricated Titanium abutments that required minimal modification (***Figs. 6.16 and 6.17***). The final restoration was checked radiographically and cemented with temporary cement (***Figs. 6.18-6.20***).

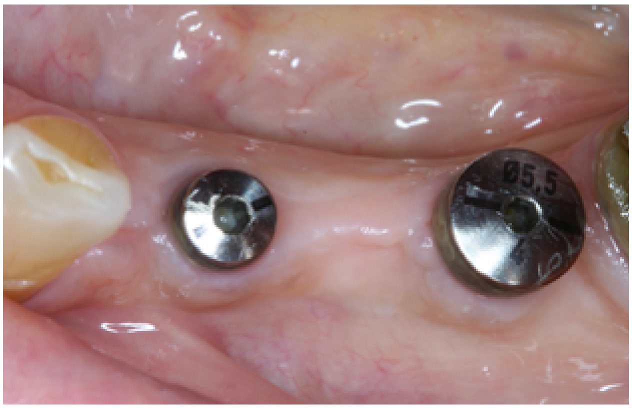

Fig. 6.15 *Case B, initial clinical situation.*

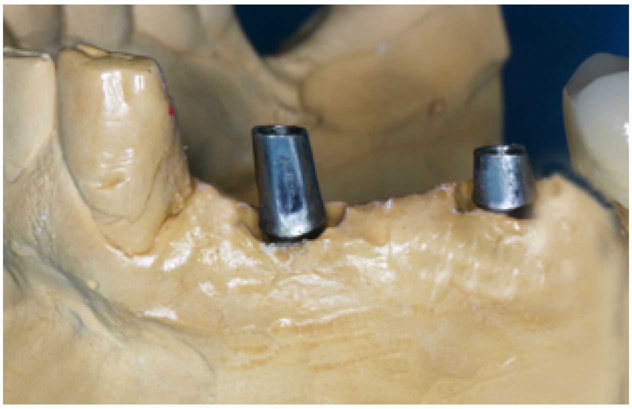

Fig. 6.16

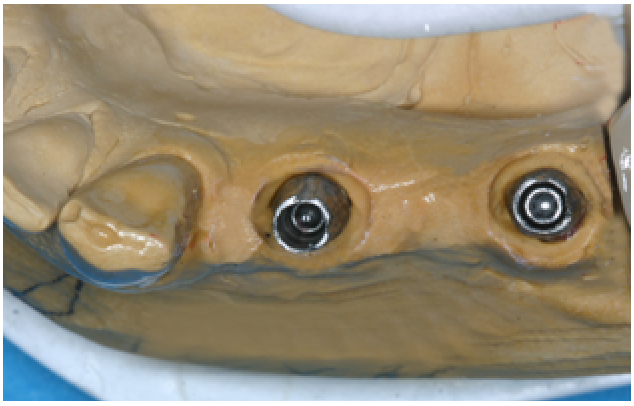

Fig. 6.17

Figs. 6.16 and 6.17 *The working cast with prefabricated titanium abutments. The soft tissue mask has been removed.*

Fig. 6.18: *The metal ceramic FDP on the working cast.*

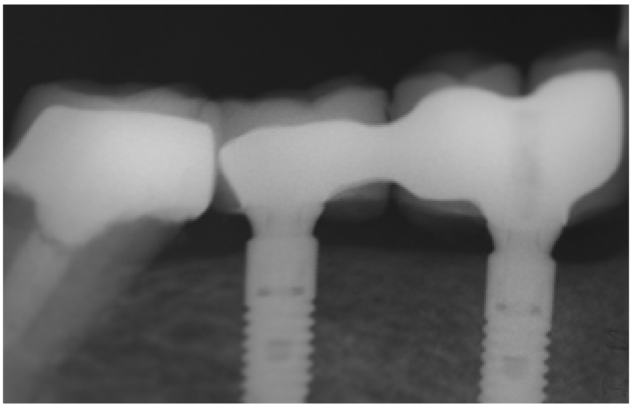

Fig. 6.19

Fig. 6.20

Fig. 6.19 *Radiographic control before cementation.*
Fig. 6.20 *Case B, the final clinical result.*

6.10 Anterior maxillary single tooth implants with ceramic abutments (Case C, Figs. 6.21-6.30)

In a female patient, two external hexagon implants had been inserted several years ago, upon completion of growth for the restoration of congenitally missing maxillary lateral incisors (***Figs. 6.21-6.23***). The implants were of external hexagon type and two metal-ceramic screw-retained crowns had been fabricated by direct fixation on the implants (***Fig. 6.24***).

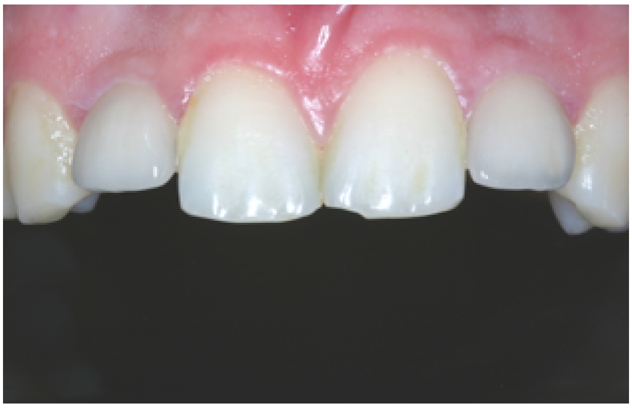

Fig. 6.21 *Case C, initial clinical situation.*

Fig. 6.22 **Fig. 6.23**

Figs. 6.22 and 6.23 *Side views of the existing implant crowns. Labial inclination of the incisal edge was necessary to place the access hole on the palatal surface. Gray discoloration was caused by the metal collar of the crowns.*

Fig. 6.24 *The existing screw-retained metal ceramic restorations.*

The implant crowns supported the soft tissues and the papillae (***Fig. 6.25***) but the patient was not satisfied with the esthetic result: The natural teeth had erupted and the lateral incisors appeared shorter with labial inclination. A gray discoloration at the marginal area was also noted, resulting from the metal finishing of the crowns.

An impression was taken at implant level with customized impression posts and a working cast was fabricated (***Figs. 6.26 and 6.27***). As the patient had high esthetic demands, two cement-retained restorations on customized all-ceramic zirconium abutments were fabricated. The use of ceramic abutments eliminated the shining of the metal collar and by cement retention the labial inclination of the previous crowns (necessary for the access hole of the screws) could be avoided (***Figs. 6.28-6.30***).

Fig. 6.25 **Fig. 6.26**

Fig. 6.25 *The soft tissue profile.* **Fig. 6.26** *Open tray impression with customized impression posts.*

Fig. 6.27

Fig. 6.28

Fig. 6.27 *The working cast.*
Fig. 6.28 *All-ceramic abutments on the cast.*

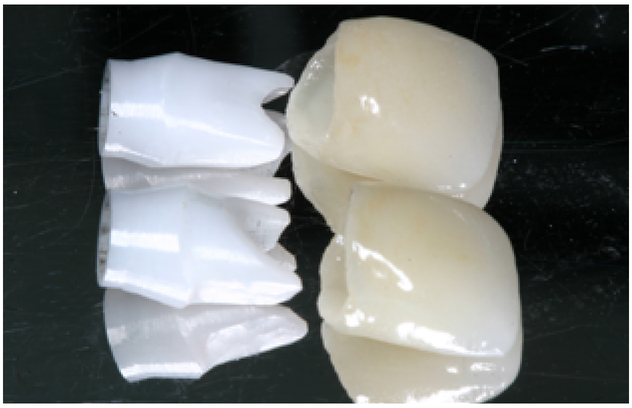

Fig. 6.29

Fig. 6.30

Fig. 6.29 *All-ceramic abutments and crowns.*
Fig. 6.30 *Case C, the final clinical result.*

6.11 Anterior maxillary single tooth implant with CAD/CAM ceramic abutment (Case D, Figs. 6.31-6.44).

An internal hexagon implant (Xive implants, Densply/Sirona Co.) was inserted in region #23 of a young female patient for the restoration of the congenitally missing lateral incisor #22. The canine had been moved orthodontically in the place of #22 and had been reshaped to mimic the morphology of a lateral incisor (***Fig. 6.31***). For the creation of a proper emergence profile, a screw-retained provisional restoration was initially fixed on the implant, based on a prefabricated titanium abutment. The soft tissues were shaped following the stage approach procedure by adding composite resin on the cervical areas and applying selective pressure (***Fig. 6.32***). The access hole of the retaining screw was placed on the incisal edge of the crown, thus making necessary the addition of composite resin on the incisal area (***Figs. 6.33 and 6.34***). For this reason, a cement-retained crown was decided as final restoration. The fit of the temporary abutment and crown was also checked radiographically (***Fig. 6.35***).

Fig. 6.31

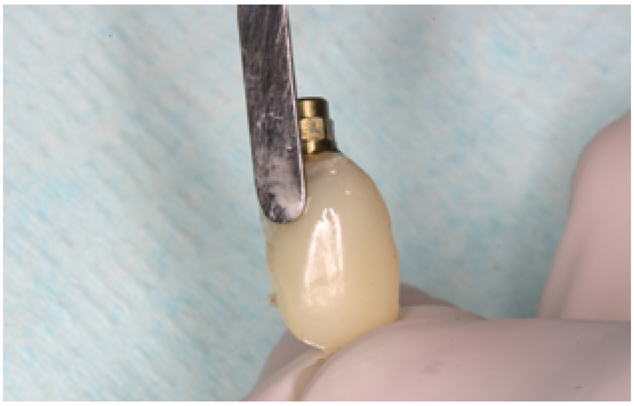

Fig. 6.32

Fig. 6.31 *Case D, initial clinical situation.*

Fig. 6.32 *Modification of the provisional screw-retained crown for selective pressure.*

Fig. 6.33

Fig. 6.34

Figs. 6.33 and 6.34 *The screw-retained provisional crown.*

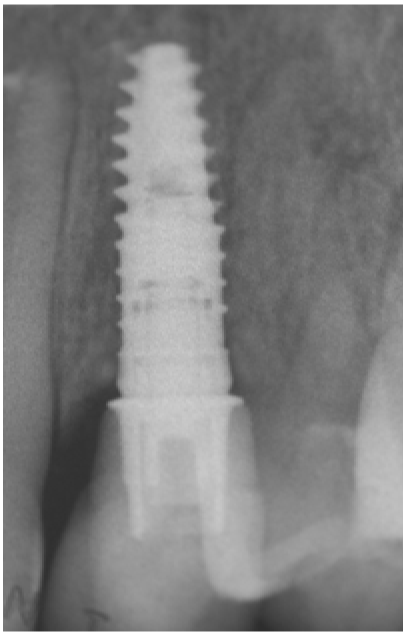

Fig. 6.35 *Radiographic control of the provisional crown.*

After shaping the desired soft tissue contour by the provisional crown, an impression was taken at implant level using a customized impression post to support the soft tissue. For the customization of the impression post, an impression was taken extraorally from the provisional restoration, and autopolymerizing resin was added around the impression post to support the soft tissues during impression (***Figs. 6.36-6.38***). The final working cast reproduced accurately the shape and the individually formed emergence profile (***Fig. 6.39***). The clinical procedure has been published previously and is strongly indicated in anterior maxillary implants to achieve the best possible esthetic result (**Papadopoulos et al., 2014**).

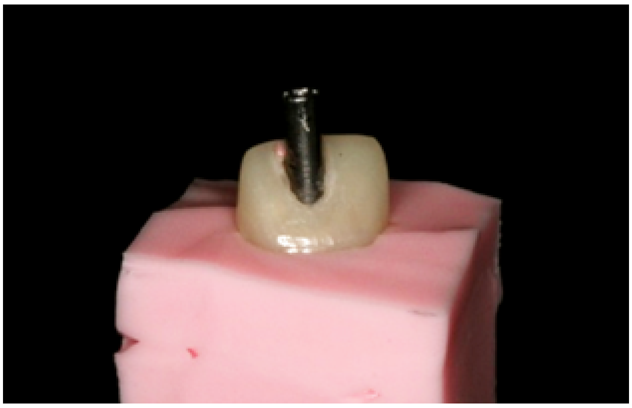

Fig. 6.36

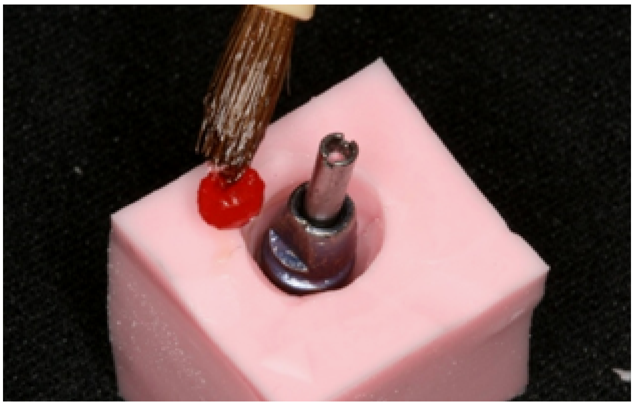

Fig. 6.37

Figs. 6.36 and 6.37 *Impression of the provisional crown for the modification of the impression post (from Papadopoulos et al., 2014).*

Fig. 6.38

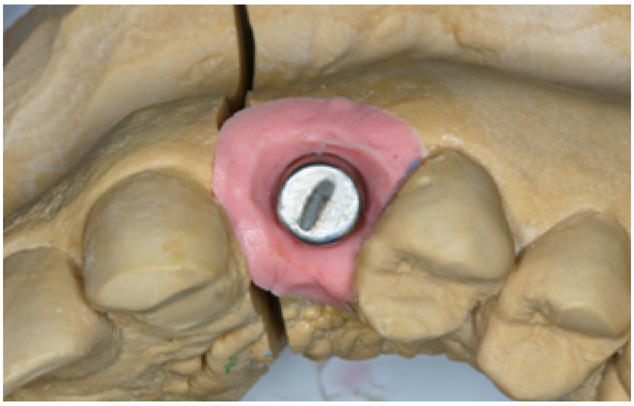

Fig. 6.39

Fig. 6.38 *The customized impression post.*

Fig. 6.39 *Working cast with a soft tissue mask. The created emergence profile differs from the contour of the prefabricated healing screw.*

As the patient had a high smile line and was concerned extremely about the esthetic result, a cement-retained all-ceramic crown was selected as the definite restoration based on a CAD/CAM ceramic abutment (***Fig. 6.40***). The customized abutment supported the contour of the soft tissues adequately and was tried intraorally to verify the depth of the margin (***Figs. 6.41 and 6.42***). The try-in of the abutment is recommended as the soft tissue mask on the model does not always reproduce the shape of(?) the soft tissue precisely. A CAD/CAM ceramic crown was fabricated on the ceramic abutment that fullfilled the patient's expectation (***Figs. 6.43 and 6.44***).

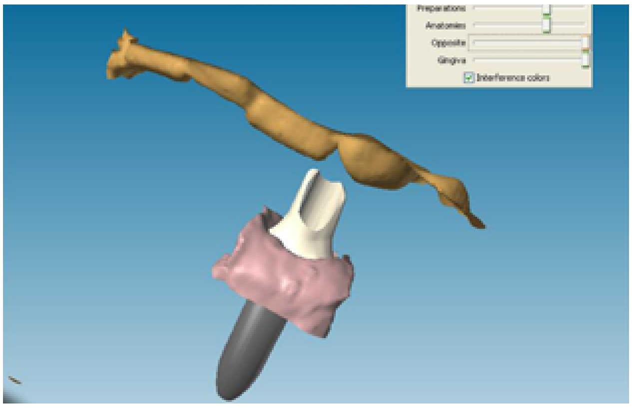

Fig. 6.40 *CAD design for a ceramic abutment.*

Fig. 6.41

Fig. 6.42

Figs. 6.41 and 6.42 *The ceramic abutment on the cast and upon intra-oral try-in.*

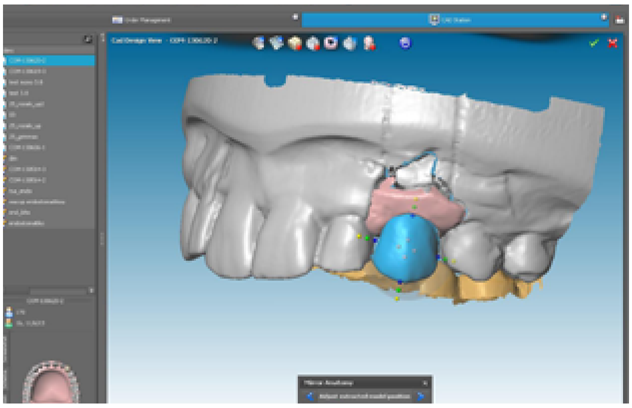

Fig. 6.43

Fig. 6.44

Fig. 6.43 *CAD design of an all-ceramic cement-retained crown.*
Fig. 6.44 *Case D, the final clinical result.*

6.14 Full-arch maxillary fixed restoration (Case E, Figs. 6.45-6.62)

In this patient, 6 internal connection implants had been placed in the maxilla in prosthetically favorable regions, namely #16, 14, 12, 22, 24 and 26. Their healing and osseointegration was uneventful (***Figs. 6.45 and 6.46***). The patient was using a maxillary complete denture for a long time but wished intensively a fixed restoration. He was also concerned about the esthetic outcome of the restoration, as he was not satisfied with the shape and size of the teeth in the existing denture (***Figs. 6.47 and 6.48***). He also wanted to avoid the protrusion of the upper lip that was caused from the labial flange of the denture. In this patient, no detailed presurgical planning was accomplished and the implants were inserted using a duplicate of the existing denture as surgical guide.

Fig. 6.45

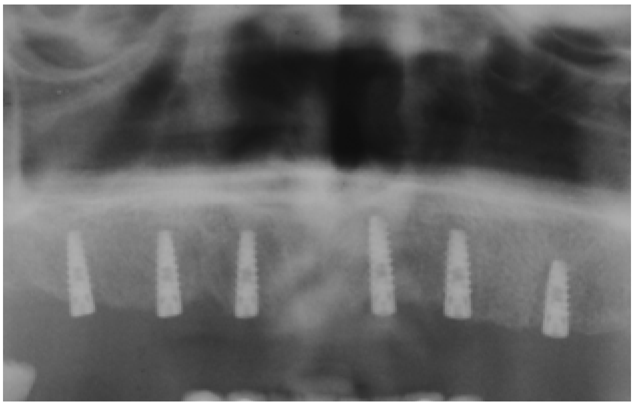

Fig. 6.46

Figs. 6.45 and 6.46 *Case E, clinical situation and radiographic examination at the end of the osseointegration period.*

Fig. 6.47

Fig. 6.48

Fig 6.47 *The existing denture.*
Fig 6.48 *Lip protrusion caused by the labial flange of the denture.*

For these reasons a diagnostic set-up of the maxillary anterior teeth was necessary to control the esthetic result prior to the fabrication of the fixed restoration. An impression was obtained at implant level and a working cast was fabricated with a soft tissue mask (***Fig. 6.49***). The cast was mounted on a semi-adjustable articulator after registration of the Central Condyle position using a base plate fixed on one implant for stability (***Fig. 6.50***). On the working cast two provisional abutments were fixed on the implants of regions # 14 and 24. A diagnostic set-up was performed using denture teeth on a base from autopolymerizing resin (***Figs. 6.51 and 6.52***). The set-up was tried intraorally to check the contour and size of the teeth in the planned restoration (***Figs. 6.53 and 6.54***). The lip support was also checked that was adequate without the previous lip protrusion from the denture.

Fig. 6.49

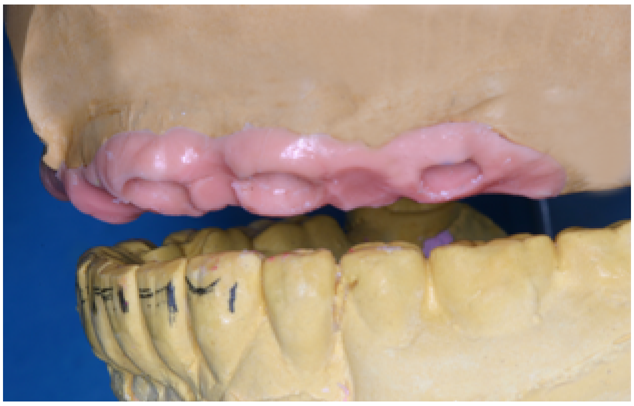

Fig. 6.50

Fig. 6.49 *The working cast with a soft tissue mimicking mask.*
Fig. 6.50 *The working cast mounted on the articulator.*

Fig. 6.51

Fig. 6.52

Figs. 6.51 and 6.52 *Diagnostic set-up on temporary implant abutments.*

Fig. 6.53

Fig. 6.54

Figs. 6.53 and 6.54 *Try-in of the diagnostic set-up.*

On the working cast prefabricated titanium abutments were selected for the fabrication of a cement-retained restoration. The inclination of the anterior implants did not allow the fabrication of a screw-retained restoration, as the access holes of the retention screws would be located on the labial surface. The abutment selection and customization were accomplished using a silicone index from the diagnostic set-up, taking into consideration the thickness of the peri-implant soft tissues and the inclination of the implants (***Figs. 6.55-6.57***). A metal framework was fabricated and tried intraorally to check the passive fit (***Fig. 6.58***).

The patient was restored with a metal-ceramic cement-retained restoration that fulfilled his demands and expectations (***Figs. 6.59 and 6.60***). The clinical condition was stable even after a long time, as it could be observed in the 10-years recall (***Figs. 6.61 and 6.62***).

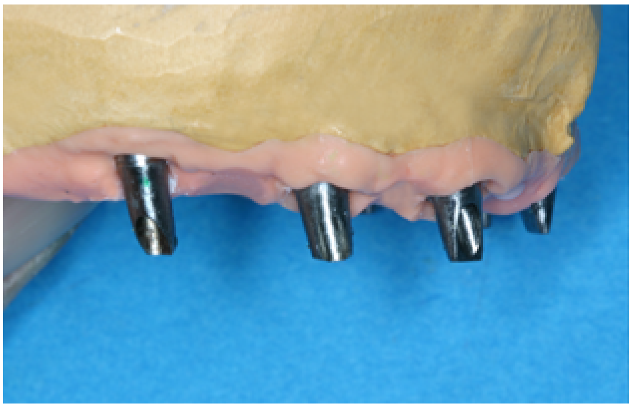

Fig. 6.55

Fig. 6.56

Figs. 6.55 and 6.56 *Selection of angulated prefabricated titanium abutments.*

Fig. 6.57

Fig. 6.58

Fig. 6.57 *The abutments after customization.*

Fig. 6.58 *The metal framework for a fixed cement-retained restoration.*

Fig. 6.59

Fig. 6.60

Figs. 6.59 and 6.60 *The final metal-ceramic restoration.*

Fig. 6.61

Fig. 6.62

Figs. 6.61 and 6.62 *Case E, clinical situation and radiographic examination at the 10-year recall.*

6.13 Survival of implants in cement-retained restorations

The 5-year survival rate and the frequency of complications for all kinds of fixed restorations were examined in a systematic review based on 59 clinical studies (**Sailer et al., 2012**). For cemented single crowns and cemented FDPs the estimated 5-year survival of the restorations was similar to screw-retained restorations. For cemented full-arch FDPs the 5-year survival was 100%, which was somewhat higher than that for screw-retained FDPs with 95.8%.

