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Preface

Life is made up of an infinite amount of choices. Most decisions, such as what you will eat for lunch today, are small and only slightly impactful, but it is the big decisions, the ones that can change our life, that are tough to make. It is really difficult for the dentist to make decisions about what kind of full-arch implant treatment system should be performed for edentulous patients who want shorten treatment times, simplified surgical management, esthetical pleasing, very precise and highly functional prosthesis, fewer clinical appointments, and affordability. We sincerely hope that this book will answer this question.

This book is about full-arch rehabilitation which is one of the most challenging therapy in implant-driven oral rehabilitation. As a result, complications occur much more frequently. One of the most stressful parts of the doctors' work is that their patients are coming in and out their offices frequently due to complaints after treatment. This can be very confronting and stressful for both the doctors and their patients. This book will attempt to find the optimum solution to avoid the complications using digital systems.

There are a variety of books with regard to restoration in the edentulous patient. Most of the books deal with complications, as dealing with the complications that arise in the course of treatment has been part and parcel of a clinician's working life. In this book, there is no topic about them. This book will attempt to focus on the method that can prevent or at least minimizing them rather than show how to deal with them. If any problem occurs after treatment, there is something wrong with the system. Digital system is used to simplify the procedure for full-arch restoration so that it minimize the problems that arise in the treatment of full-arch patients. In this book, you can find one of the newest implant therapy innovations to treat edentulous or nearly edentulous patients.

Preface

In this book, there is another topic that you cannot find is about surgical procedures such as GBR (guided bone regeneration) or bone grafting to increase the bone volume of the alveolus. This book shows how to use the remaining bone for full-arch restoration without bone grafting rather than demonstrate techniques for alveolar ridge augmentation. There is growing evidence that edentulous patients with severely resorbed ridges can be treated with implant-supported fixed prostheses with four or six dental implants while avoiding bone grafting procedures. Furthermore, the procedure without bone grafting has been reported to have a higher success rates than that with bone grafting. Therefore, the less invasive surgical concepts that rehabilitate the edentulous patient without bone grafts could be the treatment of choice for edentulous patients. This book will attempt to show definitive outcomes and scientific proof of the efficacy of digital full-arch system for the All-on-4 and All-on-6 implant treatment as well as the proper techniques necessary to obtain its greatest benefits. The entire digital workflow, from capturing the intermaxillary and occlusal relationships in a digital format prior to the extraction of teeth and transferring this information to the implant-supported fixed final prostheses without conventional impressions and models, is discussed in detail. The procedure is described with detailed photographs and especially supplemented by as many videos as possible.

I would like to express my sincere gratitude to DIO CEO Jincheol Kim and Jinbaek Kim for their unselfish sharing of their knowledge, time, and products that have contributed to the development of the digital system for full-arch treatment. Finally, I would like to thank Quintessence Publishing Company for recognizing the value of digital full-arch treatment and the need for a book on its clinical applications.