The authors concluded that both types of restorations influenced the clinical outcomes in different ways but neither of the fixation methods was clearly advantageous over the other. Cemented reconstructions exhibited more serious biological complications (implant loss, bone loss >2mm), while screw-retained reconstructions exhibited technical problems more frequently. Screw-retained reconstructions are more easily retrievable than cemented reconstructions and, therefore, technical, and eventually biological complications can be treated more easily.

6.14 Clinical performance of cement-retained restorations

The clinical performance of screw- and cement-retained restorations was examined in an extended systematic review based on 73 publications (***Wittneben et al., 2014***). The authors found the 5-year survival rates of 96.03% and 95.55% for cemented and screw-retained reconstructions respectively. Comparison of cement and screw retention showed no difference when grouped as Single Crowns or Fixed Dental Prosthesis (FDPs). Technical and biological complications demonstrating a statistically significant difference included loss of retention, abutment loosening, porcelain fracture and/or chipping and presence of fistula/suppuration.

Although no statistical difference was found between cement- and screw-retained reconstructions for survival or failure rates, screw-retained reconstructions exhibited fewer technical and biological complications overall. There were no statistically significant differences between the failure rates of the different reconstruction types or abutment materials (titanium, gold, ceramic). The failure rate of cemented reconstructions was not influenced by the choice of a specific cement, though cement type did influence loss of retention.

6.15 Complications in cement-retained restorations

6.15.1 Frequency of complications

In a recent systematic review based on 29 papers (**Gaddale et al., 2020**), cement-retained reconstructions exhibited more biological complications (implant loss, bone loss >2mm) and screw-retained prostheses exhibited more technical problems. Clinical outcomes were influenced by both fixations in different ways.

The screw-retained restorations were more easily retrievable than cemented ones; therefore, technical and eventually biological complications could be treated more easily. For this reason, and for their higher biological compatibility, these reconstructions are preferable.

Similar findings were also reported to a previous extended systematic review based on 59 publications (***Sailer et al., 2012***). The estimated 5-year cumulative incidence of technical complications at cemented single crowns was 11.9% and 24.4% at screw-retained crowns. At the partial and full-arch FDPs, in contrast, a trend to less complication at the screw-retained was found than at the cemented ones (partial FDPs cemented 24.5%, screw-retained 22.1%; full-arch FDPs cemented 62.9%, screw-retained 54.1%). Biological complications like marginal bone loss >2mm occurred more frequently at cemented crowns (5-year incidence: 2.8%) than at screw-retained ones (5-year incidence: 0%).

The authors concluded that none of the fixation methods was clearly advantageous over the others. Cemented reconstructions exhibited more serious biological complications (implant loss, bone loss >2mm), screw-retained reconstructions exhibited more technical problems. Screw-retained reconstructions are more easily retrievable than cemented reconstructions and, therefore, technical and eventually biological complications can be treated more easily.

The influence of the type of restoration on the prosthetic complication was also investigated in a systematic review based on 73 papers (**Millen et al., 2015**). Screw-retained prostheses showed a tendency toward—and significantly more—technical complications than cemented prostheses with single crowns and fixed partial prostheses respectively. For «all fixed prostheses» (prosthesis type not reported or not known), significantly fewer biological and technical complications were seen with screw retention. Multivariate analysis revealed a significantly greater incidence of technical complications with cemented prostheses. A significantly greater incidence of technical and biological complications was seen with cemented prostheses.

In the same review, screw-retained fixed partial prostheses demonstrated a significantly higher rate of technical complications, and screw-retained full-arch prostheses demonstrated a notably high rate of veneer chipping. When «all fixed prostheses» were considered, significantly higher rates of technical and biological complications were seen for cement-retained prostheses. The incidence of technical complications was more dependent upon prosthesis and retention type than upon prosthesis or abutment material.

The most common prosthetic complication in screw-retained restorations is the loosening of the fixing screw. In a clinical trial with follow-up to 3.5 years, the prevalence of reconstruction loosening was significantly lower for cement-retained FDPs when a temporary cement (10%) was used than it was for screw-retained FDPs (29%). The survival rate of the reconstructions within the observation period was 97% for screw-retained FDPs and 100% for cement-retained FDPs (**Korsch and Walther, 2015**).

The influence of the implant-abutment connection on the frequency of screw loosening was investigated in a systematic review with meta-analysis based on 60 papers (**Pjeturson et al., 2018**). Meta-analysis of these studies indicated an estimated 5-year survival rate of 97.6% for Single Crowns, 97.0% for FDPs supported by implants with internal implant-abutment connection, 95.7% for Single Crowns and 95.8% for FDPs supported by implants with external connection. The 5-year failure rate of abutments ranged from 0.7% to 2.8% for different connections with no differences between the types of connections. The total number of complications was similar between the two connections, yet, at external connections, abutment or occlusal screw loosening was more predominant.

Ceramic abutments, both internally and externally connected, demonstrated a significantly higher incidence of abutment fractures compared with metal abutments. The authors (**Pjeturson et al., 2018**) concluded that for implant-supported Single Crowns, both metal and ceramic abutments with internal and external connections exhibited high survival rates. Moreover, implant-supported FDPs with metal abutments with internal and external connections also showed high survival rates.

6.15.2 Screw loosening

Screw loosening is a major problem with screw-retained restorations. The incidence of screw loosening was 65% for single tooth implant restorations in one study (**Jemt and Linden, 1992**) whereas the incidence of unretained cemented implant restorations was reported to be less than 5% in other studies (**Misch et al., 1995**). However, the improvements in implant systems, including the advent of internal implant-abutment connections, enhancement of torque drivers, and screw materials and design, led to the reduction of incidences of screw loosening. The incidences of screw loosening were more frequent in the older types of external hex-implants that used titanium and gold screws with slot-head. In the majority of the implant systems nowadays, screws with hexagon-heads are used, which allow higher tightening torque without damage to the head (**Shaffie and White, 2014**).

On the other hand, the screw loosening of screw-retained restorations can be considered as an important advantage since the weakest component within the implant-supported restoration will be the prosthetic screw; this will allow for assessing the implant-supported restoration before more serious complications develop, such as implant fracture at screw level especially in implant systems using internal connections. Using screw-retained restorations will enable assessing the preload of implant abutment screws over time, since the preload is not constant with ongoing application of forces associated with occlusion (**Shadid and Sadaqa, 2012**).

The gingival response is found to be better when using screw-retained crowns since no cement is used. However, if prosthetic retaining screws and abutment screws become loose, granulation tissue accumulates between the prosthesis and the abutment, and also between implant and abutment leading to fistulae formation, plaque deposition, and screw fracture. Therefore, it is recommended to retighten the screws in full-arch fixed prosthesis every 5 years (**Kallus and Bessing, 1994**).

6.15.3 Loss of retention

In an extensive systematic review based on 33 articles (**Jatin et al., 2018**), less retention failures were found with cement-retained prostheses when compared to screw-retained prostheses. The retention failure rate in short-term studies (<5 years) ranged from 0% to 15.74% for cement-retained prosthesis, and from 0% to 46.66% for screw-retained prosthesis. For a long-term observation of more than 5 years, the retention failure ranged from 0% to 23.72% for cement-retained prosthesis and from 0% to 50% for screw-retained prosthesis.

In an earlier systematic review (**Weber and Sukotjo, 2007**)—where all complications were included and not only the loss of retention—the prosthetic success rates of cement and screw-retained implant prosthesis was 93.2% and 83.4% respectively, with a follow-up of more than 6 years.

It must be underlined, however, that detachment of a cement-retained implant restoration can be a disturbing event both for the patient and the clinician. It is the simplest prosthetic complication and can be treated without major procedures. On the other side, decementation of a prosthesis can be a helpful warning sign in case of occlusal overloading or misfit to avoid further complication. If additional retention is needed, grooves or sandblasting of the abutment surfaces can increase the retention of the crown and the efficacy of the luting cement.

6.15.4 Marginal Bone Loss

The findings concerning marginal bone loss around dental implants with screw- and cement-retained restorations are controversial. In a retrospective clinical trial with a follow-up of 15 years, the mean marginal bone loss was statistically significantly higher for screw-retained (1.4 ± 0.6 mm) than for cemented (0.69 ± 0.5 mm) restorations (**Nissan et al., 2011**). These results were also confirmed by another similar clinical study (**Lemos et al., 2016**).

On the other side, screw-retained restorations showed reduced marginal bone loss compared to cemented in other clinical trials (**Koller et al., 2016**). In a systematic review, screw-retained restorations also showed better results in marginal bone loss compared to cemented (**Sailer et al., 2012**).

In an extended systematic review based on 9 clinical studies comparing marginal bone loss on screw- and cement retained restorations, no difference was found between the two types (**Brandau, 2013**). These results were also confirmed by another systematic review focusing on the same clinical topic (**Sherif et al., 2014**).

6.16 Clinical relevance

Cement-retained restorations have been used for decades on dental implants with high survival rates and reduced frequency of complications. Their main advantage is the excellent esthetic result without limitations from the fixing screw. Their main restriction, however, is that retrievability cannot always be predictable, thus reducing the possibility for professional hygiene, modification and/or repair. Additionally, cement remnants may induce infection in the peri-implant tissues. The type of the prosthetic retention should be selected individually for each case, based on the specific characteristic and the demands of the patients.

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CHAPTER 7

Screw-retained Implant Restorations

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Abstract

Screw-retained prostheses were the first restorations used over implants by the Branemark group, when the implants were used at first. Later, the cement-retained implant restorations were introduced and widely used in clinical practice. Each retention mode has advantages and disadvantages that should be evaluated according to the demands of each clinical case. The aim of this chapter is to present an overview of the screw-retained restorations with clinical cases and analyze the characteristic of this type of retention.

Knowledge background

To understand the content of this chapter, the reader should be familiar with the basic principles of fixed restorations on natural teeth and have the basic knowledge of implant restorations, as analyzed in the previous chapters.

7.1 Introduction

Screw-retained prostheses were the first restorations used over implants by the Branemark group at the early stages of osseointegration, going back to 1965, when the first "tissue integrated prosthesis" was fabricated. At that time, dental implants were used only for the restoration of the edentulous mandible and 5-6 implants were considered necessary for this prosthetic treatment. The prosthetic restorations were fixed on a transmucosal (or also called transgingival) abutment which was secured by screw on the implants.

The abutments were inserted upon implant uncoverage and were fixed with high torque on the implant. Their main function was to bring the margin of the Fixed Dental Prosthesis (FDP) over the peri-implant tissue to facilitate oral hygiene. The lower surface of the prosthesis had 2-3mm distance from the peri-implant soft tissues to allow easy cleaning. The prostheses were fabricated from a metal framework covered with polymer material (Poly-Methyl-Methacrylate-Acid) and denture teeth. One to two cantilevers were added to the most distal abutment to ensure increased masticatory capacity to the patient. Up to the middle of '90s, screw-retained restorations were the only available option, although the spectrum of indications was wider including implant-supported single-tooth crowns and FDPs (**Hobkirk et al., 2003**).

The full-arch restorations that were at first introduced were highly demanding and technique sensitive. There was also no possibility to compensate for an implant with non-favorable inclination for the prosthesis. For this reason, the cement-retained restorations that were introduced in the middle of '90s were immediately adopted by the clinicians. The use of angulated abutments that allowed the fabrication of crown without access hole for the retaining screw was a solution, especially in cases of anterior maxillary implants where the implant inclination might have severe diversion to the implant axis.

In the following years, the spectrum of restorations on implants was enlarged from total edentulism to single tooth implants (**Sullivan, 1986; Jemt, 1986**). The available materials for the fabrication of implant restorations nowadays include porcelain-fused-to metal (which is the most widely used type of restoration), polymer-to-metal restoration and all-ceramic restorations. The techniques for the fabrication have also been improved, and CAD/CAM restorations made from intra-oral or laboratory scanning are widely used.

Despite the evolution of materials and techniques, there is always the issue of fixing the prosthesis on the dental implant. The two existing available options for implant supported restorations remain the screw- or cement-retention.

7.2 Aim

The aim of this chapter is to present an overview of the screw-retained restorations with clinical cases, and analyze the advantages, disadvantages and characteristics of screw retention.

7.3 Screw- or cement-retained?

A fixed implant restoration can be fabricated either by fixing the prosthetic directly to the implant head using a screw for retention or can be achieved by cementing the final prosthetic onto an abutment, which, in turn, has been screwed to the implant. There is also the possibility to secure a transmucosal abutment on the implant (also called "multi-purpose abutment") by screw, and then fix the prosthesis by a retention screw on the transgingival abutment. These abutments are prefabricated titanium abutments with diameter analogous to the implant diameter, and they are available in different heights to satisfy the clinical demands of each case.

7.4 Advantages, disadvantages, and characteristics of the screw-retention

Screw-retained restorations offer easy retrievability, which is important to allow repair and maintenance. Retrievability can be difficult in cement retention, even if temporary cement has been used. The loosening of the fixing screw in an abutment for cement-retained crown—while the crown remains cemented on the abutment—is a common clinical problem and may lead to severe prosthetic complications (**Kourtis et al., 2017**).

Careful presurgical planning and surgical skill are required during implant placement so that the access hole for the fixing screw can be located within the occlusal or the palatal surface of the crown. This is of great importance in maxillary anterior implants that usually have labial inclination.

In implant restorations, the passive fit on the implants or the transmucosal abutments is of crucial importance. This is an important factor for the long-time uneventful clinical function of the prosthesis. In this way, the masticatory forces are transmitted along the implant axis and shear tension of the retention screw can be avoided. In screw-retention the passive fit is more difficult to achieve, as in cement-retained restorations the cement is considered to be a compensating factor for minor misfits. There are, however, no published data to support this consideration.

The passive fit should be verified clinically by the Sheffield test. In this test, the restoration is fixed by the screw on the most distal implant and the existence or absence of a gap is checked on the other implants. In cases of implants with thick peri-implant tissues, radiographic control may be necessary.

In screw-retained restorations, the abutment (or the prosthesis) should be fixed by applying the torque recommended by the manufacturer. The final torque should be exerted by means of a torque measuring device upon the final fixation.

The access holes of the screws should be filled with a proper material to ensure sealing of the cavity and avoid leakage and microbial contamination. In former years, gutta-percha had been used in a plastic consistency over the head of the fixing screw, but it hardens after time and does not allow easy removal. Nowadays, teflon tape is mostly used, as it can be easily condensed and removed. Cotton, which had been proposed several years ago, should not be used as it absorbs liquids and enhances bacterial contamination. The top of the access hole is covered with composite material making it hardly distinguishable.

Cement-retained restorations may offer a better esthetic result and are often the clinical choice in anterior maxillary restorations, when the implant axis does not allow the placement of the access hole in the palatal surface. In some cases, however, it may be difficult to remove the excess cement from a deep sub-gingival abutment margin. If excess cement remains on the abutment margin it may cause severe problems to peri-implant tissues.

7.5 Indications for screw-retained restorations

For extended full-arch restorations that demand professional oral hygiene and regular recall program, screw-retained restorations are preferable due to the retrievability of the restoration. In patients that are expected to lose more teeth in the future, screw-retained restorations offer the advantage of retrievability and/or modification. In cases with minimum interocclusal space, screw-retained restorations are also preferred as there is no need for prefabricated abutments. A short prefabricated abutment for a cement-retained restoration cannot ensure proper retention, as increased height is needed for the crown materials. On the other hand, a screw-retained restoration may be fixed directly on the implant minimizing the needed vertical space. For implants that are surrounded by thick peri-implant tissues or that are placed deep subgingivaly, screw-retained restorations are preferable as the excess of cement is more difficult to remove. Implant restorations, where complications are expected, would be preferably screw-retained to allow retrievability and modification.

7.6 Fabrication of screw-retained restorations

For the fabrication of screw-retained restorations on implants there are currently four available options: Direct fixation in the implant, fixation on a transmucosal abutment, cement- and screw-retained restorations and CAD/CAM fabrication.

7.6.1 Direct fixation on the implants

Direct fixation on the implant is mainly used on single tooth implants. The lower part of the prefabricated abutment has an anti-rotational mechanism (internal/ external hexagon, conical part) made from titanium or metal alloy that fits exactly on the head of the implant ensuring antirotation of the prosthesis (***Fig. 7.***1). The upper part of the abutment is made of plastic so that it can be incorporated in the casting of the customized implant crown by overcasting. The first introduced abutments of that type were named as "UCLA" abutments and were used as the basis for customized abutments either for screw- or cement-retained restorations (**Lewis et al., 1988, 1992**).

Fig. 7.1

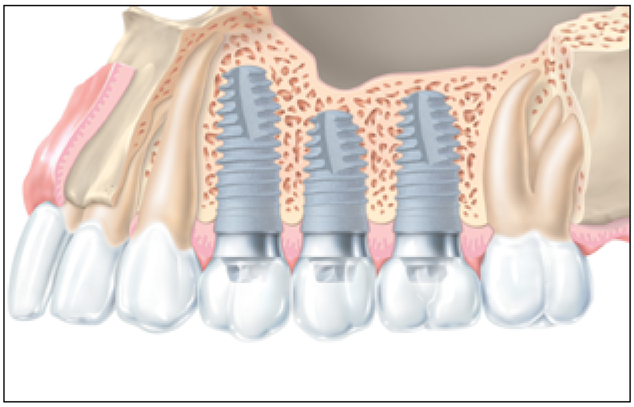


Fig. 7.2

Fig. 7.1 *UCLA type abutment (Aurobase abutments) with prefabricated gold base for overcasting (Xive implants, Dentsply/Sirona Co.).*

Fig. 7.2 *Restoration on transmucosal abutments (MP abutments) for screw-retained restorations (Xive implants, Dentsply/Sirona Co.).*

The main advantage of this type of restoration (direct fixation) is the possibility to create a customized emergence profile from the top of the implant to the margin of the peri-implant tissue, thus facilitating the esthetic result. Another advantage is that the fabrication of restorations directly on the implants eliminates the need for transmucosal abutments. Direct fixation is, however, restricted to single tooth crowns, as it is difficult—if not impossible—to achieve passive fit on the heads of two implants, especially if they are of internal connection type and divergent. The other option for the fixation of the restoration is the "indirect fixation" where the prosthesis is fixed on transmucosal abutments, as described later.

A clinical example of a screw-retained crown with direct fixation is presented in ***Case A***.

7.6.2 Indirect fixation on transmucosal abutments

Fixation on transmucosal abutments is the technique that most implant manufacturers recommend for the fabrication of multiple-unit screw-retained restorations. The transmucosal abutments raise the margin of the prosthesis from the head of the implant to the margin of the peri-implant tissues (***Fig. 7.2***). The transmucosal abutments (also called multi-purpose abutments, uni-abutments, multi abutments etc.) are available in different diameters and height according to the thickness of the peri-implant tissues. The lower part (intra-implant part) has anti-rotational mechanism fitted in the implant, while the upper part (over the neck of the implant) may be conically shaped or may have anti-rotational mechanism also (***Fig. 7.3***). The abutments are fixed by screw on the implant, either upon implant uncoverage or later, and are not removed at any following stage. Various components are available for the use with transmucosal abutments, including cover screws, impression posts, implant analogs etc.

The transmucosal abutments are always accompanied by a plastic burnable cylinder that is used for the fabrication of the metal framework (***Fig. 7.4***). Some implant manufacturers also provide burnable cylinders with a prefabricated metal basis to ensure proper fitting of the implant crown. Most implant manufacturers also offer angulated transmucosal abutments that can compensate for unfavorable or divergent implant axes. In these cases, the angulated abutment consists of two parts, the one fitting to the implant—fixed with a screw along the implant axis—and a second angulated part that supports the crown basis and receives the retention screw of the implant crown (***Fig. 7.5***). Impression is taken using the corresponding impression posts and the working cast is fabricated with implant analogs with the same geometry as the transmucosal abutments.

Fig. 7.3

Fig. 7.4

Fig. 7.3 *Titanium transmucosal abutments (Multi-Purpose abutments) for screw-retained restorations in different diameters with retention screws (Xive implants, Dentsply/Sirona Co.).*

Fig. 7.4 *Castable sleeves with and without prefabricated metal base and implant analog for screw- retained restorations on Multi-Purpose abutments (Xive implants, Dentsply/Sirona Co.).*

Fig. 7.5

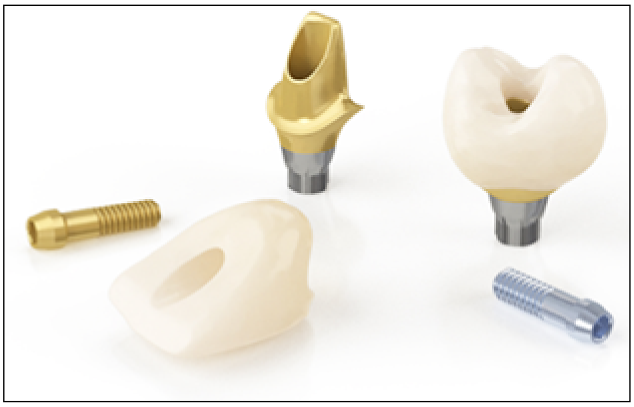


Fig. 7.6

Fig. 7.5 *Two-piece angulated abutment (Smart-Fix abutments) for screw-retained restorations (Xive implants, Dentsply/ Sirona Co.). The fixing screw of the abutment has a different inclination from the fixing screw of the restoration.*

Fig. 7.6 *Prefabricated titanium base for the fabrication of customized cement- and screw-retained restorations (Xive implants, Dentsply/Sirona Co.).*

Transmucosal abutments are widely used nowadays as they offer multiple advantages. The margin of the restoration is moved from the head of the implant to the height of the peri-implant tissue. In this way the height of the implant crown is reduced, the crown-to-implant ratio is changed favorably, and an easier fit can be achieved on the conical abutment compared to the need of fixation into the implant. Their use has not been documented with long term clinical trials focused on their clinical performance, but no complications have so far been reported associated with this type of abutments.

Clinical examples of a screw-retained restorations on transmucosal abutments are presented in ***Cases C, E, F and G***.

7.6.3 Cement- and screw-retained restorations

The term "cement- and- screw-retained-restoration" is used to describe screw-retained restorations that are made using prefabricated titanium abutments for cement-retained crowns and an overlying metal framework that fits exactly on the prefabricated part. These abutments offer the advantage of the prefabricated titanium base with the antirotation mechanism (hexagon) without any inaccuracy caused by casting (***Fig. 7.6***). The metal framework is formed surrounding the prefabricated part (usually formed as cylinder with orientation grooves or surfaces) and can be cast in any dental alloy, thus avoiding the need for overcasting with high-cost precious alloys that are needed in the UCLA abutments. The access hole for the retention screw is kept free during the laboratory procedure to allow smooth and undisturbed insertion and removal of the fixation screw.

The two parts are checked for the precise fit intra-orally and are cemented after the final glaze of the ceramic veneer with dual polymerization resin cement either in the dental laboratory or chairside. This kind of fixation was lately introduced to combine the industrial accuracy of the prefabricated part on the implant with the possibility of a simple cast restoration integrating the titanium part. Their use has not been investigated extensively with focused clinical trials but their adoption by the clinicians seems promising. A limitating factor is that in case of two or more implants a common insertion path must be ensured to allow the restoration to "glide" over the prefabricated parts, eliminating the possibility of use in implants with divergent axes.

A clinical example of a cement-screw-retained restoration is presented in clinical ***Case D***.

7.6.4 CAD/CAM fabrication of screw-retained restorations

CAD/CAM technology for implant restorations offers prosthetic solutions for the fabrication of screw-retained restorations in one piece without the need of abutments. In this way, the restoration is fabricated after digital design, usually by milling or sintering. Another option is the fabrication of a screw-retained restoration to fit over transmucosal abutments. In both cases, the digital designs of the fitting part of the restoration is captured from digital libraries that are available from most manufacturers.

7.7 Single-tooth screw-retained restoration with direct fixation (Case A, Fig 7.7-7.12)

In this case, an internal connection implant (MIS Implants, MIS Co.) was placed in region #15 to replace a missing maxillary second premolar (***Fig. 7.7***). An impression was taken at implant level and the working cast was fabricated. As it can be observed, the peri-implant tissues had increased thickness (***Fig. 7.8***). The implant axis was favorable and, in a screw-retained restoration the access hole would be located within the occlusal surface. On the other side, in a cement-retained crown, the increased depth of the peri-implant tissue would make the removal of excess cement more difficult, and infection might be provoked by cement remnants. An additional advantage of the screw-retained crowns is the possibility to create a fully customized emergence profile supporting the soft tissues and enhance the esthetic outcome (***Figs. 7.9 and 7.10***).

A UCLA abutment (prefabricated titanium basis with burnable cylinder) was used to fabricate the metal framework by overcastting for a screw-retained implant crown. After the fixation with the recommended torque, the access hole was covered with composite resin.

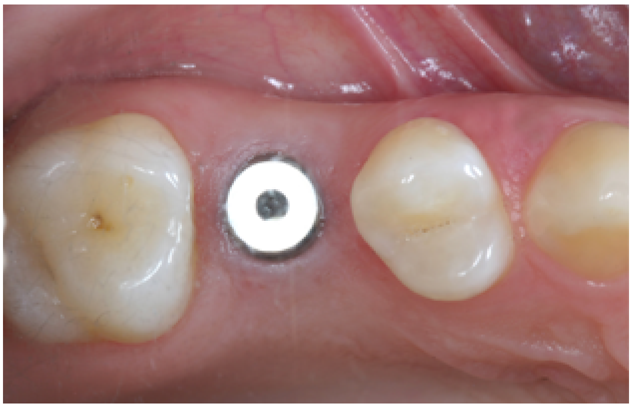


Fig. 7.7

Fig. 7.8

Fig. 7.7 *Case A, initial clinical situation.*

Fig. 7.8: *Working cast from an impression at implant level.*

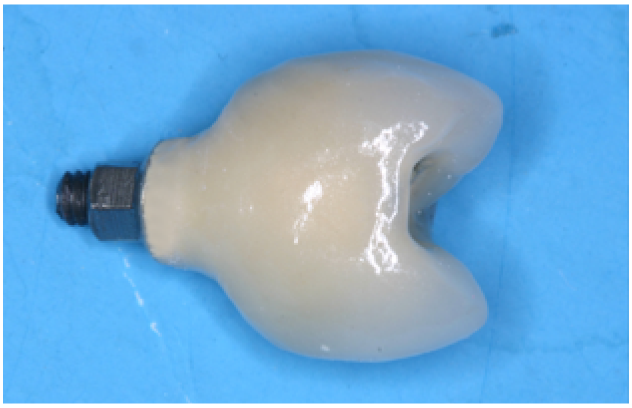


Fig. 7.9

Fig. 7.10

Fig. 7.9 *The screw-retained crown. The emergence profile has been customized to support the peri-implant soft tissues.*

Fig. 7.10 *The restoration of the working cast.*

Fig. 7.11

Fig. 7.12

Figs. 7.11 and 7.12 *Case A, the final restoration.*

7.8 Screw-retained Fixed Dental Prosthesis with direct fixation (Case B, Figs. 7.13-7.20)

The patient of this case presented for the restoration of the missing lower mandibular incisors (***Fig. 7.1***3). As an immediate transitional restoration, a partial coverage FDP was fabricated and fixed adhesively on the adjacent teeth (***Fig. 7.14***). Two internal connection implants were placed in the regions of the mandibular lateral incisors and their healing was uneventful (***Fig. 7.15***). An impression was taken on implant level with the open tray technique and a working cast with a soft tissue mask was fabricated (***Figs. 7.16 and 7.17***).

Fig. 7.13

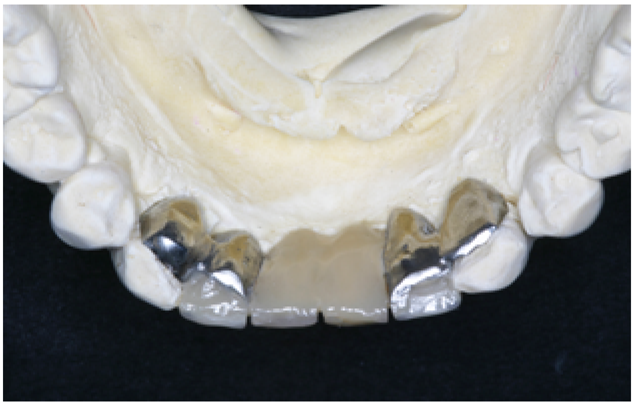


Fig. 7.14

Fig. 7.13 *Case B, initial clinical situation.*

Fig. 7.14 *Partial coverage adhesive restoration as interim prosthesis.*

Fig. 7.15

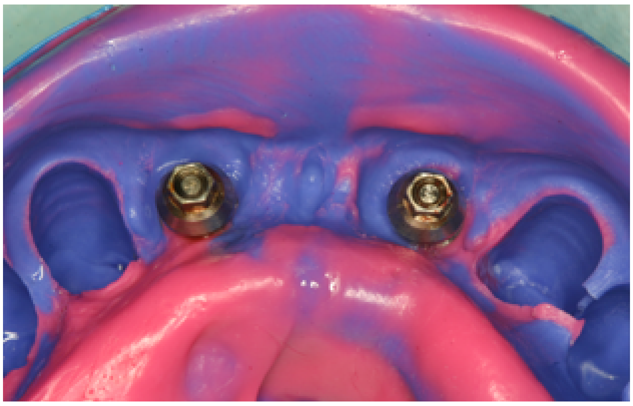


Fig. 7.16

Fig. 7.15 *Placement of two implants in the areas of lateral incisors.*

Fig. 7.16 *Open tray impression at implant level.*

The implants were parallel, and a common insertion path could be achieved. A screw-retained restoration was decided with direct fixation in the implants, as inclinations were favorable with the access holes situated on the lingual surfaces of the teeth. A metal ceramic restoration was fabricated using castable abutments with prefabricated metal basis (***Figs. 7.18-7.20***). These abutments—provided by the implant manufacturer—ensure precise fit of the abutment in the implant through industrial manufacture. The upper part of the abutment can be modified and/or customized for the creation of the proper metal framework. In case of two or more implants, the antirotation mechanism (e.g. hexagon) at the basis of the abutment is not necessary. The restoration was fixed by retention screws directly in the implants.

Fig. 7.17

Fig. 7.18

Fig. 7.17 *The working cast with a soft tissue mask.*
Fig. 7.18 *Metal ceramic screw-retained FDP.*

Fig. 7.19

Fig. 7.20

Fig. 7.19 *Direct fixation in the implants without antirotation.*
Fig. 7.20 *Case B, the final restoration.*

7.9 Splinted crowns on transmucosal abutments (Case C, Figs. 7.21-7.30)

In this case, two internal connection implants (Astra implants, Dentsply/Sirona Co.) were inserted in regions #46 and 47 (***Fig. 7.21***). The soft tissues over and around the implants had increased thickness (***Fig. 7.22***). An impression was taken at implant level and a working cast was poured in stone with a gingival mask mimicking the surrounding soft tissues (***Figs. 7.23 and 7.24***). As the implants were not completely parallel and a common insertion path for the intra-implant part of the abutments could not be ensured, it was decided to construct screw-retained splinted crowns on transmucosal abutments.

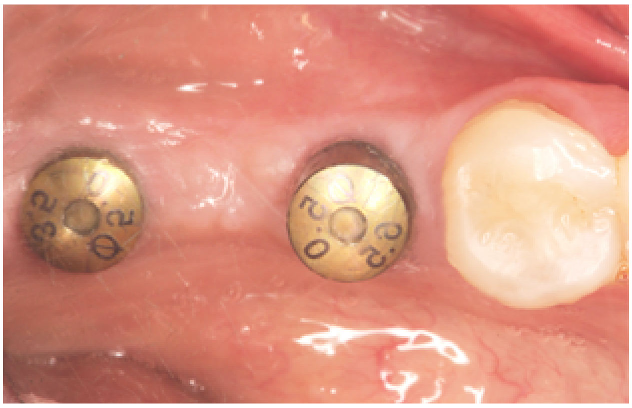


Fig. 7.21

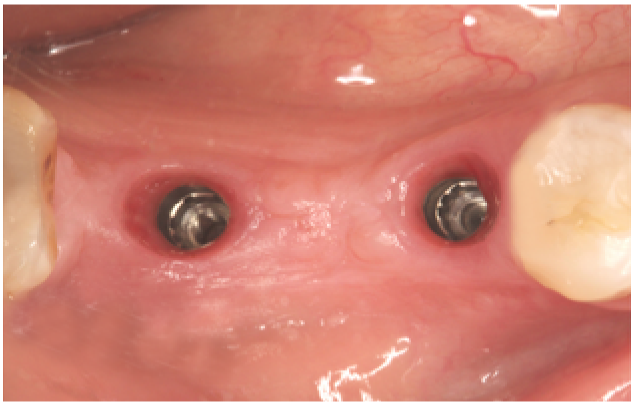


Fig. 7.22

Fig. 7.21 *Case C, initial clinical situation.*

Fig. 7.22 *The soft tissues around the implants after removal of the healing screws.*

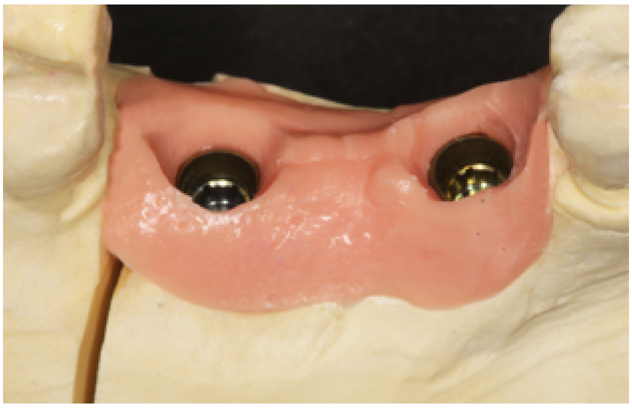


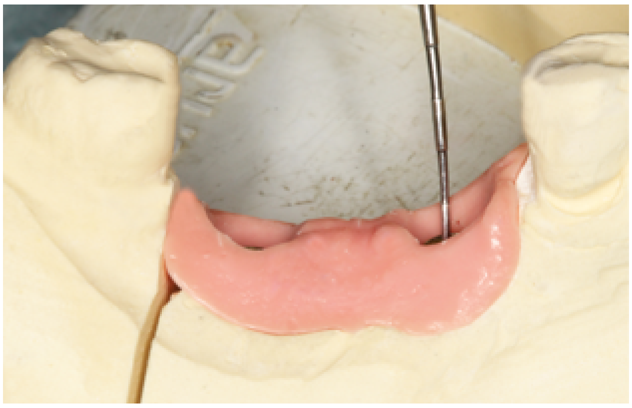
Fig. 7.23

Fig. 7.24

Figs. 7.23 and 7.24 *The working cast from an impression at the implant level.*

On the working cast the height (thickness) of the peri-implant tissue could be accurately measured and the proper transmucosal abutments were selected (***Fig. 7.25***). As the axes of the implants were not severely divergent, straight transmucosal abutments with conical head were used (***Fig. 7.26***). The abutments were fixed on the implants with the recommended torque using the indicated insertion tool (***Fig. 7.2****7*). An impression was taken at abutment level and a new working cast was fabricated with implant analogs corresponding to the transmucosal abutments (***Fig. 7.28***).

The metal framework was cast using the prefabricated burnable cylinders for the specific abutments and tried intra-orally. The accuracy of fit was verified radiographically, after applying the Shefield test. The final restoration was splinted screw-retained crowns with conical basis fitted exactly on the conical surfaces of the abutments and retained with screws securing the crowns on the abutment (***Figs. 7.29 and 7.30***).



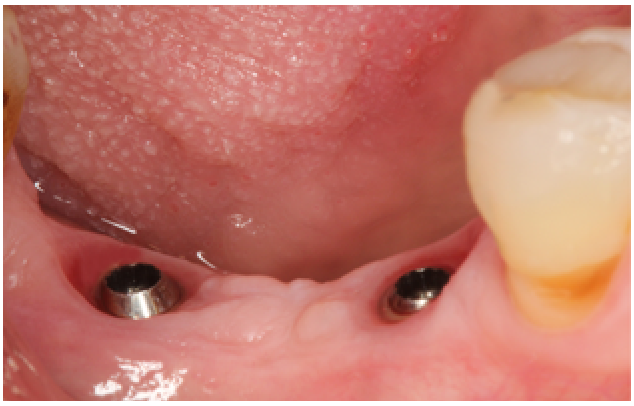


Fig. 7.25 **Fig. 7.26**

Fig. 7.25 *Measurement of the peri-implant tissues for the selection of the transmucosal abutment.*
Fig. 7.26 *The transmucosal abutments fixed on the implants.*

Fig. 7.27 **Fig. 7.28**

Fig. 7.27 *The transmucosal abutment on the insertion tool and the fixing screw for the crown.*
Fig. 7.28 *Working cast from an impression taken at abutment level. Implant analogs with geometry corresponding to the transmucosal abutments have been used.*

Fig. 7.29 **Fig. 7.30**

Fig. 7.29 *The splinted screw-retained crowns.*
Fig. 7.30 *Case C, the final restoration.*

7.10 Screw- and cement-retained single implant crown (Case D, Figs. 7.31-7.38)

In this case, an internal connection implant (Astra implant, Dentsply/Sirona implants) was inserted in region #15 to replace a missing maxillary premolar (***Fig. 7.31***). An impression was taken at implant level for the planned restoration, a screw-retained crown. Customization of the abutment was necessary to support the thick peri-implant tissues (***Fig. 7.32***) but the fit in the base of the abutment should have industrial precision. For this reason, a screw-and-cement retained crown was decided as the most favorable prosthetic option. A prefabricated titanium abutment was selected with the proper contour at the cervical area. The titanium abutment could be further modified in height and along the marginal line. Two flat parallel surfaces were created by milling on the abutment to prevent rotation of the crown. The supporting surface of the abutment over the marginal line was sandblasted to increase retention upon cementation (***Figs. 7.33 and 7.34***).

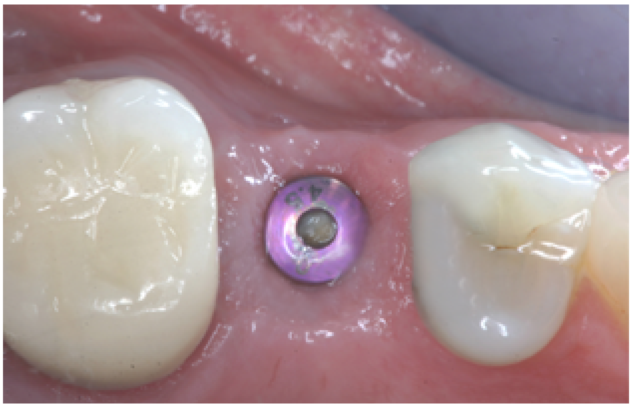


Fig. 7.31

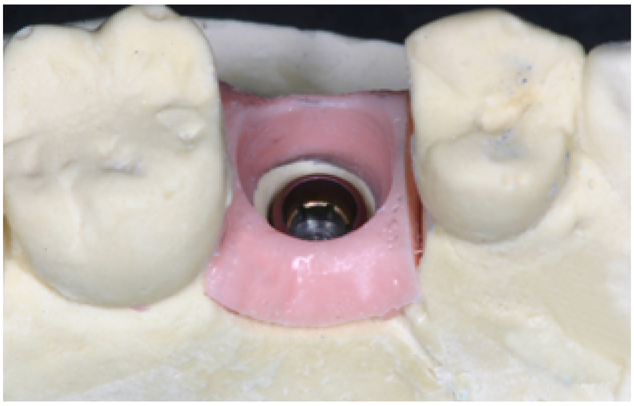


Fig. 7.32

Fig. 7.31 *Case D, initial clinical situation.*

Fig. 7.32 *The working cast. Peri-implant tissues show increased depth, and a favorable soft tissue profile has been created from the healing abutment.*

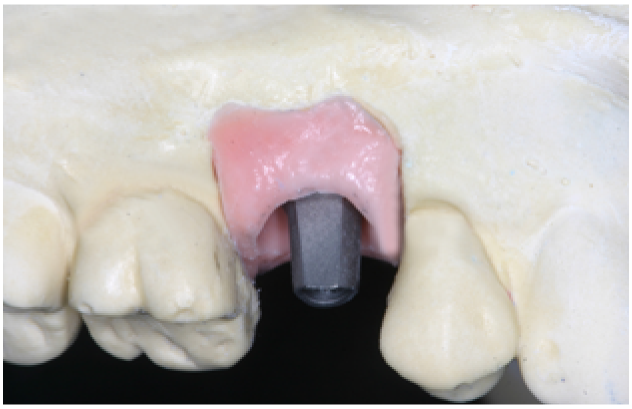


Fig. 7.33

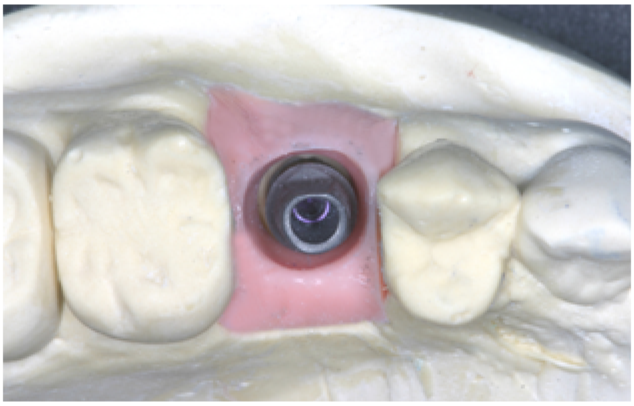


Fig. 7.34

Figs. 7.33 and 7.34 *Prefabricated titanium abutment customized to support the screw-retained crown.*

An all-ceramic crown was fabricated over the titanium abutment and tried intra-orally for proper fit and esthetic outcome (***Figs. 7.35 and 7.36***). After the final try-in, the crown was glazed and cemented with dual-polymerization cement in the dental laboratory. The excess of the cement at the marginal line was removed and the surface was polished again. The cementation can also be accomplished chairside but it is important to be done after the final glaze or the cement will be burned out. In all laboratory stages, the access hole must be kept free to allow smooth and undisturbed insertion and removal of the retention screw (***Fig. 7.37***). The cement-screw-retained crown was fixed with the recommended torque and the emergence profile of the soft tissues was supported properly by the abutment-crown complex in one piece (***Fig. 7.38***).

Fig. 7.35 Fig. 7.36

Fig. 7.35 *An all-ceramic crown was fabricated on the titanium abutment.*
Fig. 7.36 *Cementation of the crown on the titanium abutment prior to fixation in the implant.*

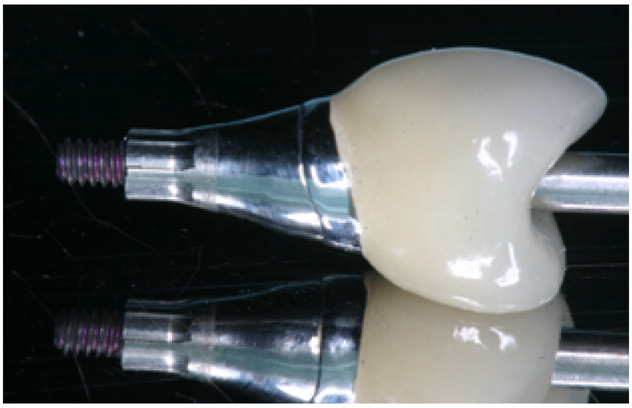


Fig. 7.37 Fig. 7.38

Fig. 7.37 *The all-ceramic crown prior to the final glazing.*
Fig. 7.38 *Case D, the final restoration.*

7.11 Fixed Dental Prosthesis on transmucosal abutments in reduced vertical space (Case E, Figs. 7.39-7.42)

In this clinical case, two internal hexagon implants (Xive Implants, Dentsply/Sirona Co.) were inserted in the regions #45 and 47 for the restoration of the mandibular right posterior area. The existing vertical prosthetic space was very limited due to over-eruption of the maxillary teeth (***Fig. 7.39***). The patient wished for a simple and cost-effective solution rejecting any treatment involving the maxillary teeth. A screw-retained restoration was planned supported by transmucosal abutments (***Figs. 7.40 and 7.41***).

These abutments (older type with conical top) were fitted in the implants by means of the hexagon on the lower part of the abutment and the restoration was fixed in the implant by a screw through the abutment. Screw retention was the only available treatment option for the reduced height, as there was not available occlusal space for a cement-retained prosthesis. For this reason, the most distal crown remained without occlusal veneering, as the needed thickness for the ceramic layer could not be achieved (***Fig. 7.42***).