Byung-Ho Choi, DDS, MS, PhD

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2013	Dental Prosthodontics, Daehan Narae Publishing Company
2015	Digital Flapless Implantology. JeeSung Publishing Company.
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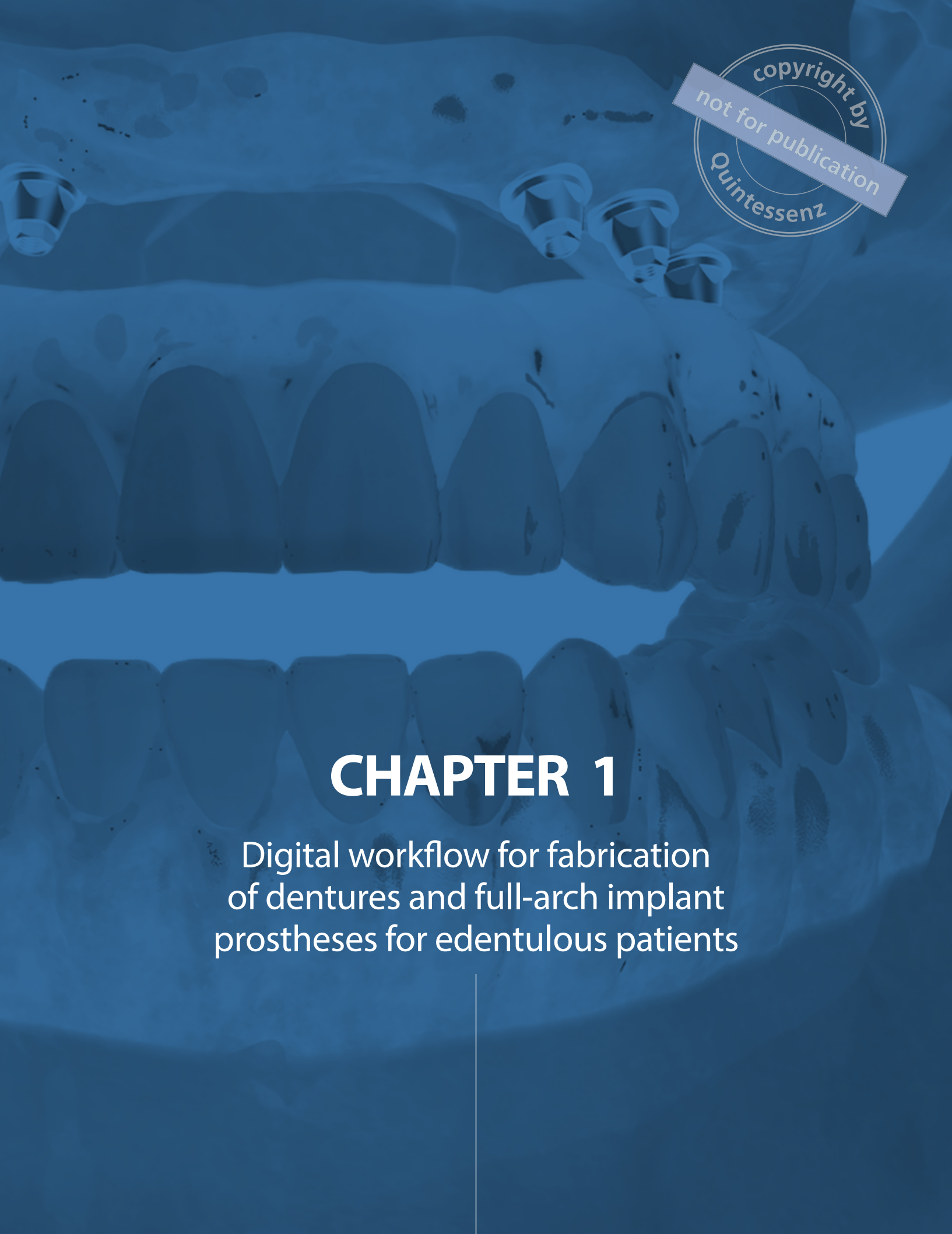


CHAPTER 1

Digital workflow for fabrication of dentures and full-arch implant prostheses for edentulous patients

Introduction

The digital workflow for the fabrication of dentures and full-arch implant prostheses for edentulous patients or those becoming edentulous after the removal of the remaining teeth uses image data and computer-aided design and manufacturing (CAD-CAM) technologies. The entire workflow, from capturing the intermaxillary and occlusal relationships in a digital format prior to the extraction of teeth and transferring this information to the implant-supported fixed final prostheses without conventional impressions and models, is discussed in detail in this chapter (1-1).

1-1. Digital workflow for fabrication of dentures or full-arch implant prostheses for edentulous patients.

Digital workflow stages

The digital workflow for the fabrication of dentures and full-arch implant prostheses for edentulous patients is split into the following three stages:

First stage: From before the extraction of the tooth to the fabrication of the immediate denture.

Second stage: From denture to immediate provisional prosthesis

Third stage: From provisional prosthesis to final prosthesis

First stage workflow

Immediate dentures are fabricated prior to the extraction of the natural teeth so that these can be inserted immediately after the removal of the teeth. The patient's original occlusal vertical dimension (OVD) is registered using an intraoral scanner prior to the extraction of the teeth, because it is difficult to assess the OVD after the removal of the teeth. The virtual occlusal registration is stored in a digital format, which ensures it portable and reusability.

These data are used for the fabrication of the immediate complete denture and the provisional and final prostheses. After deleting the images of the teeth from the virtual image of the jaw, the digital data are used to design denture bases and teeth. The gathered data are input to a 3D printer to print the denture. The following steps are followed to fabricate immediate dentures for patients who become edentulous after the removal of the remaining teeth.

Step 1. Intraoral digital impression

Digital scans of the mouth are obtained before extracting the teeth using an intraoral scanner (1-2). The intraoral scanning area includes the teeth, adjacent mucosa, edentulous ridge, vestibule, and palate. The opposite teeth are also scanned.

Step 2. Bite scanning

The assessment and reestablishment of OVD are significant in the treatment of edentulous patients. If the existing OVD is good to maintain, a virtual occlusal record is registered by optically scanning the labial surfaces of the mandibular and maxillary teeth using an intraoral scanner while maintaining the occlusal relationship with the opposite teeth. If the OVD is decreased owing to the abrasion of the artificial or natural teeth, missing teeth, or loose teeth, the reestablishment of the OVD is necessary to prevent significant changes in the jaw and occlusal relationship. In patients who have a reduced OVD, the bite scan is obtained while maintaining the occlusal relationship with an increased OVD. The scanned mandibular and maxillary intraoral images are then virtually aligned using the virtual occlusal record as a reference (1-3). This completes the scanning of the digital mandibular and maxillary teeth with occlusal relationships.

Step 3. Deleting tooth image

After the virtual model mounted at the OVD is obtained, the images of the remaining teeth are deleted from the virtual 3D image (1-4).

Step 4. Designing immediate denture

The obtained data are imported into denture planning software (Dental System; 3Shape A/S) to design the complete denture. The denture base and teeth are virtually designed using the software (1-5). The program allows for the occlusal adjustment using a virtual articulator. More accurate denture teeth are fabricated by simulating mastication using the virtual articulator.

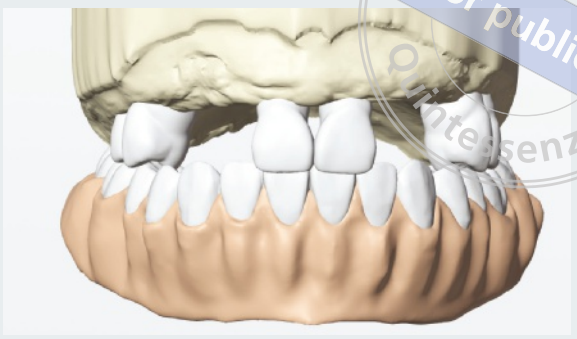
Step 5. Fabrication of immediate denture

The designed denture teeth and base can be 3D printed separately or together as a single piece. When the denture teeth and base are printed in as a single unit, tissue-colored composite resin is applied onto the denture flange. Otherwise, the printed teeth are bonded to the printed denture base using a light-cured bonding agent (1-6).

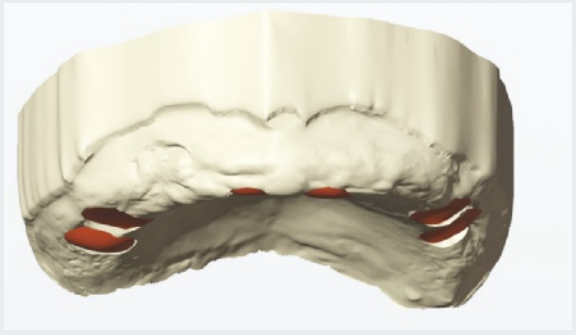
Step 6. Extraction of teeth and placement of immediate denture