Fig. 7.39 *Case E, initial clinical situation on the working cast. Reduced vertical space.*

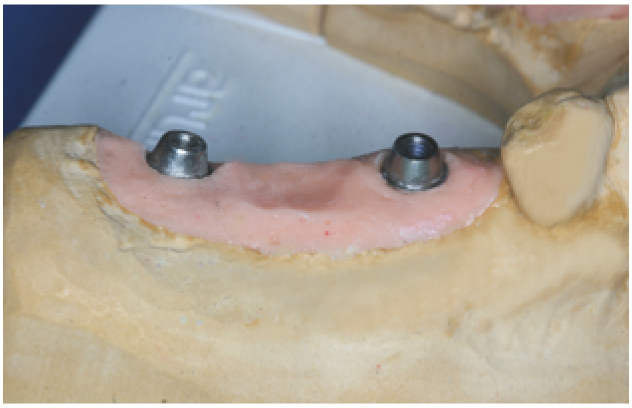


Fig. 7.40

Fig. 7.41

Figs. 7.40 and 7.41 *The transmucosal abutments on the working cast.*

Fig. 7.42 *The final restoration of the working cast. On the distal abutment there was no space for ceramic veneering on the occlusal surface.*

7.12 Fixed Dental Prosthesis on transmucosal abutments for the restoration of completely edentulous mandible (Case F, Figs. 7.43-7.52)

In this clinical case, six internal connection implants (Astra implants, Dentsply/Sirona Co.) were inserted in the completely edentulous mandible (***Fig. 7.4***3). The planned prosthetic restoration was a screw-retained Fixed Dental Prosthesis on transmucosal abutments (Astra Tech TX Uni-abutments). These abutments are available in different heights, according to the thickness of the peri-implant soft tissues. They are also available in straight and angulated form to compensate for a possible unfavorable implant inclination. The healing screws were removed, the thickness of the soft tissue was measured, and the proper abutments were selected. Long fixing screws were fitted in the implants, and their inclination was checked with the surgical guide that reproduced the contour of the planned restoration (***Figs. 7.44-7.45***). All implants were in prosthetically favorable positions and inclination except for the implant #46 that had severe labial inclination. On this implant, an angulated transmucosal abutment was used to compensate for the labial inclination and allow the access opening of the fixing screw on the occlusal surface (***Fig. 7.4***6).

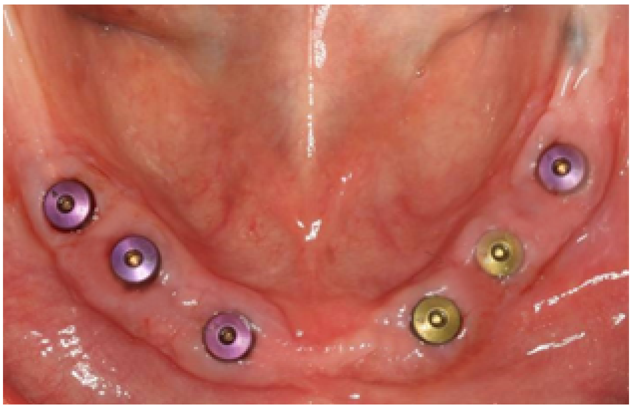


Fig. 7.43

Fig. 7.44

Fig. 7.43 *Case F (Courtesy of Dr. E. Bahlava), initial clinical situation.*

Fig. 7.44 *The surgical guide with lingual opening for the check of implant inclination.*

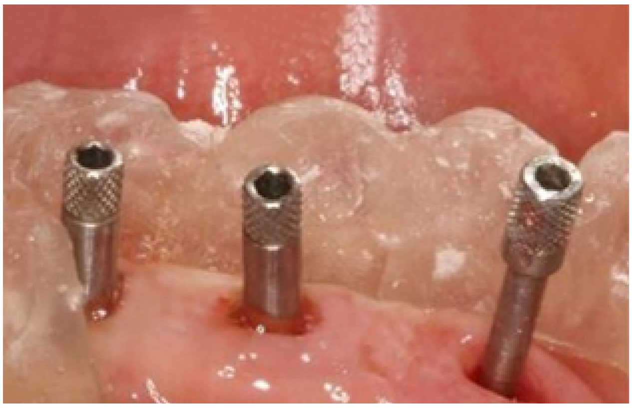


Fig. 7.45

Fig. 7.46

Fig. 7.45 *Long screws fixed in the implants of the mandibular left side: All implants are within the contour of the planned restoration.*

Fig. 7.46 *Long screws fixed in the implants of the mandibular right side: Implant #46 has labial inclination and an angulated transmucosal abutment was selected.*

The transmucosal abutments were fixed with the recommended torque, and titanium sleeves were fitted on the abutments for the fabrication of a screw-retained provisional restoration (***Figs. 7.47 and 7.48***). The provisional restoration was fabricated from autopolymerizing resin as a duplicate of the existing denture after removing the flanges (***Fig. 7.4***9). The final impression was obtained by using special impression posts and the working cast was fabricated with implant analogs similar in shape and geometry to the top of the transmucosal abutments. The final restoration was a metal-polymer screw-retained restoration, mimicking the absorbed soft and hard tissues, fixed on the abutments by special screws (***Figs. 7.50-7.52***).

Fig. 7.47

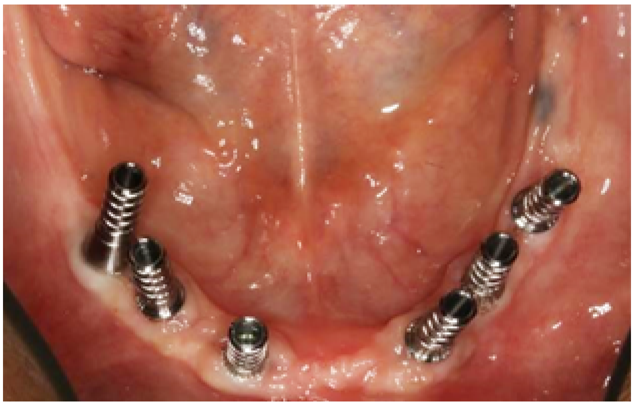


Fig. 7.48

Fig. 7.47 *The transmucosal abutments fixed on the implants.*
Fig. 7.48 *Titanium sleeves fixed on the abutments.*

Fig. 7.49

Fig. 7.50

Fig. 7.49 *A screw-retained provisional restoration fabricated as a duplicate of the existing denture.*
Fig. 7.50 *The framework for the final metal-polymer restoration.*

Fig. 7.51

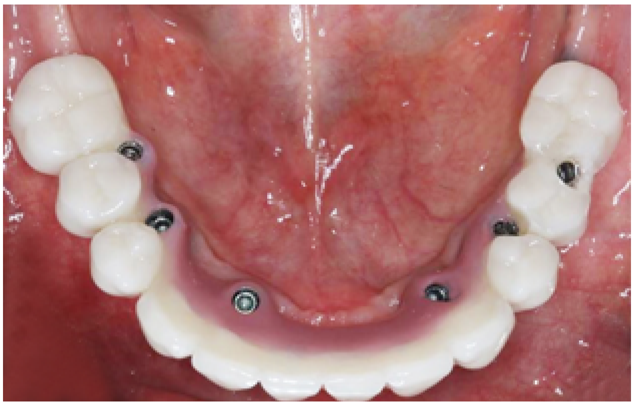


Fig. 7.52

Figs. 7.51 and 7.52 *Case F, the final metal-polymer restoration.*

7.13 Fixed Dental Prosthesis on transmucosal abutments for the restoration of completely edentulous maxilla (Case G, Figs. 7.53-7.70)

The patient of this case had been restored with four internal connection implants (Xive implants, Sirona/Densply Co., Germany) and an implant overdenture on ball attachments several years ago (***Figs. 7.53 and 7.54***). The patient had used the removable restorations but was not keeping adequate oral hygiene. As a result, at the 10-year recall hyperplasia of the peri-implant soft tissues was obvious (***Figs. 7.55 and 7.56***). Extreme wear and multiple reparations could also be observed around the female parts of the implants in the denture base. The patient wished for a fixed restoration, even with a reduced number of teeth and occlusal units. On the other side, the patient was satisfied with the shape and size of the teeth in the overdenture and the support of soft tissues, which was identical with his previously existing natural teeth (***Figs. 7.57 and 7.58***).

Fig. 7.53

Fig. 7.54

Figs. 7.53 and 7.54 *Case G, initial restoration of the patient with ball attachments and maxillary overdenture.*

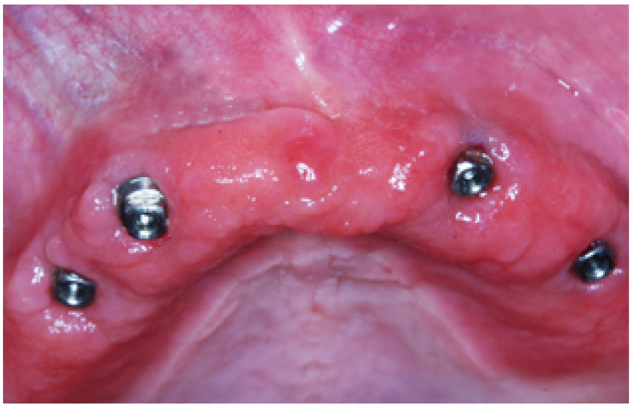


Fig. 7.55

Fig. 7.56

Fig. 7.55 *Clinical situation at the 10-year recall.*

Fig. 7.56 *Multiple repairs had been made in the overdenture.*

Fig. 7.57 **Fig. 7.58**

Fig. 7.57 *The smile of the patient with the existing overdenture.*
Fig. 7.58 *Teeth with labial inclination and diastemas in the overdenture.*

An impression was obtained on implant level and a working cast was fabricated. On the working cast a base plate was fabricated retained by screw on one implant, and it was used for registration of the interarch relation (***Fig. 7.59***). On the base plate, a diagnostic set-up was accomplished with teeth mimicking the previous removable restoration. The patient insisted on having labial inclination of the anterior teeth with diastemas as they were identical to his previously existing natural teeth (***Fig. 7.60***).

The planned restoration for this patient was a screw-retained restoration fixed on transmucosal abutments. An initial impression was obtained at implant level and a working cast was fabricated (***Fig 7.61***). On the working cast with the soft tissue mask, the transmucosal abutments were selected taking into consideration the height of soft tissues and the inclination of the implants. For the anterior implants angulated abutments were selected, and the selected abutments were tried and fixed intra-orally with the torque recommended by the manufacturer (***Fig. 7.62***).

Fig. 7.59 **Fig. 7.60**

Fig. 7.59 *Teeth set-up on a screw-retained base plate.*
Fig. 7.60 *The existing overdenture and the new set-up.*

Fig. 7.61

Fig. 7.62

Fig. 7.61 *Working cast from an impression at implant level.*

Fig. 7.62 *The transmucosal abutments fixed in the implants.*

A new impression on abutment level was obtained and a new working cast with implant analogs identical to the transmucosal abutments was poured (***Fig. 7.63***). A metal framework was fabricated using a silicone index from the set-up to allow even thickness for the veneering material (***Fig. 7.6***4). The framework was tried intra-orally for passive fit using the Shefield test. If the fit is not completely passive, it must be separated and fixed intra-orally. Besides fixing the connectors between implants with autopolymerizing resin, a metal rod was fitted connecting the most distal parts of the framework to avoid any minor distortion during transfer to the laboratory (***Fig. 7.64***). The metal framework was welded in the laboratory and tried again intra-orally.

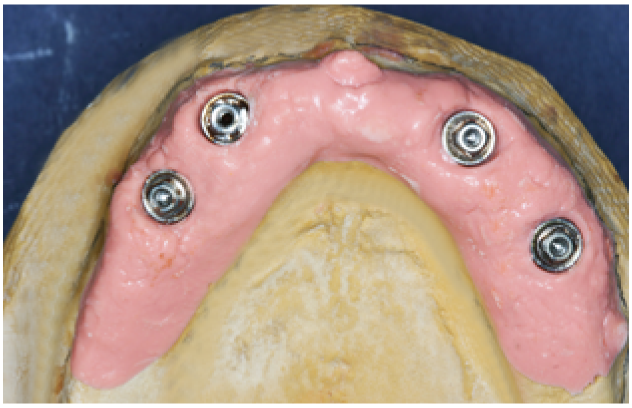


Fig. 7.63

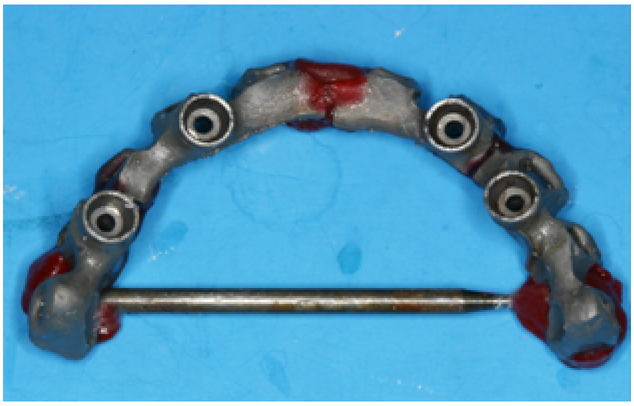


Fig. 7.64

Fig. 7.63 *Working cast from an impression at abutment level.*

Fig. 7.64 *The metal framework after intra-oral try-in.*

To ensure adequate support of the lips and soft tissues, the cervical part of the restoration was shaped as gingival tissue in pink-colored ceramic with natural-looking texture (***Figs. 7.65 and 7.66***). Adequate space was left under the basal surface of the restoration for the use of interdental brushes and proper oral hygiene. The new restoration was mimicking the previous restoration in detail but with a better esthetic outcome. The patient was satisfied with the new restoration, regarding both the shape of teeth and the soft tissue support (***Figs. 7.67-7.70***).

Fig. 7.65

Fig. 7.66

Figs. 7.65 and 7.66 *The new screw-retained restoration.*

Fig. 7.67

Fig. 7.68

Fig. 7.67 *The new metal ceramic restoration and the existing overdenture.*
Fig 7.68 *The restoration in-situ. Pink-shaded ceramic material has been added in the cervical areas.*

Fig. 7.69

Fig. 7.70

Figs. 6.69 and 6.70 *Case G, adequate support of the soft tissues from the new restoration.*

7.14 Fixed Dental Prosthesis on transmucosal abutments for the restoration of completely edentulous mandible in the short arch concept with immediate loading (Case H, Figs. 7.71-7.92)

The patient in this case was completely edentulous in the mandible and the maxilla. His main concern was the instability of the mandibular denture, and wished for a fixed restoration with the minimum cost (***Fig.*** *7.71*). The suggested plan for this patient was a fixed restoration on four implants in the interforaminal area of the mandible, following the shortened dental arch concept, due to economic reasons. If adequate initial torque could be achieved, immediate loading of the implants would be done. As the existing mandibular denture had an acceptable esthetic result, it was duplicated in translucent resin to be used as radiographic and surgical guide (***Fig.*** *7.72*).

Four dental implants were placed interforaminal with increased initial stability (>35 Ncm). The thickness of the overlying soft tissue was measured and transgingival abutments with corresponding height were fixed on the implants with the recommended torque (***Figs.*** ***7.73 and 7.74***).

Fig. 7.71

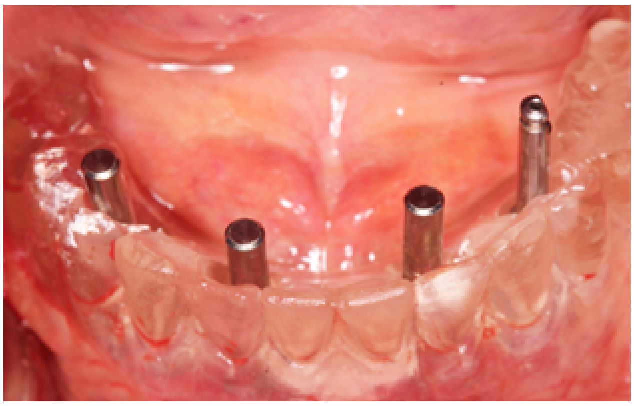


Fig. 7.72

Fig. 7.71 *Case H, initial clinical situation.*
Fig. 7.72 *Implant placement in the planned areas.*

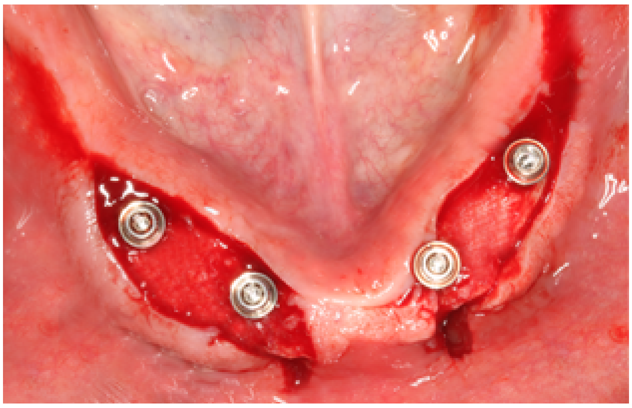


Fig. 7.73

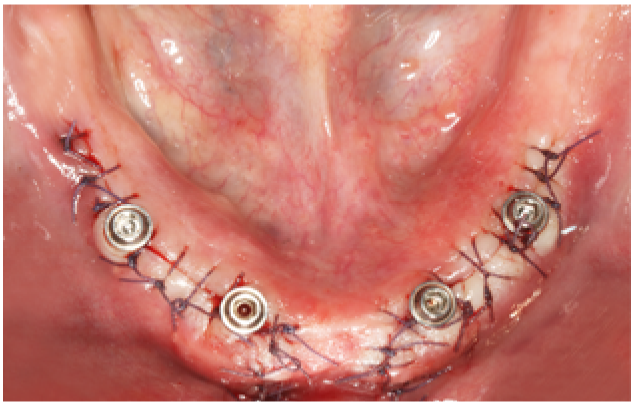


Fig. 7.74

Figs. 7.73 and 7.74 *Immediate fixation of the transmucosal abutments and suturing (Surgery Prof. P. Madianos).*

The existing denture would be transformed into a screw-retained interim restoration. Titanium cylinder with undercuts on the surface were fixed on the implants to be integrated in the denture base as provisional abutments. The denture base was drilled in the corresponding regions and was seated over the provisional abutments. A rubber dam sheet was perforated and seated over the titanium cylinders to prevent resin to leak under the abutments (***Figs.*** ***7.75 and 7.76***). Pink-colored autopolymerizing acrylic resin was used to fix the denture on the provisional abutments (***Fig. 7.77***). After complete polymerization of the resin, the denture was removed and was transformed into a screw-retained fixed restoration by removing the flanges and the occlusal surfaces of the molars, leaving one premolar bilaterally. The basal surface of the provisional restoration was also shaped accordingly to allow oral hygiene (***Fig. 7.78***). The patient was instructed to a soft diet for the next three months and followed a regular recall program to control the maintenance of oral hygiene.

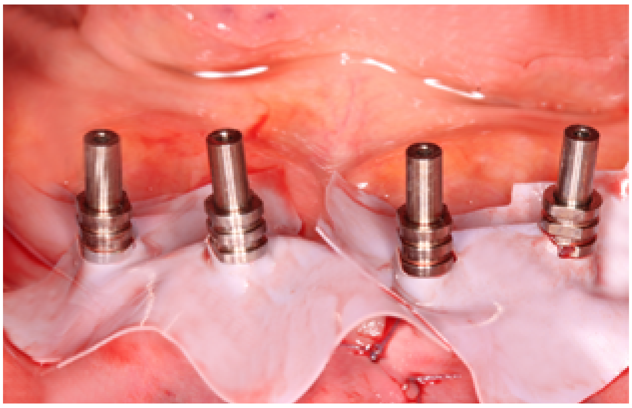


Fig. 7.75

Fig. 7.76

Fig. 7.75 *Titanium abutments for the provisional restoration.*
Fig. 7.76 *The denture fitted over the abutments.*

Fig. 7.77

Fig. 7.78

Fig. 7.77 *The provisional abutments integrated in the denture base.*
Fig 7.78 *The existing denture transformed to a screw-retained provisional restoration.*

The osseointegration of the implants was uneventful. Three months after implantation, the clinical condition was healthy and stable, and the peri-implant soft tissue had adapted to the transmucosal abutments (***Figs. 7.79 and 7.80***). The abutments were not removed, and impression was obtained on the abutment level. A working cast was fabricated with a soft tissue mask and implant analogs corresponding to the abutments (***Figs. 7.81 and 7.82***).

On the working cast a full set-up was accomplished on a base plate fixed on one implant (***Figs. 7.83 and 7.84***). The set-up was tried intra-orally to check the esthetic outcome of the restoration. In this case, a screw-retained metal-polymer restoration was planned to restore the missing teeth and the resorbed tissues. This kind of restoration offers adequate support to the peri-oral soft tissues while the size of the teeth remains independent from the resorbed alveolar crest. It also has easy retrievability, and possible corrections or repairs can be accomplished even chairside.

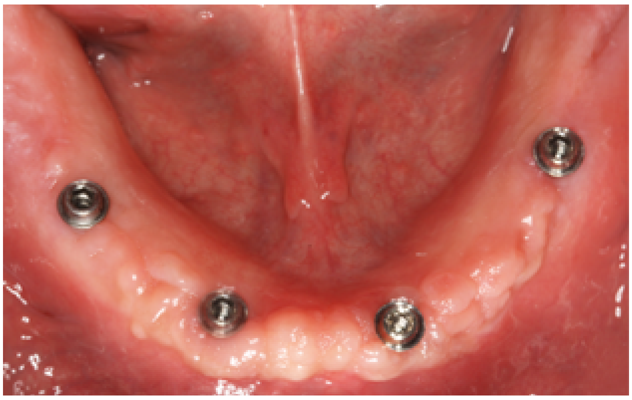


Fig. 7.79

Fig. 7.80

Fig. 7.79 *Clinical situation at the end of the osseointegration period.*
Fig. 7.80 *Impression posts for impression at implant level.*

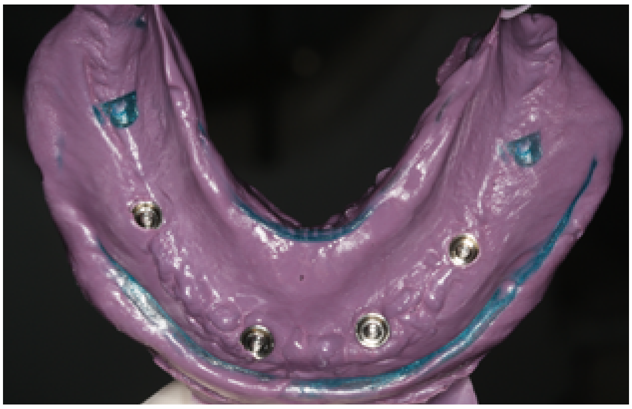


Fig. 7.81

Fig. 7.82

Fig. 7.81 *Open tray impression.*
Fig. 7.82 *Working cast with implant analogs corresponding to the abutments.*

Fig. 7.83

Fig. 7.84

Figs. 7.83 and 7.84 *Diagnostic set-up.*

The set-up was scanned in a laboratory scanner and the date was used for the CAD/CAM fabrication of the metal framework (***Figs. 7.85-7.88***). The metal framework was tried intra-orally and checked for passive fit with the single-screw test (Sheffield test). In screw-retained restorations, passive fit should be checked meticulously, as any inaccuracy may result in stress by the tightening of the fixing screws, thus resulting in mechanical complications.

The final restoration was delivered to the patient (***Figs. 7.89 and 7.90***) and the situation remained stable as it could be noted in the radiographic examination at the 5-years recall (***Figs. 7.91 and 7.92***).

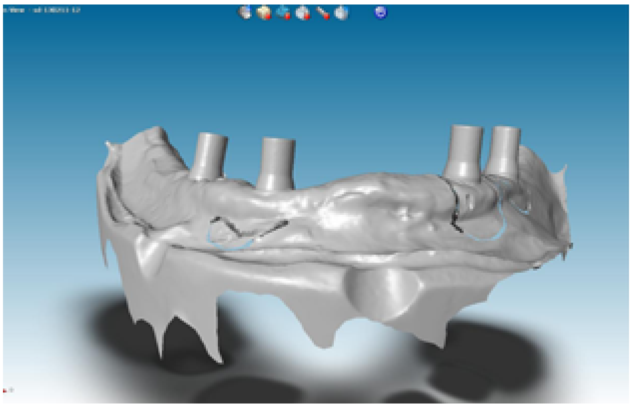


Fig. 7.85

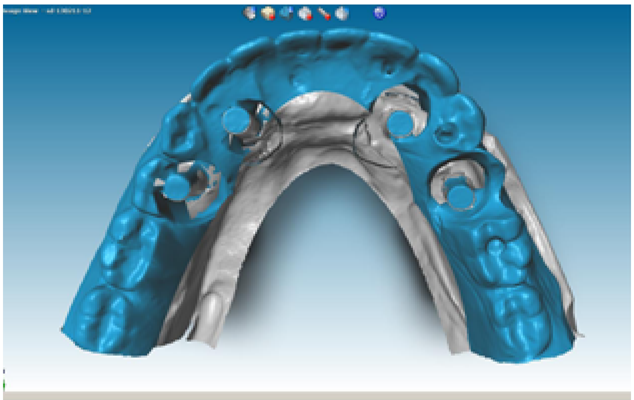


Fig. 7.86

Fig. 7.85 *Scanning of the working cast.*
Fig. 7.86 *Superimposition of the scanning and the set-up.*

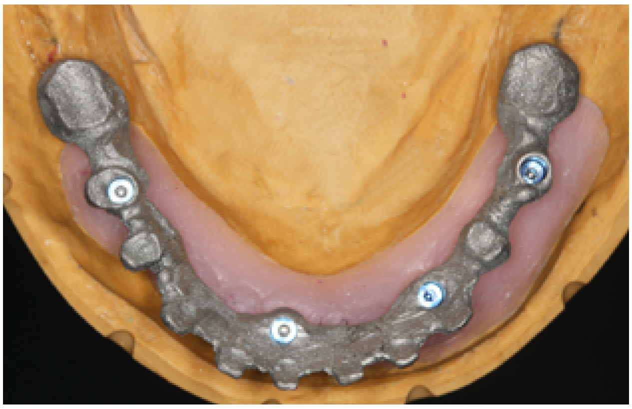


Fig. 7.87

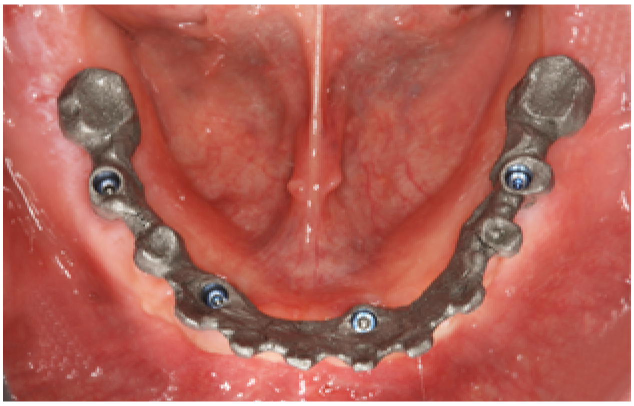


Fig. 7.88

Figs. 7.87 and 7.88 *The metal framework on the model and try-in.*

Fig. 7.89

Fig. 7.90

Figs. 7.89 and 7.90 *The final restoration.*

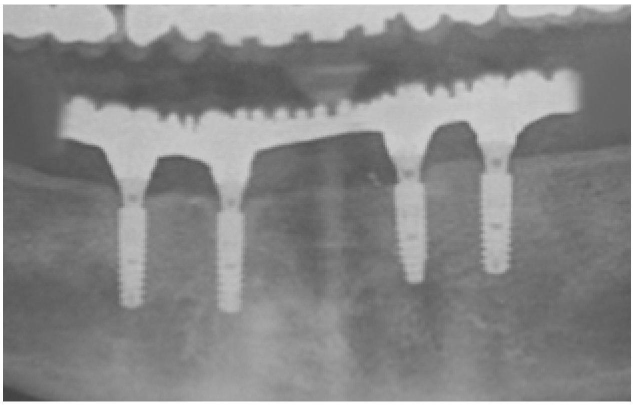


Fig. 7.91 **Fig. 7.92**

Figs. 7.91 and 7.92 *Case H, clinical and radiographic examination at the 5-year recall.*

7.15 Survival of implants in screw-retained restorations

The 5-year survival rate and the frequency of complications was examined in a systematic review based on 59 clinical studies (**Sailer et al., 2012**). The 5-year survival for cemented partial Fixed Dental Prostheses (FDPs) was similar to the rate of screw-retained partial FDPs reaching 98%. For cemented full-arch FDPs, the 5-year survival was 100%, which was somewhat higher than that for screw-retained FDPs, which reached as high as 95.8%. As the authors concluded, both types of reconstructions influenced the clinical outcomes in different ways, and none of the fixation methods was clearly advantageous over the other. Cemented restorations showed more serious biological complications (implant loss, bone loss >2 mm), while screw-retained reconstructions exhibited mainly technical problems. Screw-retained prostheses are more easily retrievable than cemented reconstructions; therefore, technical and eventually biological complications can be treated more easily.

Immediate loading for implants in the mandibular interforaminal area has been introduced since decades. The main prerequisite for a successful clinical outcome is the increased primary stability of the implants (**Tettamanti et al., 2017; Chen et al., 2019**).

Implant failures for fixed restoration with immediate loading in the mandible have been shown comparable to the standard late loading protocol (**Esposito et al., 2013; Papaspyridakos et al., 2014; Kern et al., 2016**). It must be underlined, however, that this treatment options should be limited to patients complying with a regime of soft diet and regular recall system, as immediate loading in general (including maxillary and mandibular implants both in anterior and posterior areas) has been associated with increased failure rate compared to late loading (**Chen et al., 2019**).

7.16 Clinical performance of screw-retained restorations

The clinical performance of screw- and cement-retained restorations was examined in an extended systematic review based on 73 publications (**Wittneben et al., 2014**). The authors reported 5-year survival rates of 96.03% and 95.55% for cemented and screw-retained reconstructions respectively. Comparison of cement and screw retention showed no difference when grouped as Single Crowns or Fixed Dental Prostheses. The 5-year survival rate for screw-retained full-arch reconstructions was 96.71%. Although no statistical difference was found between cement- and screw-retained reconstructions for survival or failure rates, screw-retained reconstructions exhibited fewer technical and biological complications overall. There were no statistically significant differences between the failure rates of the different reconstruction types or abutment materials (titanium, gold, ceramic).

7.17 Complications in screw-retained restorations

7.17.1 Frequency of complications

In a recent systematic review based on 29 papers (**Gaddale et al., 2020**), cement-retained reconstructions exhibited more biological complications (implant loss, bone loss >2mm) and screw-retained prostheses exhibited more technical problems. The clinical outcomes were influenced by both fixations in different ways. The screw-retained restorations were more easily retrievable than cemented; therefore, technical and eventually biological complications could be treated more easily. For this reason, and for their higher biological compatibility, these reconstructions are preferable.

Similar findings were also reported to a previous extended systematic review based on 59 publications (**Sailer et al., 2012**). The estimated 5-year cumulative incidence of technical complications at cemented single crowns was 11.9% and 24.4% at screw-retained crowns. At the partial and full-arch FDPs, in contrast, a trend to less complication at the screw-retained was found than at the cemented ones (partial FDPs cemented 24.5%, screw-retained 22.1%; full-arch FDPs cemented 62.9%, screw-retained 54.1%). Biological complications like marginal bone loss >2mm occurred more frequently at cemented crowns (5-year incidence: 2.8%) than at screw-retained ones (5-year incidence: 0%). The authors concluded that both types of reconstructions influenced the clinical outcomes in different ways, but none of the fixation methods was clearly advantageous over the other. Cemented reconstructions exhibited more serious biological complications (implant loss, bone loss >2mm), screw-retained reconstructions exhibited more technical problems.

The influence of the type of restoration on the prosthetic complications was also investigated in a systematic review based on 73 papers (**Millen et al., 2015**). Screw-retained prostheses showed—a tendency toward and—significantly more technical complications than cemented prostheses with single crowns and fixed partial prostheses respectively. Resin and ceramic veneer chipping had high mean event rates, at 10.04% and 8.95% per 10 years respectively for full-arch screwed prostheses. For "all fixed prostheses" (prosthesis type not reported or not known), significantly fewer biological and technical complications were seen with screw retention. Multivariate analysis revealed a significantly greater incidence of technical complications with cemented prostheses. Full-arch prostheses, cantilevered prostheses, and "all fixed prostheses" had significantly higher complication rates than single crowns. A significantly greater incidence of technical and biological complications was reported with cemented prostheses.

Screw-retained fixed partial prostheses demonstrated a significantly higher rate of technical complications and screw-retained full-arch prostheses demonstrated a notably high rate of veneer chipping. When "all fixed prostheses" were considered, technical and biological complications were seen for cement-retained prostheses. Multivariate Poisson regression analysis failed to show a significant difference between screw- and cement-retained prostheses with respect to the incidence of failure but demonstrated a higher rate of technical and biological complications for cement-retained prostheses. The incidence of technical complications was more dependent upon prosthesis and retention type than prosthesis or abutment material.

7.17.2 Screw loosening

The most common prosthetic complication in screw-retained restorations is the loosening of the fixing screw. The incidence of screw loosening was 65% for single-tooth implant restorations in one classical but older study (**Jemt et al., 1992**), whereas the incidence of unretained cemented implant restorations was reported to be less than 5% in other studies (**Sinfer and Serfaty, 1996; Misch, 1995**). However, the improvements in the implant systems, including the advent of internal implant-abutment connections, the enhancement of torque drivers, screw materials and design, led to a reduction in the incidence of screw loosening. The incidence of screw loosening was more frequent in the older types of external hex-implants that used titanium and gold screws with slot-head screws. Nowadays, in the majority of the implant systems, hex-heads screws are used, which allow higher torque without damage to the head.

On the other hand, the screw loosening of screw-retained restorations can be considered an important advantage since the weakest component within the implant-supported restoration will be the prosthetic screw; this will allow for assessing the implant-supported restoration before more serious complications develop, such as screw fracture especially in implant systems using internal connections. Using screw-retained restorations will enable assessing the preload of implant abutment screws over time, since the preload is not constant with ongoing application of forces associated with occlusion (**Shadid and Sadaqa, 2012**).

The gingival response is found to be better when using screw-retained crowns since no cement is used. However, if the retaining screws become loose, granulation tissue may probably accumulate between the prosthesis and the abutment or at the implant-abutment interface leading to fistulae formation, plaque deposition, and possibly screw fracture. Therefore, it is recommended to retighten the screws in full arch fixed prosthesis every 5 years. (**Kallus and Bessing, 1994**).

In a clinical trial with a follow-up of 3.5 years the prevalence of screw loosening was significantly lower for cement-retained FDPs when a temporary cement (10%) was used compared to screw-retained FDPs (29%). The survival rate of the reconstructions within the observation period was 97% for screw-retained FDPs and 100% for cement-retained FDPs without significant difference (**Korsch and Walther, 2015**).

The influence of the implant-abutment connection on the frequency of screw loosening was investigated in a systematic review based on 60 papers (**Pjeturson et al., 2018**). Meta-analysis of these studies indicated an estimated 5-year survival rate of 97.6% for Single Crowns, 97.0% for FDPs supported by implants with internal implant-abutment connection, 95.7% for Single Crowns and 95.8% for FDPs supported by implants with external connection. The 5-year abutment failure rate ranged from 0.7% to 2.8% for different connections with no differences between the types of connections. The total number of complications was similar between the two connections; yet, at external connections, abutment or occlusal screw loosening was more predominant.

7.17.3 Marginal Bone Loss

The findings concerning marginal bone loss around dental implants with screw- and cement-retained restorations are controversial. In a retrospective clinical trial with a follow-up in 15 years, the mean marginal bone loss was statistically significantly higher for screw-retained (1.4±0.6mm) than for cemented (0.69±0.5 mm) restorations (**Nissan et al., 2011**). These results were also confirmed by another similar clinical study (**Lemos et al., 2016**).

On the other side, screw-retained restorations showed reduced marginal bone loss compared to cemented in clinical trials (**Koller et al., 2016**). In a systematic review, screw-retained restorations also showed better results in marginal bone loss compared to cemented (**Sailer et al., 2012**).

In an extended systematic review based on 9 clinical studies comparing marginal bone loss on screw- and cement-retained restorations, no difference was found between the two types (**Brandau, 2013**). These results were also confirmed by another systematic review focusing on the same clinical topic (**Sherif et al., 2014**).

7.18 Clinical relevance

Screw-retained restorations have been used for decades in dental implants with high survival rates and reduced frequency of complications. Their main advantage is the predictable retrievability that allows easy professional cleaning and the possibility for modification or repair. However, difficulties may arise through their use regarding the esthetic results in the anterior region due to implant inclination. The type of the prosthetic restoration should be selected individually for each case based on the specific criteria of each case and the demands of the patients.

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CHAPTER 8

Completely Digital Workflow for Implant Restorations

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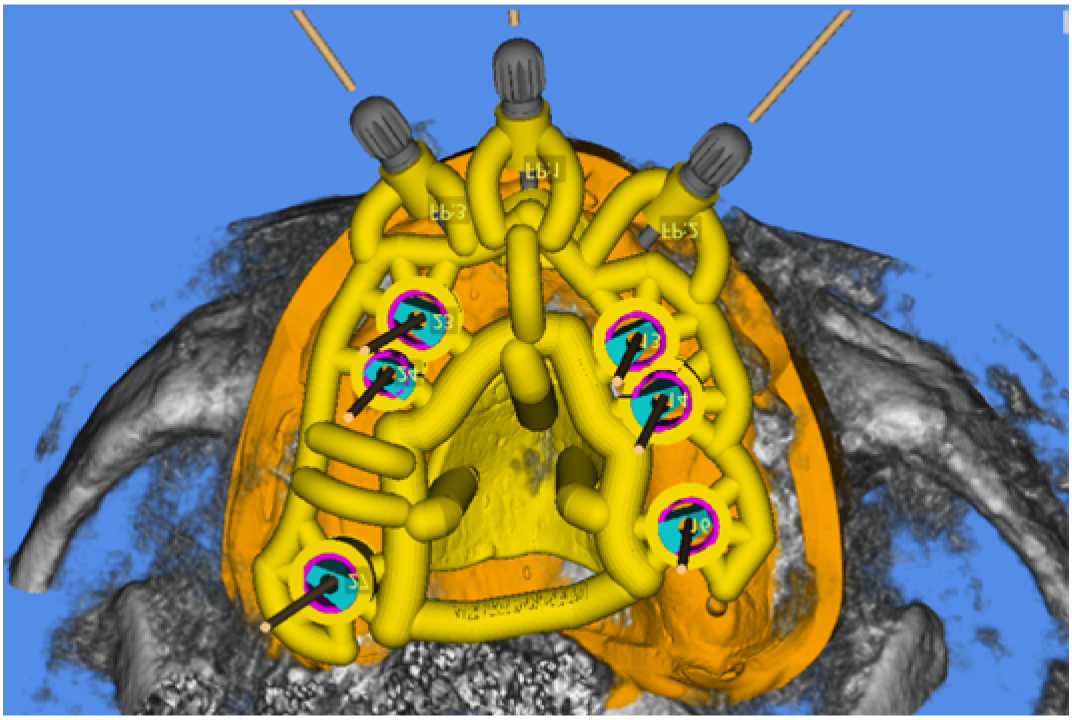
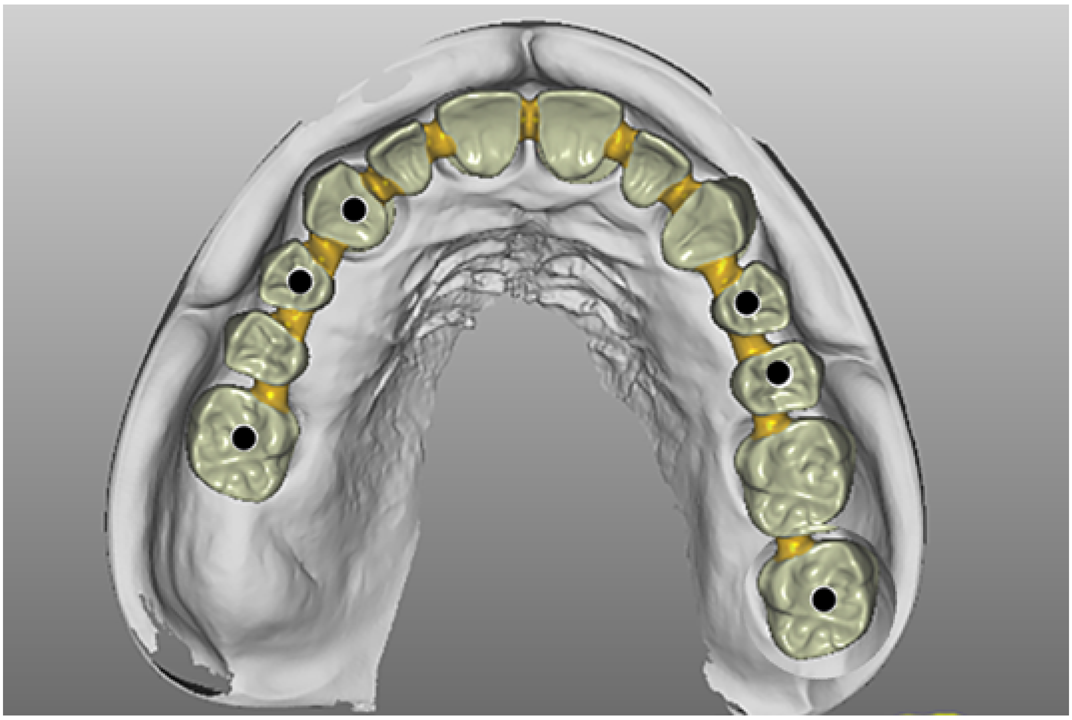




Abstract

Digital technology has been introduced in the clinical practice for implant restorations and becomes increasingly popular among clinicians. The advantages of digital technology in Implantology include accurate presurgical planning, possibility for guided implant placement and even the fabrication of interim restorations prior to surgery by CAD/CAM technique. However, even if devices and software are improving constantly, there may always be deviations from the initial planning. The clinician must be aware of the possibilities that current technology may offer but they should also be able to recognize and correct any inaccuracies during the whole surgical and prosthetic procedure.

Knowledge background

To understand the content of this Chapter, the reader should have read extensively the previous Chapters of this book.

8.1 Introduction

Digital workflow in dentistry is becoming increasingly popular nowadays and is supported mainly from the available software; namely, the Cone Beam Computed Tomography (CBCT), the intraoral scanning and the CAD/CAM technology (**Fasbinder, 2010; van der Meer, 2012**). The evolution of digital technology offers advantages such as accurate presurgical diagnosis, precision and safety during implant placement through guided surgery, shorter surgical time, flapless surgery, prefabrication of interim or provisional restorations, easy documentation and archiving of the data from each patient and finally a predictable result.

In the restorative procedure, the initial digital impressions and the virtual (digital) wax-up can be used for the fabrication of the provisional restoration, while the implants can be placed in prosthetically favorable positions and inclinations. The CAD/CAM technology is the sequence of the first digital steps in each restoration and the impression-free and model-free fabrication of a prosthesis can be an option (**Hämmerle, 2009; Christensen, 2009; Miyazaki and Hotta, 2011**).

The evolution of the digital workflow has been promoted by new techniques and materials as for example the Poly-ether-ketone (PEEK) and the 3D printing. The fabrication of prostheses in the dental laboratory has been simplified by the CAD/CAM technique and the spectrum of clinical options has been increased.

8.2 Aim

The aim of this chapter is to present the digital workflow in implant restorations through selected clinical cases.

8.3 Prosthetically driven Implant Dentistry

Prosthetically driven implant dentistry is the optimal way to treat patients with dental implants (**Zitzmann and Marinello, 1999**). It requires detailed pretreatment planning to ensure a correct three-dimensional (3D) implant position within the alveolar bone, relative to the planned prosthetic restoration (**Belser et al., 2007**). A 3-D model or digital file of the alveolar bone can be generated using either Computer Tomography (CT Dental Scan) or Cone Beam Computed Tomography (CBCT). CBCT offers significant reduction of the radiation dose and detailed imaging of the bone substrate (**Worthington et al., 2010; Behneke et al., 2012**). In addition, scanning technology, either by intra-oral or laboratory scanning, creates a further 3D digital model of the patients' oral condition, which can be superimposed on the radiographic data set to create realistic 3D images of the bone and clinical conditions (**Tahmaseb et al., 2018**).

Computer-aided methods realize the 3D visualization of the implant recipient site including the neighboring anatomical structures. Prior to any invasive treatment, the clinician has the opportunity to gain insights into the patient's individual situation considering prosthetic and surgical requirements. Complex and invasive treatment steps can be anticipated in advance for a predictable and safe outcome (**Orentlicher and Abboud, 2011; Pozzi et al., 2016; Joda et al., 2018**).