After the denture is fabricated, all the remaining teeth are extracted (1-7). Interrupted sutures are then placed if necessary. The immediate denture is inserted immediately after the suturing (1-8). To improve denture retention, chair-side adjustments are made to the internal surface, borders, and undercut areas of the immediate denture using a soft tissue conditioning material (1-9).[1] Any residues of the material are removed from the extraction sites to aid normal healing of the socket. Therefore, a careful check of the extraction sites after the use of the conditioning material is necessary. Occlusal adjustment is performed to obtain bilateral balanced

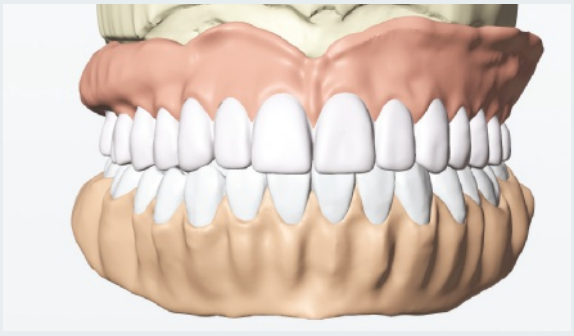
1-2. Digital scan of the mouth is obtained using an intraoral scanner prior to the extraction of teeth.



1-3. Scanned mandibular and maxillary intraoral images with occlusal relationship.



1-4. Images of the teeth that are to be removed are removed from the virtual 3D image.

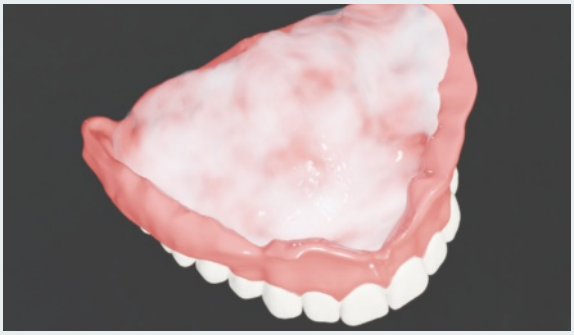


1-5. Immediate denture is designed using denture planning software.

1-6. Printed immediate denture.

1-7. All the remaining teeth are extracted after the immediate denture has been fabricated.

1-8. Immediate denture is inserted immediately after the extraction of teeth.



1-9. Chair-side adjustments are made to the internal surface, borders, and undercut areas of the immediate denture using a soft tissue conditioning material.

occlusion. Finally, the denture border is checked to ensure that it provides enough space for the labial and buccal frenum.

Step 7. Aftercare

After the teeth are extracted, patients are advised to wear the denture for 24 h because it acts as a splint to help minimize bleeding, swelling, and discomfort. The bone resorption and shrinkage of the healing soft tissues occur at an increased rate when compared with the already well-healed tissue. These changes require reline procedures to maintain a well-adapted fit.

Second stage workflow

In this stage, a provisional prosthesis for fully edentulous patients wearing dentures is fabricated. Data are acquired from both the patient's denture and using cone beam computed tomography (CBCT). The denture provides information on soft tissue surfaces of edentulous ridges, their teeth positions, and occlusal vertical dimension. The CBCT scans provide information on the condition of the bone. The following steps are followed to fabricate provisional prostheses for edentulous patients wearing dentures.

Step 1. Placing markers

Vinyl polysiloxane is placed on the denture base. The denture is used as a custom tray to obtain an impression. After the impression is obtained, at least three radiopaque markers are placed on the labial and buccal surfaces of the denture (1-10). Light-curing resin is used to attach the markers to the denture.

Step 2. CBCT scanning

The CBCT scan is obtained while the patient is wearing the denture with the markers (1-11). The denture must be stable while performing the CBCT.

Step 3. Denture scanning

The denture is removed from the mouth after CBCT is performed. Next the denture and markers are scanned using an intraoral scanner (1-12). The denture scanning area includes all areas of the denture, such as the denture base, border, teeth, and palate. The markers are precisely scanned to obtain a proper match with the CBCT images.