The advancement of digital technology allows new treatment options. Nowadays, accurate presurgical planning and guided implant surgery are possible using complete digital workflow. The digital files from the intra-oral scanning and a visual prosthetic set-up in STL format (Standard Tesselation Language) can be superimposed onto the DICOM files (Digital Imaging and Communication in Medicine) from the CBCT and depict the planned implants and restoration to the bone substrate without the formerly used radiographic templates (**Flügge et al., 2017**). This development approximates the interfaces of surgical and prosthetic treatment steps, from the virtual planning, plotted implant guides, to the CAD/CAM-based design, including production of the final prosthetic reconstruction (**Joda and Buser, 2013**).

8.4 Basic steps for the Complete Digital Workflow

The basic steps for a digital workflow in implant restorations prior to surgery are:

- Intra-oral scanning of both arches or digitalization of study casts by a laboratory scanner and transformation into STL format.
- Virtual wax-up of the missing teeth on the digital models using various types of teeth available in the digital library of the software. If a conventional wax-up has been done on mounted study casts, it can also be digitalized by a laboratory scanner.
- Cone Beam Computed Tomography of the patient and import of the DICOM files in the software.
- Superimposition of the digital files from the CBCT, the scanned arch and the wax-up.
- Initial selection of implants from the library and virtual placement in the planned position and inclination.
- Correction of implant axis, diameter or length.
- Final selection of implants in the selected positions, dimensions and inclinations.
- Design of a surgical guide with titanium sleeves for guided implant placement.
- Selection of the transmucosal or temporary abutments (in case of a planned immediate loading).
- Export of the designed surgical guide with the position of the sleeves to a 3D printing device.
- Fabrication of the surgical guide and integration of the titanium sleeves.
- Fabrication of the provisional restoration in case immediate loading is planned. If the loading of implants is planned upon uncoverage, the fabrication of the provisional restoration can be done at a later stage.
- Try-in of the surgical guide to the patient.
- Guided surgical procedure.

The basic steps for the digital workflow after the osseointegration period are:

- Intra-oral scanning of the arch with scanbodies, either on implant or abutment level.
- Scanning of the opposing arch.
- Scanning of the provisional restoration, if it fulfills the patient's esthetic and functional demands.
- Scanning of the peri-implant soft tissues in cases of impression at implant level to reproduce the desired emergence profile.
- Export of the files to the CAD/CAM software for the design of the definite restoration.
- Design of customized abutments, if needed.
- Design and fabrication of the final restoration.

8.5 Presurgical Digital Planning

The first publications for complete digital workflow in implant restorations were focused on the fabrication of single all-ceramic crowns (**Patel, 2010; Joda and Brägger, 2014**). Initially, the CAD/CAM fabrication of implant-supported ceramic restorations from a digital impression was the main innovation (**Takaba et al., 2013; Brand et al., 2015**). The possibility of combining the digital files from an intra-oral scanning and the DICOM files by superimposition expanded the complete digital workflow, especially if the guided surgery protocol is followed. The whole procedure can also be accomplished without intra-oral scanning as the study casts and the wax-up can be digitalized by a laboratory scanner.

In the presurgical planning the implants can be inserted virtually, checking the bone substrate in all three dimensions. There is several software available and most major implant manufacturers recommend their own program. Most of the existing software is also compatible with various implant systems that are available in their digital libraries. There is also the possibility to correlate the implant position and inclination with the soft tissue thickness and the contour of the planned restoration, as depicted from the wax-up or the set-up. As with everything in clinical Dentistry, there is a learning curve, and the clinician should familiarize with the software before integrating it to clinical cases.

The final outcome of the digital planning is the fabrication of a surgical guide with titanium sleeves indicating the positions and inclinations of the implants. The guide is fabricated from special resin by 3D printing and the sleeves are attached to the predetermined positions. For the surgical drillings special drilling kits are available from the implant manufacturers, and the head of each drill is designed to fit accurately in the metal sleeve. The drill has also a stopping end that prevents drilling deeper than initially planned. The guide is supported and fixed on the existing teeth and its fit should be checked prior to surgery. In edentulous patients, the guide should be fixed in the bone by special fixing screws in other regions than the planned implantations.

The surgical procedure can be accomplished either flapless by removing a small circular part of the covering mucosa or through a minimal flap. In case of thin bone plate or if an augmentation is planned, a mucoperiosteal flap is preferred to allow better control of the drilling and implant insertion.

8.6 Guided Implant Surgery

Guided Implant Surgery has been introduced several years ago but it has been widely accepted from the clinicians after its combination with accurate presurgical planning by superimposition of the DICOM files onto the clinical digital images. The variety of available 3D printing devices has also enhanced the introduction to clinical practice. In the early days of guided surgery, the surgical guides had to be fabricated in special centers, at a great distance from the clinician. Nowadays, this technology can be adapted and accomplished within a dental office.

There are two available options for guided surgery: the fully guided and the partially guided technique. In fully guided surgery, all drillings and the final insertion of the implant are performed through the sleeve of the surgical guide. In partially guided technique, the pilot and/or the first drillings are made through the sleeve but the final positioning of the implants is carried out by visual inspection without the guide. Fully guided surgery has been found more accurate compared to the partially guided (**Bover-Ramos et al., 2018**). The first publications on guided surgery were encouraging but at that time much time and effort should be invested to reach an acceptable outcome (**Sarment et al., 2003; Di Giakomo et al., 2005; Fortin et al., 2009; Schmeider et al., 2009**).

The evolution of technology, including both software and devices, has also increased the accuracy of guided surgery and has simplified its adoption in the clinical practice. The advantages of guided surgery include reduced surgical time, reduced pain, discomfort and swelling for the patient if a flapless procedure is followed, and a predictable surgical result if the presurgical planning has been accomplished accurately (**Jung et al., 2009; Marchack and Chew, 2015; Tahmaseb, 2014**). On the other side, meticulous presurgical planning is mandatory including digitalization of the clinical situation, the set-up and the DICOM files. Increased time must be invested prior to surgery and the final cost is also increased, as a surgical guide must be fabricated by 3D printing.

Computer-Aided Implant Surgery (CAIS) involves either a guided pilot drilling approach or a fully guided protocol for the entire drilling sequence regularly including implant placement through the surgical guide. The indications range from single implants to completely edentulous patients for mono- or bimaxillary treatment. The surgical implant guides can be classified according to their functional design, as tooth retained, mucosa- or bone-supported or a combination type (**Joda et al., 2018**). In addition, the surgical placement can be performed completely flapless with a soft tissue punches, or open flap varying from small crestal incisions up to the preparation of a full thickness mucoperiosteal flap with complete exposure of the alveolar bone (**Laleman et al., 2016**).

8.7 Posterior single implant (Case A, Figs. 8.1-8.16)

This patient had the first left mandibular molar (#36) missing, and the extraction was performed several months ago (***Fig. 8.1***). For this patient a guided implant placement was planned. A full arch intra-oral scanning was performed for the maxilla and the mandible (***Fig. 8.2***), and the files were exported as STL files. The STL files were superimposed onto the DICOM files of the Cone Beam Computed Tomography (CBCT). The surgical planning was accomplished virtually, using the MSoft software (MIS Implants Technologies, MIS Co, Israel) after a virtual diagnostic wax-up, using the digital library of the software (***Figs. 8.3 and 8.4***). Accurate measurements of the bone substrate can be made using the various measuring tools of the software, and the position of the guiding metal sleeve in the surgical guide can be defined precisely. The software also allows a very precise planning taking into consideration the type of the abutment that is planned for use (***Figs. 8.5 and 8.6***). In this case, an internal connection implant was selected.

Fig. 8.1

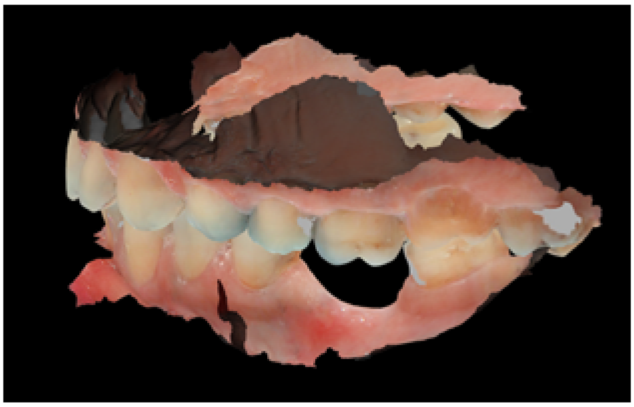


Fig. 8.2

Fig. 8.1 *Case A, initial clinical situation (Dr. P. Lampropoulos).*

Fig. 8.2 *Intra-oral scanning of maxillary and mandibular arch.*

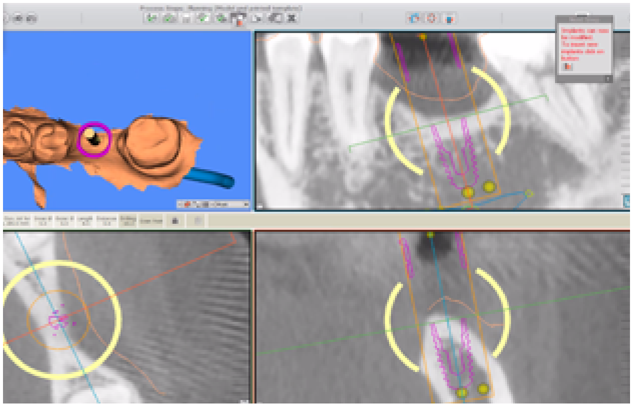


Fig. 8.3

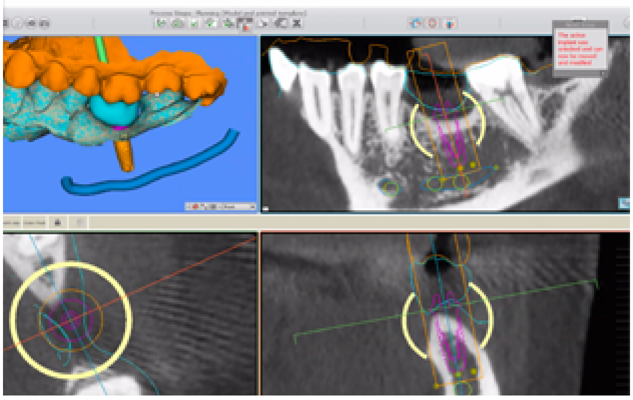


Fig. 8.4

Fig. 8.3 *Digital planning, initial virtual positioning of the implant.*

Fig. 8.4 *Virtual positioning of the implant with the virtual wax-up.*

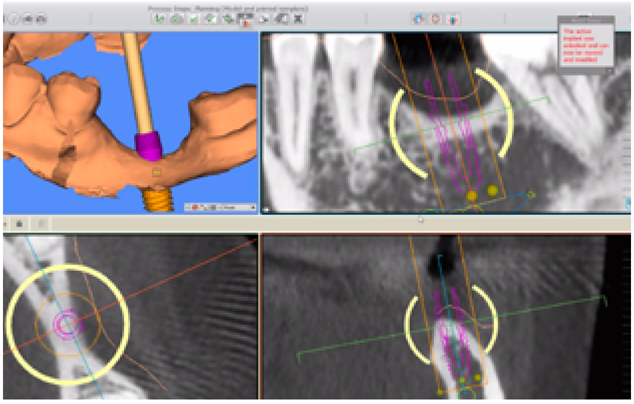


Fig. 8.5

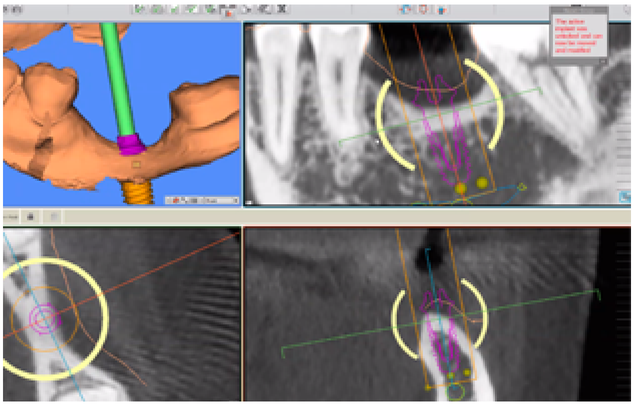


Fig. 8.6

Fig. 8.5 *Digital planning with a Ti-base abutment.*

Fig. 8.6 *Digital planning with a transmucosal (multi) abutment.*

A model was fabricated from the files of the software by means of 3D printing and a surgical guide for the edentulous area (***Figs. 8.7 and 8.8***). The surgical guide was fixed and supported by the adjacent natural teeth (***Figs. 8.9 and 8.10***). The drillings were performed through the metal sleeve of the surgical guide using the surgical drills for this purpose (***Figs. 8.11 and 8.12***). Following strictly the protocol of guided implant placement, the whole surgical procedure can be accomplished flapless, through a circular incision on the mucosa. In this case, however, reduced bone width was noted by the presurgical evaluation and the CBCT. For this reason, a minimal flap was elevated, without vertical incisions, to allow better control of the thickness of the labial bone plate (***Figs. 8.13 and 8.14***). The initial stability was not adequate for immediate loading and the implant was left for closed healing.

Fig. 8.7

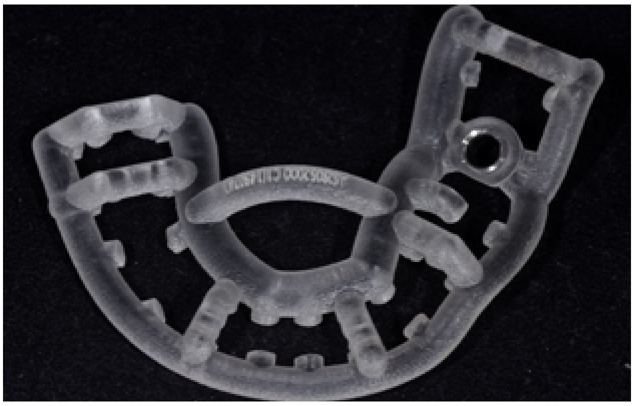


Fig. 8.8

Fig. 8.7 *Study cast fabricated by 3D printing.*

Fig. 8.8: *The surgical guide fabricated by 3D printing.*

Fig. 8.9

Fig. 8.10

Fig. 8.9 *The surgical guide on the study cast.*
Fig 8.10 *The surgical guide intraorally.*

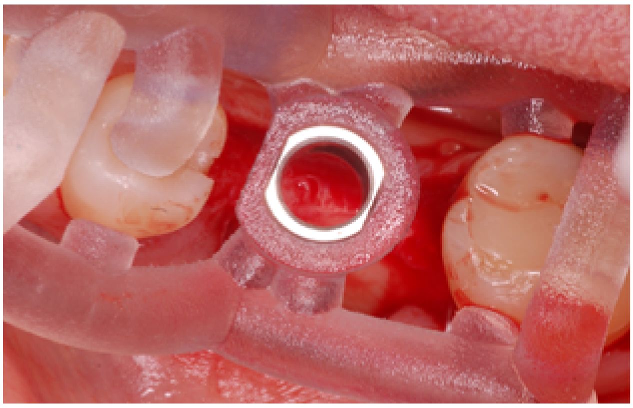


Fig. 8.11

Fig. 8.12

Fig. 8.11 *A minimal flap was raised allowing the fit of the guide.*
Fig. 8.12 *The drillings were made through the metal sleeve.*

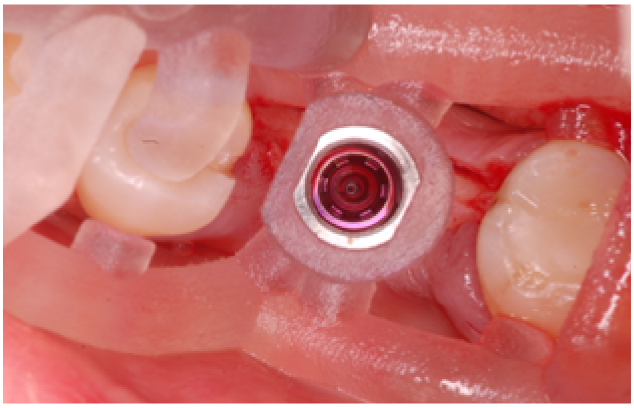


Fig. 8.13

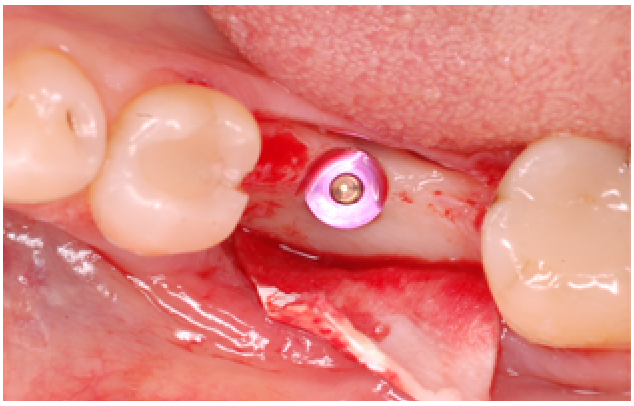


Fig. 8.14

Figs. 8.13 and 8.14 *The implant in position.*

The osseointegration of the implant was uneventful. At the end of the 3-month period, the implant was uncovered using minimal invasive technique, as the surgical guide allowed precise location and inclination of the implant.

A scanbody corresponding to the implant was fixed and a new intra-oral scanning was performed. The files were sent to the dental laboratory for the fabrication of the restoration. The patient was restored with a cement-retained all-ceramic monolithic zirconia crown with CAD/CAM as the fabrication technique and it was fixed on a Ti-base abutment (***Figs. 8.15 and 8.16***).

Fig. 8.15

Fig. 8.16

Figs. 8.15 and 8.16 *Case A, the final restoration.*

8.8 Posterior unilateral mandibular implants (Case B, Figs. 8.17-8.34)

The patient in this case was missing the mandibular molars and the second premolar on the left side. The treatment plan was a screw-retained Fixed Dental Prosthesis (FDP) on two implants in the regions #35 and 37. The first premolar and canine on this quadrant were prepared and had crowns with inadequate fit that would be replaced (***Figs. 8.17 and 8.18***).

Fig. 8.17

Fig. 8.18

Figs. 8.17 and 8.18 *Case B, initial clinical situation (Dr. P. Lampropoulos).*

Fig. 8.19

Fig. 8.20

Figs. 8.19 and 8.20 *initial intra-oral scanning.*

Both arches were scanned (***Figs. 8.19 and 8.20***) and the STL files were superimposed onto the DICOM files from the CBCT. In the initial planning, the axes of the implants were defined taking into consideration the mental foramen and the inclination of the adjacent teeth (***Fig. 8.21***). Implants with proper diameter and length were selected from the digital library and were virtually positioned (***Fig. 8.22***). The position of the sleeves for the surgical guide was finalized and the whole planning was correlated to the virtual wax-up of the restorations for teeth and implants (***Figs. 8.23-8.26***).

A surgical guide was fabricated based on the digital planning and was fixed on the adjacent teeth (***Fig. 8.27***). A minimal flap was elevated to allow precise control of the labial bone plate (***Fig. 8.28***), and the implants were inserted to the planned positions and inclinations.

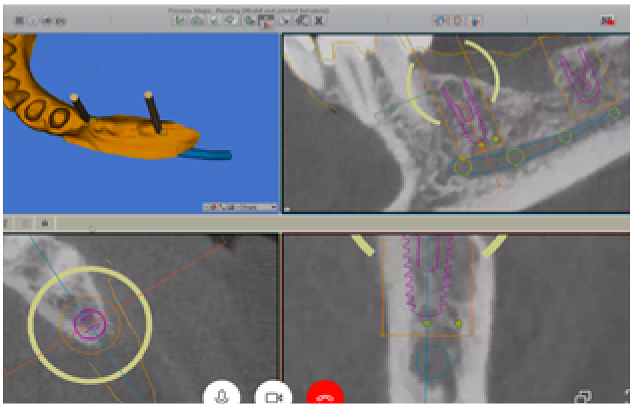


Fig. 8.21

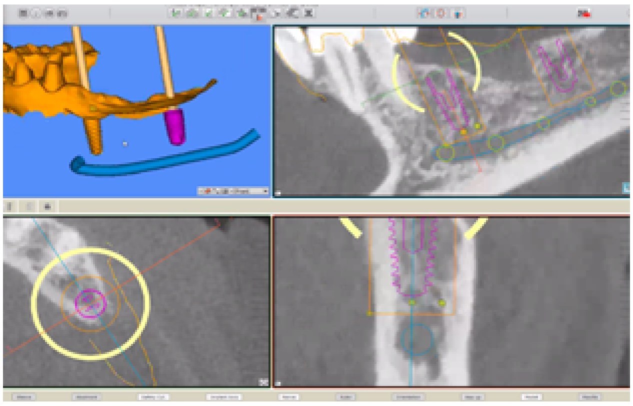
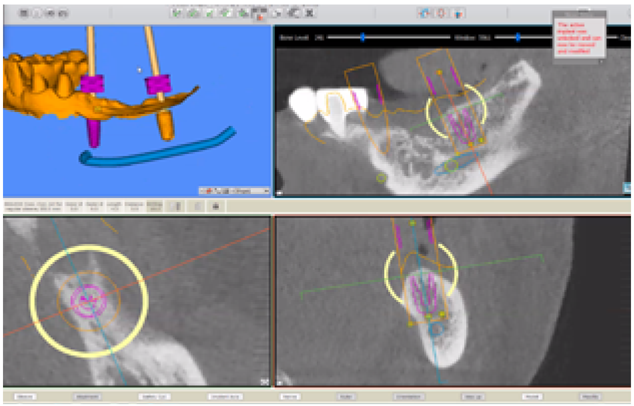


Fig. 8.22

Fig. 8.21 *Initial definition of the implant axis.*

Fig. 8.22 *Digital positioning of the implants in the defined diameter and length.*



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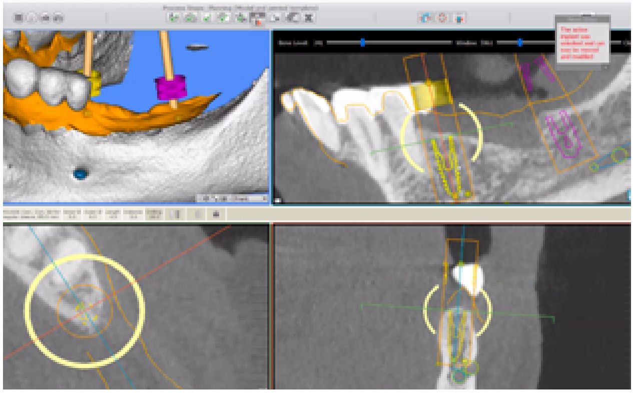


Fig. 8.24

Figs. 8.23 and 8.24 *Positioning of the guiding sleeves with and without the digital wax-up of the restoration.*

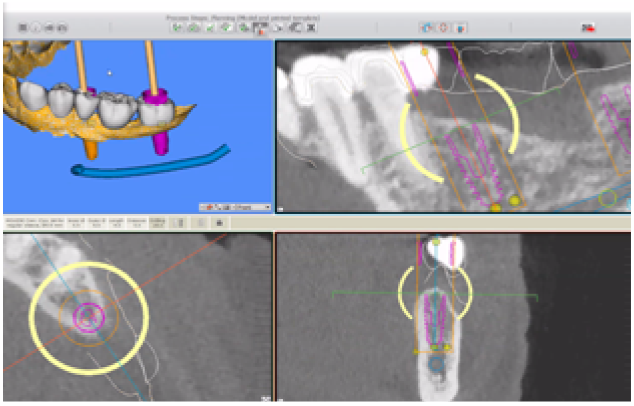


Fig. 8.25

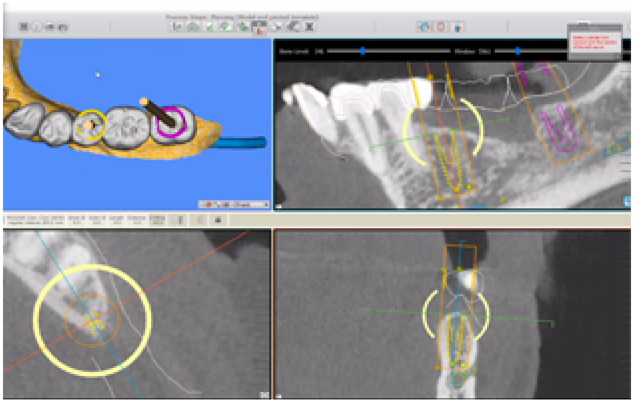


Fig. 8.26

Figs. 8.25 and 8.26 *Final positioning of the guiding sleeves.*

Fig. 8.27

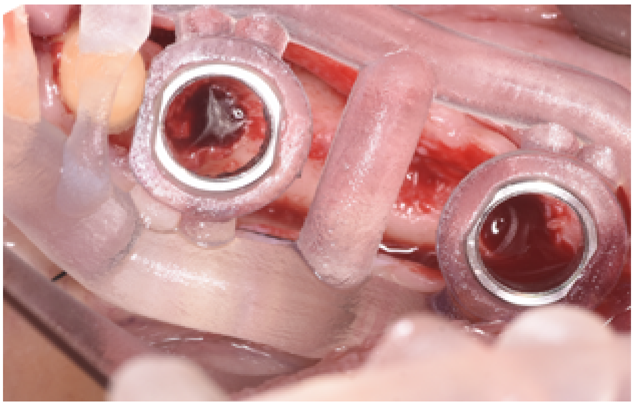


Fig. 8.28

Figs. 8.27 and 8.28 *The surgical guide fitted on the adjacent teeth and drillings through the guide.*

The osseointegration period was uneventful and upon implant uncoverage transmucosal abutments were fixed on the implants (***Fig. 8.29***). Scanbodies were fixed on the abutments and a digital impression was obtained on abutment level (***Figs. 8.30 and 8.31***).

A metal framework was fabricated by CAD/CAM on the digital model (***Fig. 8.32***) and was tried intra-orally. The final restoration was a metal-ceramic screw-retained FDP on the two implants (***Figs. 8.33 and 8.34***).

Fig. 8.29 **Fig. 8.30**

Fig. 8.29 *Insertion of transmucosal abutments.*

Fig. 8.30 *Digital impression with scanbodies on abutment level.*

Fig. 8.31 **Fig. 8.32**

Fig. 8.31 *The digital model with the abutments.*

Fig. 8.32 *The metal framework.*

Fig. 8.33 **Fig. 8.34**

Figs. 8.33 and 8.34 *Case B, the final restoration.*

8.9 Completely edentulous mandible (Case C, Figs. 8.35-8.56)

The patient of this case was missing all the mandibular posterior teeth and the canines (***Figs 8.35-8.38***). The remaining incisors had poor prognosis and were to be extracted. The maxillary teeth of these patients had restorations that were protruding from the occlusal level but the patient denied any treatment on the maxillary teeth. His intense wish was an immediate rehabilitation of the mandible with a fixed restoration.

Fig. 8.35

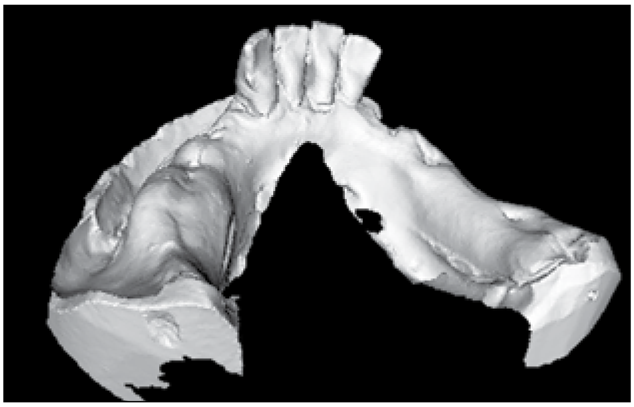


Fig. 8.36

Fig. 8.35 *Case C, initial clinical situation (Dr. P. Lampropoulos).*
Fig. 8.36 *Initial intra-oral scan of the mandible.*

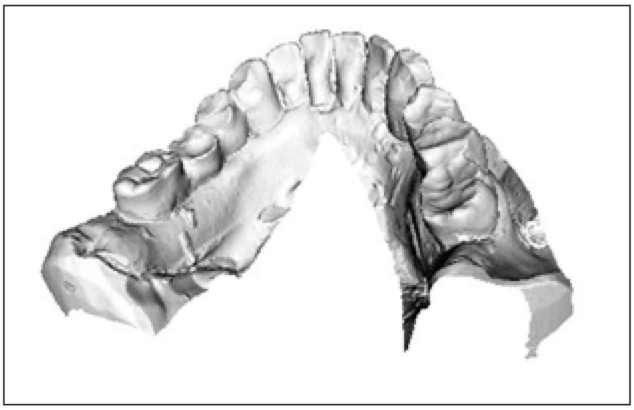
Fig. 8.37

Fig. 8.38

Figs. 8.37 and 8.38 *Initial clinical situation, side views.*

Upon the initial examination, a first intra-oral scan was obtained from the patient (***Fig. 8.36***) along with initial impressions. Stone models were fabricated from the initial impressions, and a set-up of the missing teeth was accomplished. In this case, the conventional set-up was preferred to the digital technique, as the occlusal surfaces of the mandibular teeth should be adapted to the irregular occlusal level defined by the maxillary teeth.

The treatment plan for this patient was a fixed implant-supported mandibular restoration. The remaining anterior mandibular teeth would be kept until the implant surgery to facilitate the support and fit of the surgical guide. The set-up of the mandibular teeth was scanned by a laboratory scanner and was opposed to the digital model of the maxilla (***Fig. 8.39***). The files from the scanning and the DICOM files from the CBCT were imported to the software program for the digital presurgical planning. The axes of the implants were at first defined and correlated to the existing bone substrate and to the planned contour of the restorations, as it was depicted by the set-up (***Fig. 8.40***). The implant diameter and length were selected, and the positions of the final sleeves were finalized (***Figs. 8.41 and 8.42***).



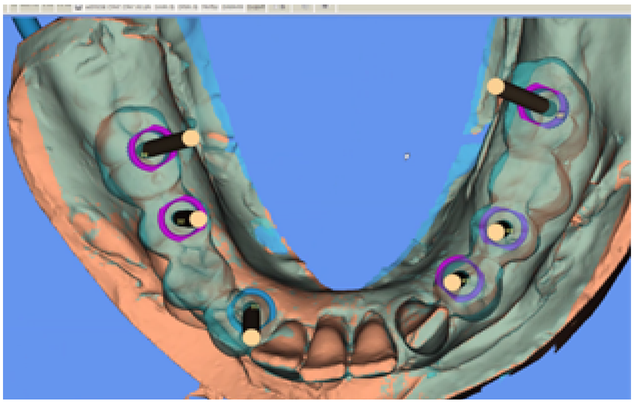
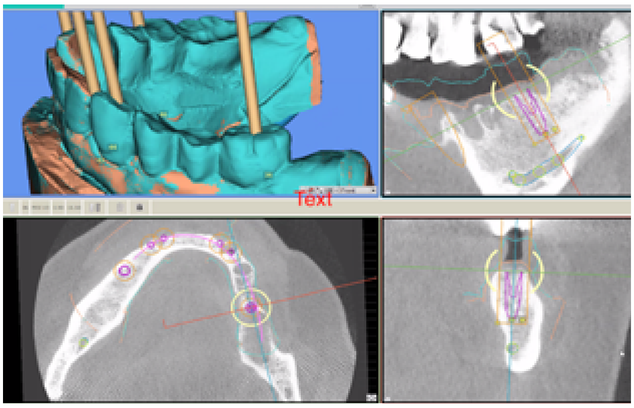


Fig. 8.39 **Fig. 8.40**

Fig. 8.39 *Scanned set-up of the mandible.*
Fig. 8.40 *The axes of the implants are defined related to the set-up.*



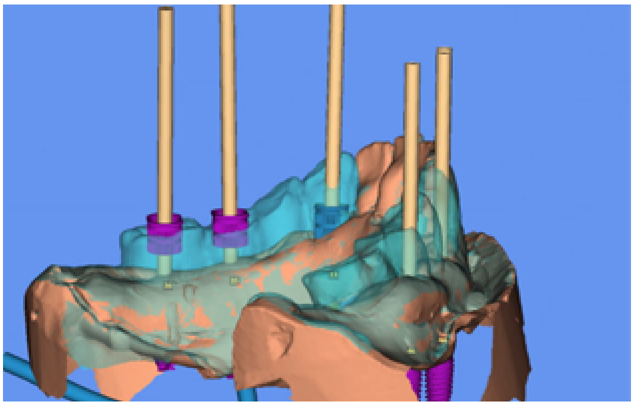
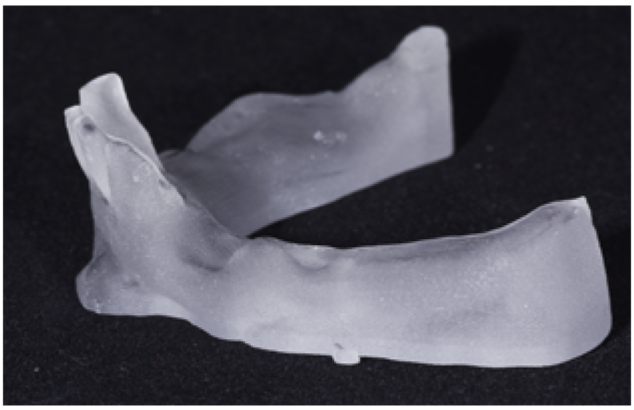


Fig. 8.41 **Fig. 8.42**

Figs. 8.41 and 8.42 *Digital positioning of the implants and the guiding sleeves.*

A plastic model and a surgical guide were fabricated using 3D printing with the titanium sleeves corresponding to the implant diameter (***Figs. 8.43 and 8.44***). The surgical guide was tried intra-orally for proper fit and retention (***Figs. 8.45 and 8.46***). As the patient wished for immediate rehabilitation, immediate loading of the implants might be possible, if the implants had the needed primary stability. For this reason, a provisional restoration was fabricated using CAD/CAM milling from a PMMA block, according to the digital planning of the implants (***Figs. 8.47 and 8.48***). The provisional restoration would be seated over titanium sleeves on transmucosal abutments.



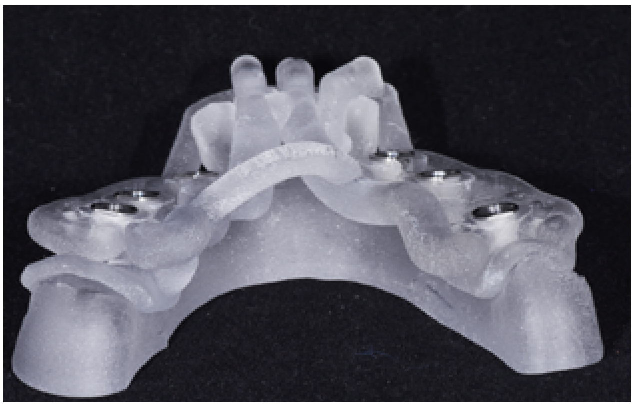


Fig. 8.43 **Fig. 8.44**

Fig. 8.43 *3D printed model of the mandible.* **Fig. 8.44** *The surgical guide on the printed model.*

Fig. 8.45 Fig. 8.46

Figs. 8.45 and 8.46 *The surgical guide with the guiding sleeves and intra-oral try-in.*

Fig. 8.47 Fig. 8.48

Figs. 8.47 and 8.48 *A provisional restoration fabricated using the CAD/CAM technique, according to the presurgical digital plan.*

The posterior implants were inserted flapless through the surgical guide. The remaining incisors facilitated the positioning and stability of the surgical guide. A minimal flap was raised in the premolar region on the left side because the labial bone plate was thin, as shown during the presurgical digital planning. All implants had increased initial stability, except the implant in region #34, where a minor labial augmentation was needed and it was decided to be left for closed healing. The incisors were extracted after implant placement.

The transmucosal abutments were fitted on the rest five implants and tightened to the torque as it is recommended by the manufacturer (***Fig. 8.49***). Titanium copings were fitted on the abutments and the prefabricated provisional restoration was seated over the sleeves (***Fig. 8.50***). The titanium copings were integrated in the provisional restoration by adding autopolymerizing resin around them. In this way, passive fit of the provisional restoration could be achieved. The provisional restoration was removed, trimmed, polished, and checked for even occlusal contacts (***Figs. 8.51 and 8.52***). The patient was instructed to meticulous oral hygiene and a soft diet for the next three months. The interdental spaces around the implants in the restoration were widened to allow the use of interdental brushes.

Fig. 8.49 | **Fig. 8.50**

Fig. 8.49 *The transmucosal abutments fixed on the implants with adequate initial stability and suturing.*
Fig. 8.50 *Titanium copings fitted on the abutments and the provisional restoration seated over the copings.*

Fig. 8.51 | **Fig. 8.52**

Figs. 8.51 and 8.52 *The provisional restoration with integrated copings.*

The osseointegration period was uneventful and the transmucosal abutment on implant #34 was fixed upon implant uncoverage (***Figs. 8.53 and 8.54***). The patient was restored with a metal-polymer screw-retained Fixed Dental Prosthesis with mimicking of the missing soft tissues (***Fig. 8.55***). The implants and the restoration were in a healthy and stable condition as was noted in the 1-year recall (***Fig. 8.56***).

Fig. 8.53 | **Fig. 8.53**

Fig. 8.53 *Clinical situation at the end of osseointegration period.*
Fig 8.54 *The transmucosal abutments before the final impression.*

Fig. 8.55

Fig. 8.56

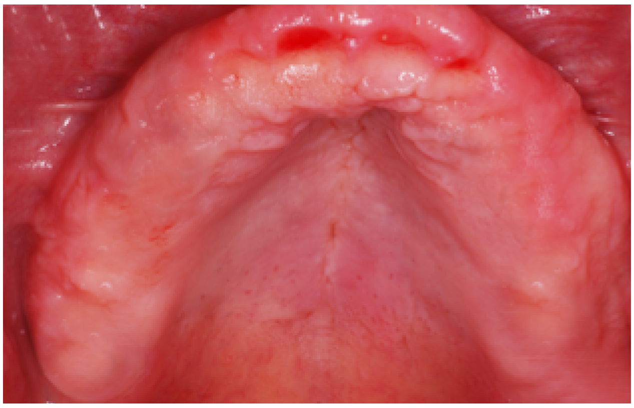
Fig. 8.55 *The final restoration.*

Fig. 8.56 *Case C, radiographic examination at the 1-year recall.*

8.10 Completely edentulous maxilla (Case D, Figs. 8.57-8.88)

The patient of this case was completely edentulous in the maxilla (***Figs. 8.57 and 8.58***). He was wearing a complete denture for a short period and was not satisfied with the functional result. The patient wished for a fixed restoration—if possible—immediately. The bone substrate appeared adequate for the placement of six implants, as shown in the initial radiographic examination and the CBCT (***Fig. 8.58***).

A study cast was fabricated, and both the cast and the existing denture were scanned in a laboratory scanner (***Figs. 8.59 and 8.6***0). As the esthetic outcome of the denture was accepted by the patient, the existing denture was used as a set-up for the fabrication of the surgical guide. On the denture base, three circular openings were created to serve as reference points for the later superimposition.



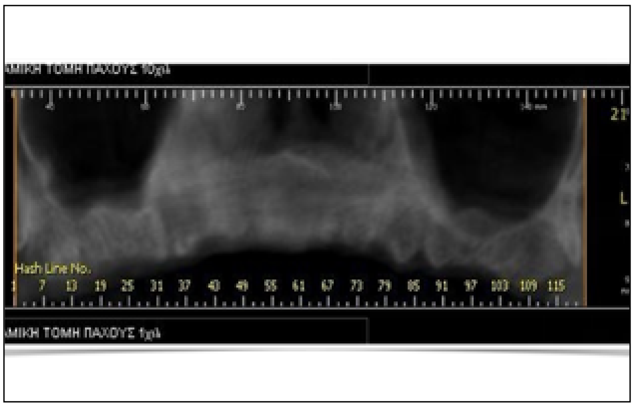


Fig. 8.57

Fig. 8.58

Figs. 8.57 and 8.58 *Case D, initial clinical situation and radiographic examination (Dr. P. Lampropoulos).*

Fig. 8.59

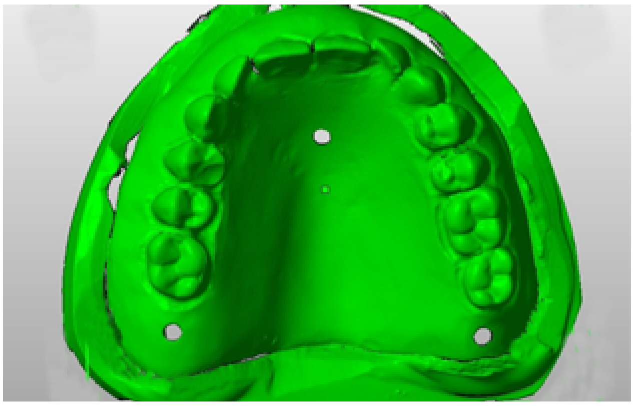


Fig. 8.60

Figs. 8.59 and 8.60 *Scanning of the existing denture for the digital planning.*

The digital files from the laboratory scanning were exported and superimposed onto the DICOM files from the CBCT in the planning software. The planning for the placement of six implants in the maxilla was accomplished digitally. As the patient was edentulous, the surgical guide would be bone-supported and fixed on the alveolar crest by special pins in areas between the planned implant positions (***Figs. 8.61-8.64***).

The files from the digital planning were used for the fabrication of a surgical guide with metal sleeves for guided surgery and pins for fixation in the bone (***Figs. 8.65 and 8.66***). As the patient wished for an immediate fixed restoration, the data from the digital planning were also used for the fabrication of a provisional restoration from PMMA by milling in a CAD/CAM device (***Figs. 8.67 and 8.68***). The provisional prosthesis would be used, if adequate initial stability of all six implants could be achieved. The restoration was designed as screw-retained polymer restoration fitted on transmucosal abutments and titanium copings (sleeves) integrated intra-orally with autopolymerizing resin.

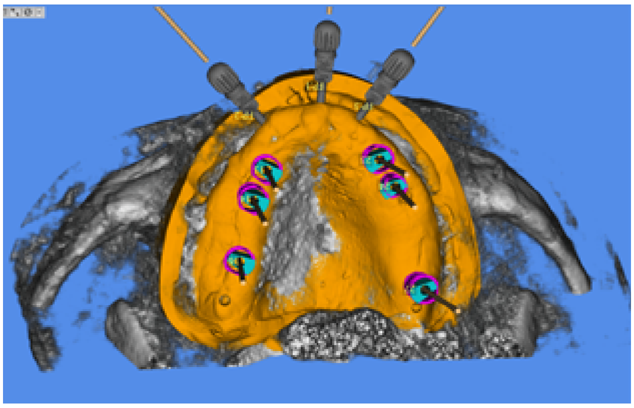


Fig. 8.61

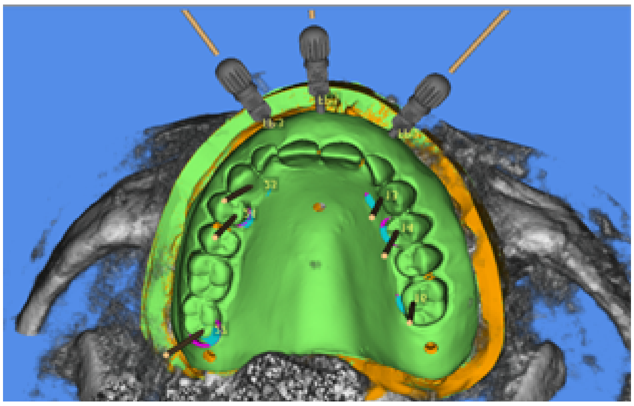


Fig. 8.62

Fig. 8.61 *Digital planning, initial positioning of the implants.*
Fig. 8.62 *The implants correlated to the positions of the teeth in the denture.*

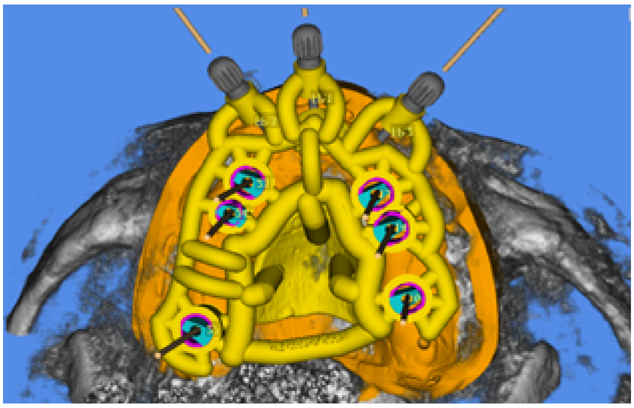


Fig. 8.63

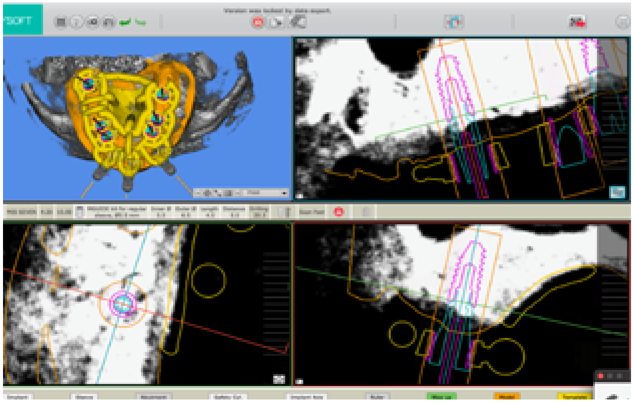


Fig. 8.64

Figs. 8.63 and 8.64 *Design of the surgical guide and correlation to the bone substrate.*

Fig. 8.65

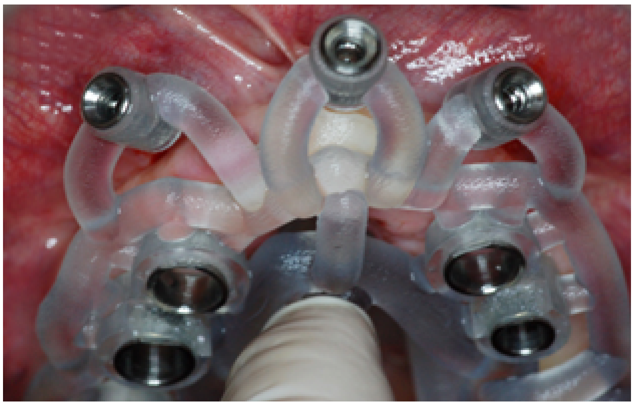


Fig. 8.66

Figs. 8.65 and 8.66 *The surgical guide on the cast and tried intra-orally.*

Fig. 8.67

Fig. 8.68

Figs. 8.67 and 8.68 *Provisional restoration fabricated using the CAD/CAM technique according to the presurgical digital planning.*

For the surgical procedure the guide was stabilized in the bone by the fixation screws on the anterior area and the whole surgical procedure was accomplished flapless though circular incisions made through the openings of the sleeves using a tissue punch (***Figs. 8.69 and 8.70***). Six internal connection implants were inserted in the regions #16, 14, 13, 23, 24 and 27. The initial stability of the implants was adequate, and immediate loading with the prefabricated provisional restoration was decided. Following the final torque of the implants, the thickness of the peri-implant tissue was measured and transmucosal abutments were tried and fitted with the torque, as recommended by the manufacturer (***Figs. 8.71-8.74***). In some implants, the use of angulated abutments was necessary due to their inclination.