Step 4. Bite scan

In this step, the opposite teeth are scanned and a virtual bite is registered by optical scanning of labial surfaces of the maxillary and mandibular teeth in the patient's mouth using an intraoral scanner while maintaining both jaws at the OVD (1-13, 14).

Step 5. Image merging

The digital STL files generated from the denture scans are imported into editing software (Dental Designer; 3Shape A/S). The scanned image of the impression is inverted to obtain the details of the surface of the edentulous tissue and exported as an STL file (1-15). The edited digital STL file from the Dental Designer software and the DICOM data acquired from the CBCT scan are imported into the virtual implant planning software (Implant Studio; 3Shape A/S). The image of the edited digital STL file and the CBCT data are fused by matching the markers present on the two sets of images.

Step 6. Implant planning

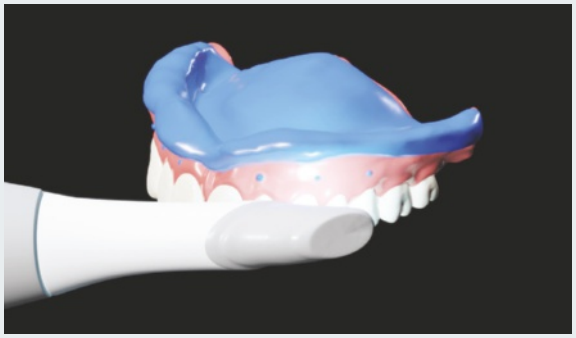
After the images are fused, the implant position is planned based on the shape of the bone and the virtual alignment of teeth using virtual implant planning software (Implant Studio; 3Shape A/S) (1-16).

Step 7. Fabrication of surgical guide

After the implant location is determined, the surgical guide is designed based on the intraoral scan that has

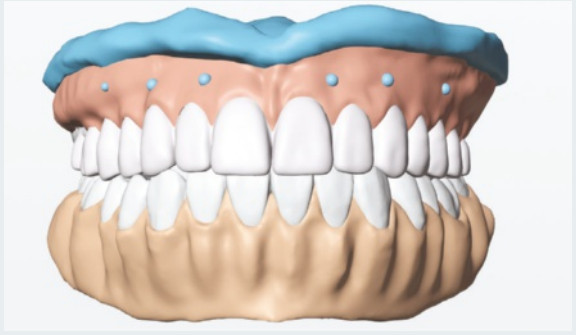
1-10. Markers are placed on the labial and buccal surfaces of the denture after obtaining its impression.

1-11. CBCT is performed while the patient is wearing the denture with the markers.



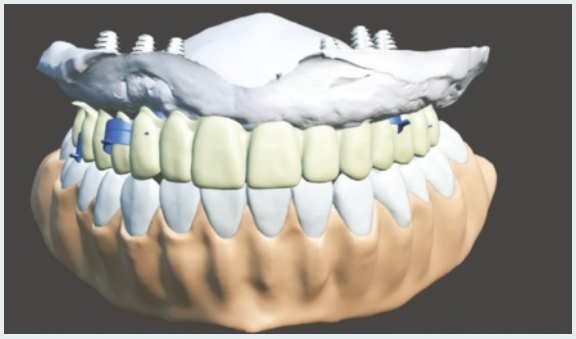
1-12. The denture is scanned after CBCT using an intraoral scanner.

1-13. Virtual occlusal record is registered by scanning the labial surfaces of the upper and lower teeth.



1-14. Images of the scanned denture and opposite teeth are virtually aligned using the virtual occlusal record as a reference.

1-15. Denture scan images are inverted to obtain edentulous tissue surface images.



1-16. Implant position is planned based on the shape of the bone shape and the virtual alignment of teeth using virtual implant planning software.

1-17. Surgical guide is fabricated using a 3D printer.

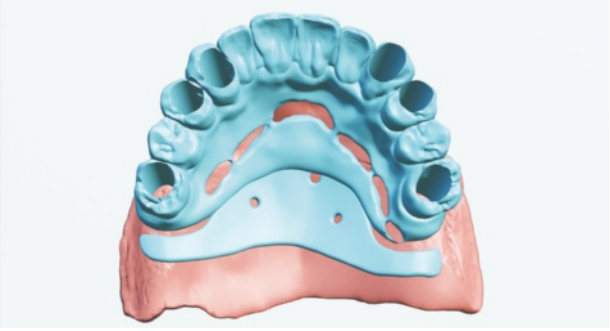
the implant position information. Holes for anchor screws are also designed. The designed surgical guide is fabricated using a 3D printer (1-17).

Step 8. Fabrication of provisional prosthesis denture

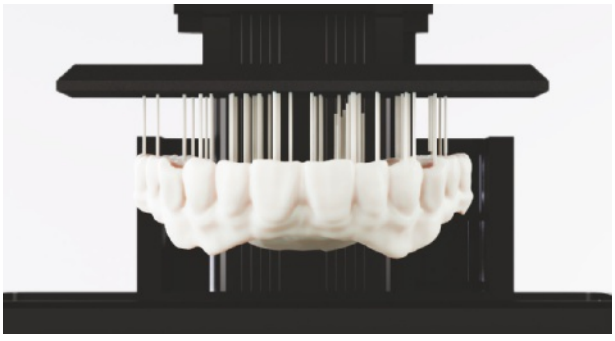
A provisional prosthesis denture is fabricated to deliver a provisional implant-supported fixed prosthesis immediately after the placement of the implant. Based on the intraoral scan that has the implant position information, an interim restoration is designed using 3Shape dental designer software. The interim restoration has two parts: a fixed prosthesis and a denture flange (1-18). The fixed prosthesis is designed to have the cylinder access holes considering the planned implant positions. The size of cylinder access holes is Ø6.0 mm, which is adequate for the cylinders to pass through the restoration. The design of the fixed prosthesis is identical with the definitive restoration in terms of the esthetics, occlusion, ideal emergence profile, and accessibility for oral hygiene. The denture flange is designed as a complete denture for repositioning the provisional prosthesis denture is in the mouth. Later on, this flange part is easily cut off from the fixed prosthesis. After the restoration design is complete, commercial printable resin is used to fabricate the restoration using a 3D printer (1-19). Subsequently, tissue-colored composite resin is applied on the gingival area of the denture with subsequent light polymerization to simulate the gingival tissue (1-20).

Step 9. Implant surgery

The surgical guide is placed in the patient's mouth using the bite registration putty and fixed in place using anchor screws (1-21, 22). This guide is used to perform



1-18. Provisional prosthesis denture is designed based on the intraoral scan image that has the implant position information.



1-19. Provisional prosthesis denture is fabricated using a 3D printer.

1-20. Tissue-colored composite resin is applied onto the gingival area of the denture.

1-21. Surgical guide is placed in the patient's mouth using the bite registration putty and fixed in place using anchor screws.

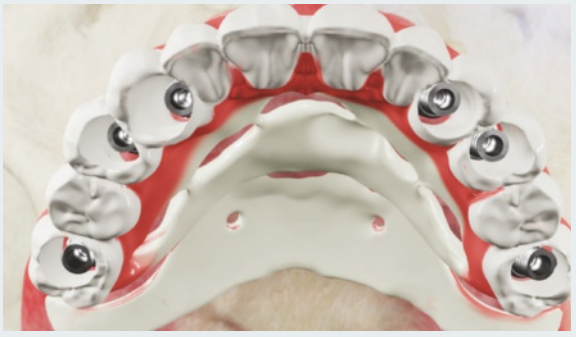
1-22. Surgical guide is fixed with two anchor screws.

1-23. Guided flapless implant surgery is performed using the surgical guide.