Titanium copings were fixed on the transmucosal abutments, and the provisional restoration was fitted over the sleeves. In some parts, minor adjustments were necessary to pass the restoration over the sleeves. The gaps were filled with autopolymerizing resin, and the sleeves were integrated in the restoration. The provisional prosthesis was polished and checked for even occlusal contacts in maximal intercuspation and side movements. The patient was instructed to a soft diet, meticulous oral hygiene, and a strict recall program for the osseointegration period (***Figs. 8.75-8.78***). In the anterior edentulous area, selective pressure was applied by the pontics, to enhance the creation of an esthetic contour of the soft tissue for the final restoration.

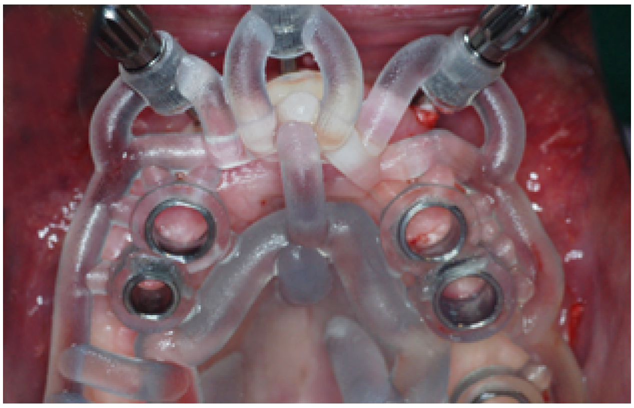


Fig. 8.69

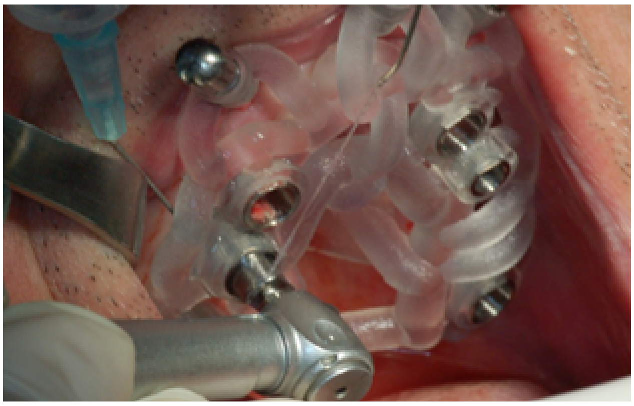


Fig. 8.70

Fig. 8.69 *Fixation of the guide to the bone by anchor pins.*

Fig. 8.70 *Drilling and insertion of the implants through the sleeves of the guide.*

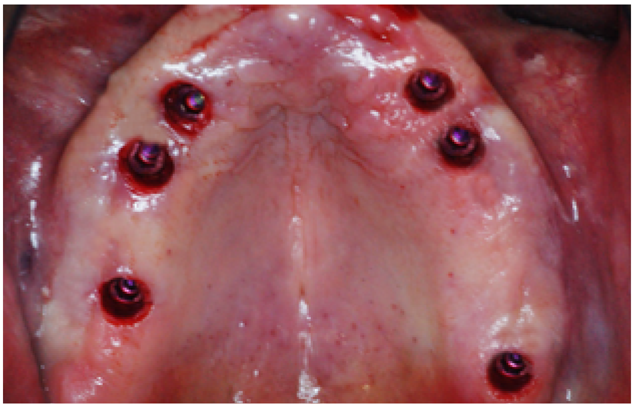


Fig. 8.71

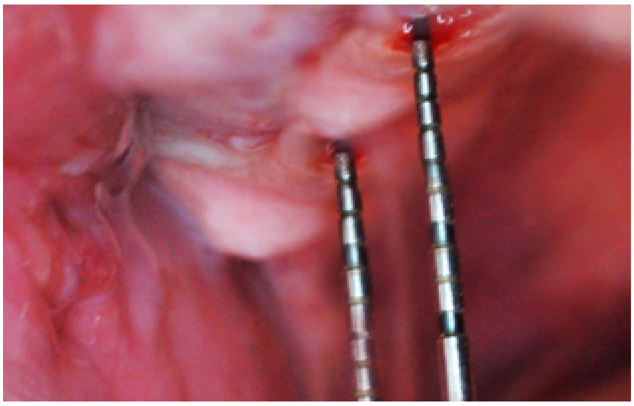


Fig. 8.72

Fig. 8.71 *Flapless insertion of the implants.*

Fig. 8.72 *Measurement of the thickness of peri-implant soft tissues.*

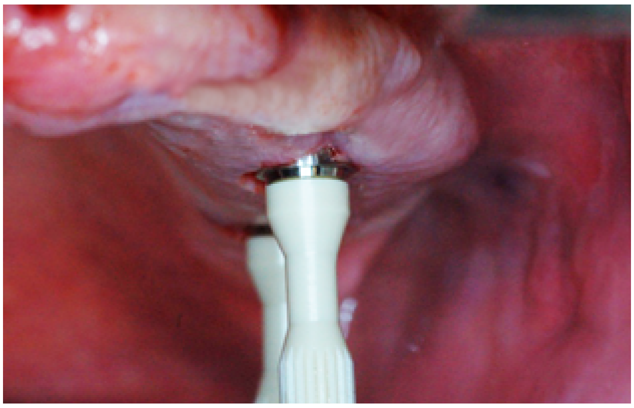


Fig. 8.73

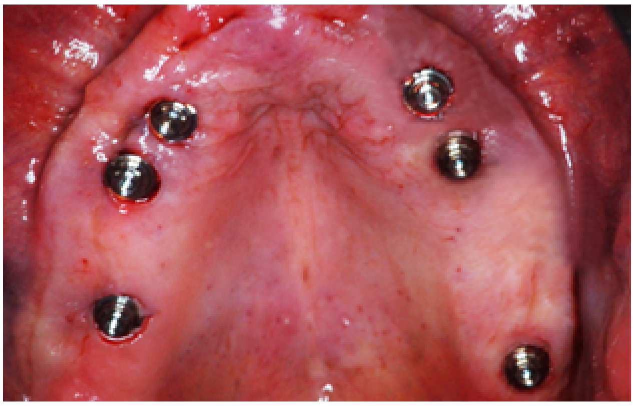


Fig. 8.74

Fig. 8.73 *Fixing of the transmucosal abutments.*
Fig. 8.74 *The transmucosal abutments fitted on the implants.*

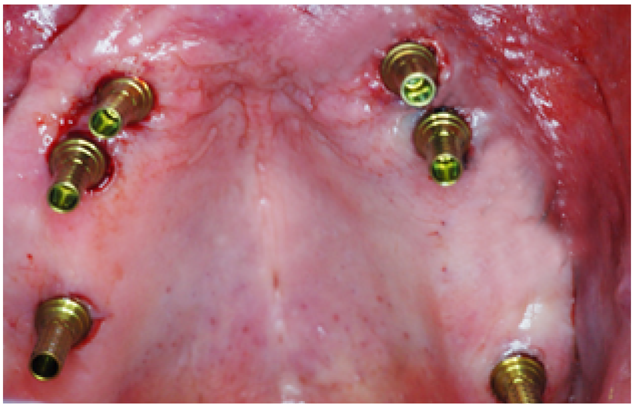


Fig. 8.75

Fig. 8.76

Fig. 8.75 *Titanium copings fitted on the transmucosal abutments.*
Fig. 8.76 *The provisional restoration over the titanium copings.*

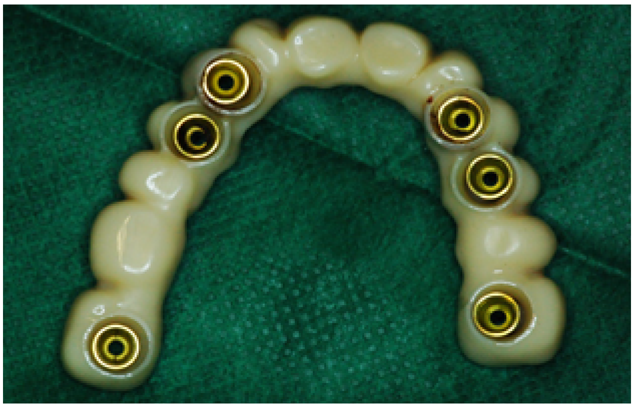


Fig. 8.77

Fig. 8.78

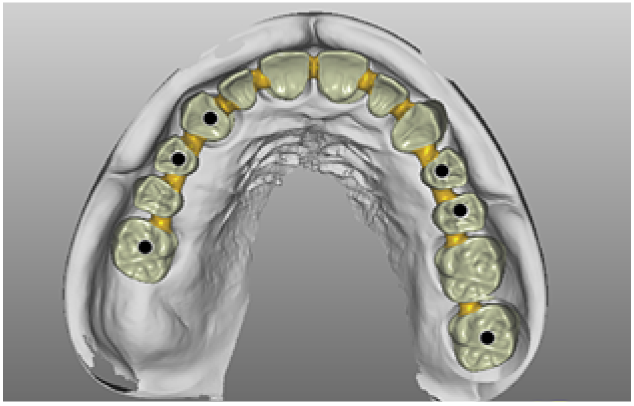
Figs. 8.77 and 8.78 *The provisional restoration.*

The osseointegration period was uneventful and at the end of the 3-month period the peri-implant soft tissues appeared healthy and keratinized. In the anterior area indentations had been created on the edentulous space by selective pressure , facilitating the creation of an esthetic emergence profile for the pontics (***Figs. 8.79 and 8.80***).

Fig. 8.79 Fig. 8.80

Figs. 8.79 and 8.80 *Clinical situation at the end of osseointegration period.*

An intra-oral scanning was performed with scanbodies fitted on the transmucosal abutments. The data from the scanning were exported to a CAD software for the design of the framework for the metal-ceramic restoration (***Figs. 8.81 and 8.82***). Minor corrections were made in the design of the anterior teeth to correct the overlapping of the lateral incisors over the central incisors. The metal framework was tried intra-orally for passive fit and the final restoration was a metal-ceramic screw-retained restoration (***Figs. 8.83 and 8.84***).



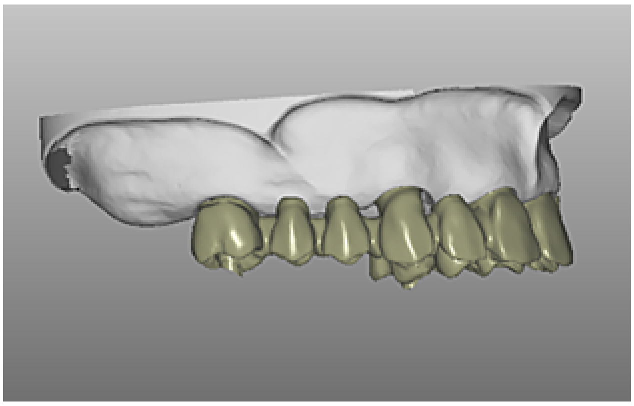


Fig. 8.81 Fig. 8.82

Figs. 8.81 and 8.82 *CAD design of the metal framework for a screw-retained restoration.*

Fig. 8.83 Fig. 8.84

Fig. 8.83 *The metal framework tried intra-orally.*
Fig. 8.84 *Case D, the final restoration.*

The clinical condition remained stable both for the soft tissues and the marginal bone around the implants, as it can be observed in the clinical and radiographic examination at the 5-year recall (***Figs. 8.85-8.88***).

Fig. 8.85

Fig. 8.86

Figs. 8.85 and 8.86 *Case D, clinical situation at the 5-year recall.*

Fig. 8.87

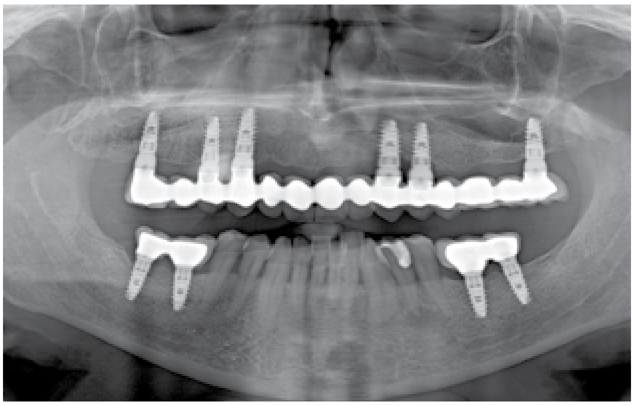


Fig. 8.88

Fig. 8.87 *Clinical situation at the 5-year recall, occlusal view.*
Fig 8.88 *Radiographic examination.*

8.11 Accuracy of Guided Implant Surgery

Accuracy evaluation for 3D guided surgery can be performed by comparing preoperative virtual planning with the postoperative location of the implants in the bone substrate. This is performed by matching virtual planning with the actual position, as they were visible on the 3D images using specific software (**Naeni et al., 2020**).

The accuracy of Computer Guided Implant surgery was investigated in a systematic review based on 20 studies. Different levels of quantity and quality of evidence were noted, as well as a lack of homogeneity among the used techniques. However, the authors concluded that the accuracy of guided surgery is within the acceptable range but a safety margin of at least 2mm from vital anatomic structures should be kept (**Tahmaseb et al., 2018**). In another systematic review based on 14 publications, the incidence of surgical complications was minimal and comparable to the conventional technique (**Joda et al., 2018**).

A systematic review, which focused on the accuracy of implant placement with guided surgery in partially edentulous patients and was based on 8 studies, concluded that higher accuracy was found for implants placed between existing teeth compared to implants placed in distal edentulous areas. The authors came to the conclusion that the edentulous space, the type and the fabrication of the surgical guide along with the surgical protocol may influence the accuracy of implant placement (**Putra et al., 2022**).

In another systematic review on the accuracy of Guided Implant Surgery in fully edentulous jaws, angular deviations were noted in most of the studies, mainly in the maxilla. Cervical and apical deviations were lower in the mandible (**Marliere et al., 2018**). The authors concluded that the surgeon should always keep the safety margins in clinical situations.

In a systematic review of 13 clinical studies (**Moraschini et al., 2015**), survival rates of 97.2% of 2,019 implants were reported as well as low marginal bone loss for the guided surgery technique during a 1- to 4-year follow-up period. The associated complications included implant loss (2.53%), provisional and definitive prosthesis fracture, surgical guide fracture, low primary stability or even implant fenestration. It was concluded that there is certainly a learning curve involved with guided surgery in order to achieve treatment success.

In another systematic review (**D'Haese et al., 2012**) based on 31 clinical studies, the authors concluded that guided surgery yields a more accurate placement than a free-hand implant placement. Nevertheless, both cadaver and clinical studies made it obvious that guided surgery is far from accurate. Deviations at the shoulder of the implant may jeopardize the accurate fit of the restoration and it seems that chair-side modifications are necessary to adapt the occlusion and the articulation. They suggested that at least a 2mm apical safety margin from the planned position is required to avoid any critical anatomical structures.

Summarizing the above mentioned, it can be deduced that guided flapless surgery is comparable—if not more accurate—to the free-handed technique. The results from the currently available studies strongly suggest that there is an association between guided(?) support, the protocol used and clinical accuracy of computer-guided surgery, wherein tooth-supported guides show more accuracy than bone or mucosa-supported guides, and fully guided surgery yields higher accuracy compared to partially guided surgery (**Raico et al., 2017; Naeni et al., 2020**).

8.12 Clinical relevance and limitations of the Digital Workflow

As in every new method in Dentistry, the digital workflow requires a certain period and a learning curve for the operator to familiarize with the technique. The clinician that starts with a new device or software should have extreme caution at the first cases to recognize any deviation or inaccuracy, and complete the case in the indicated way for a satisfactory result. The technique is still sensitive to cumulative errors; therefore clinicians are advised to take great care in all steps of the guided-surgery protocol, and in particular, to include safety margins around the virtually planned implants (**Naeni et al., 2020**). Additionally, as stated in an extensive review (**Joda et al., 2017**), "… a complete digital approach for treatment with implant-supported fixed dental prostheses has not yet been scientifically investigated, and therefore cannot be recommended for routine use at this time."

References for Chapter 8

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Glossary of scientific terms

Απόδοση στα ελληνικά των επιστημονικών όρων
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Abutment: Εμφυτευματικό στήριγμα
Alveolar crest: Φατνιακή ακρολοφία
Attachment: Σύνδεσμος ακριβείας
Ball attachment: Σφαιρικός σύνδεσμος
Bar: Δοκός
Base plate: Βασική πλάκα
Bone substrate: Οστικό υπόβαθρο
Cement-retained restoration: Συγκολλώμενες αποκαταστάσεις
Cantilever: Πρόβολος
Castable: Χυτεύσιμο
Cone Beam Computed Tomography: Υπολογιστική Τομογραφία Κωνικής Δέσμης
Closed tray: Κλειστό δισκάριο αποτύπωσης
Computer Tomography: Υπολογιστική Τομογραφία
Copings: Κυλινδρικά στηρίγματα
Cortical plate: Φλοιώδες πέταλο
Cross-section image: Εικόνες τομών
Custom tray: Ατομικό δισκάριο
Diagnostic wax-up/set-up: Διαγνωστικό κέρωμα/διαγνωστική σύνταξη
Digital impression: Ψηφιακό αποτύπωμα
Emergence profile: Περίγραμμα ανάδυσης
Fixed Dental Prosthesis: Ακίνητη προσθετική αποκατάσταση (γέφυρα)
Fixing screw: Βίδα στερέωσης
Flap: Κρημνός
Framework: Σκελετός
Full-mouth restoration: Ολική στοματική αποκατάσταση
Guided Tissue Regeneration: Κατευθυνόμενη ιστική αναγέννηση
Hinge axis: Γίγγλυμος άξονας
Implant-abutment connection (internal or external): Σύνδεση εμφυτεύματος και στηρίγματος (εσωτερική ή εξωτερική)
Implant carrier: Εξάρτημα μεταφοράς εμφυτεύματος
Implant head/ implant neck: Κορυφή (αυχένας) εμφυτεύματος
Implant overdenture: Εμφυτευματική επένθετη οδοντοστοιχία
Impression post: Άξονας αποτύπωσης
Initial stability: Αρχική σταθερότητα
Intra-oral scanning: Ενδοστοματική σάρωση
Luting cement: Κονία συγκόλλησης
Magnification: Μεγέθυνση
Mandible: Κάτω γνάθος
Maxilla: Άνω γνάθος
Occlusal plane: Μασητικό επίπεδο
Open tray: Ανοικτό δισκάριο αποτύπωσης
Overeruption: Υπερέκφυση
Panoramic radiography: Πανοραμική ακτινογραφία
Passive fit: Παθητική εφαρμογή
Prefabricated: Προκατασκευασμένο, εργοστασιακής κατασκευής

Provisional restoration: Μεταβατική αποκατάσταση
Radiographic guide: Ακτινογραφικός οδηγός (νάρθηκας)
Radiopaque: Ακτινοσκιερό
Recall: Επανέλεγχος
Reconstruction (for CBCT): Ανασύνθεση (για υπολογιστική τομογραφία)
Removable Partial Denture: Κινητή μερική οδοντοστοιχία
Retention elements: Συγκρατητικά στοιχεία (σύνδεσμοι)
Retaining screw: Βίδα στερέωσης
Retentive clip: Συγκρατητικό εφίππιο
Scanbody: Εξάρτημα ενδοστοματικής σάρωσης
Screw-retained restoration: Κοχλιούμενη αποκατάσταση
Short dental arch: Βραχύ οδοντικό τόξο
Soft tissue mask: Μάσκα απομίμησης μαλακών ιστών
Splinting: Σύνδεση, ναρθηκοποίηση
Study cast: Εκμαγείο μελέτης
Superimposition: Αλληλεπίθεση
Superstructure: Υπερκατασκευή
Surgical guide: Χειρουργικός οδηγός (νάρθηκας)
Telescoping crown: Τηλεσκοπική στεφάνη
Thermoplastic sheet: Θερμοπλαστικό φύλλο
Tightening torque: Ροπή στερέωσης
Transfer cap (for impression post): Βοήθημα επανατοποθέτησης (για άξονα αποτύπωσης)
Transmucosal abutment: Διαβλεννογόνιο στήριγμα
Treatment plan: Σχέδιο θεραπείας
Veneering: Επικάλυψη
Vertical dimension: Κάθετη διάσταση
Wax rims: Κέρινα ύψη
Working cast: Εκμαγείο εργασίας

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