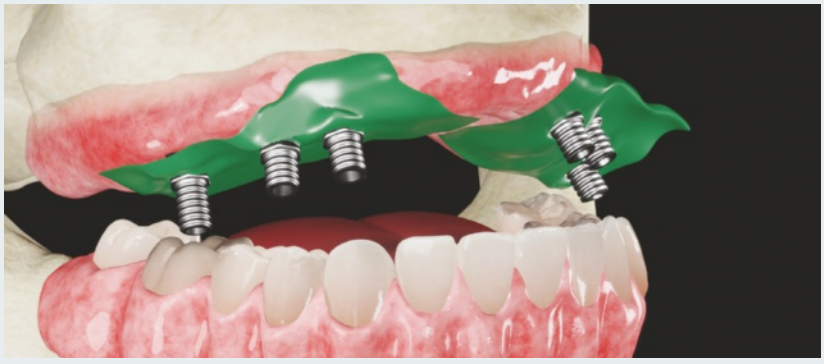
1-24. Implants are placed using the surgical guide.

1-25. Multiunit straight abutments are connected to implants.

1-26. Predetermined temporary cylinders are connected to abutments.



1-27. It is necessary to check and rule out any interference between the provisional prosthesis denture and cylinders.



1-28. Rubber dam sheet is placed around cylinders to cover and protect the gum tissue and abutment.

the computer-guided flapless implant surgery (1-23, 24).

Step 10. Immediate restoration

After the implants are placed, multiunit abutments are connected to them (1-25). Next, predetermined temporary cylinders are connected to the abutments. The height of the cylinders is adjusted prior to the surgery so that their tops are below the occlusal surface (1-26). After the cylinders are connected, the interim prosthesis denture is placed in the mouth. The denture is placed passively into its proper position in the mouth and has an occlusal relationship with the opposite teeth (1-27). The cylinders must not cause any interference with the denture. A rubber dam sheet is placed around the cylinders such that it covers and protects the gum tissue and abutments (1-28). The interim prosthesis denture is repositioned in the mouth and bonded with the cylinders by injecting acrylic resin around the cylinders using a syringe (1-29, 30). After the resin has polymerized, the interim prosthesis denture is removed from the mouth and the denture flange is sectioned (1-31, 32). The remaining fixed prosthesis is attached to the implant abutments in the mouth by screwing it to the cylinders. The occlusion is evaluated and adjustments, if necessary, are made.

1-29. Provisional prosthesis denture is bonded to cylinders by injecting acrylic resin around them.

1-30. Acrylic resin is polymerized by light.

1-31. Denture flange part is removed.

1-32. Provisional prosthesis after removing the flange.

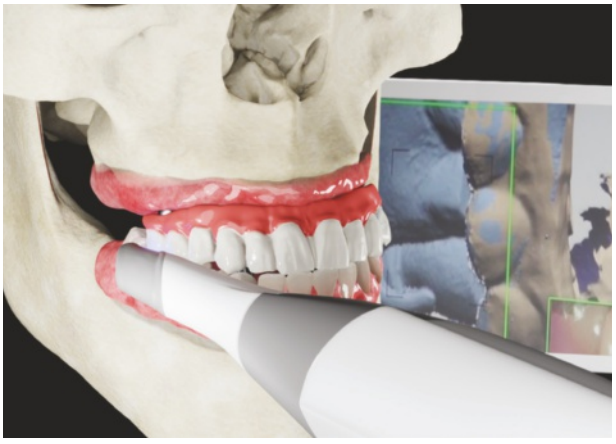
Third stage workflow

Provisional prostheses are considered to be the prototype for the final prostheses because they provide the prosthetic information such as the occlusion, interarch relationship, implant fixtures and abutments. Therefore, the final prosthesis is fabricated using the scanned images of the provisional prosthesis. The following steps are followed to fabricate the final prosthesis using the provisional one.

Step 1. A digital model of the provisional prosthesis is generated by scanning the prosthesis outside the mouth using an intraoral scanner (1-33).

Step 2. After the prosthesis is scanned, it is reseated and fixed onto the abutments. Next, a bite scan is obtained by scanning of the labial surfaces of the upper and lower teeth in the mouth using an intraoral scanner while maintaining the occlusal vertical dimension (1-34).

1-33. Provisional prosthesis is scanned outside the mouth using an intraoral scanner.



1-34. Bite scan is obtained by scanning the labial surfaces of the upper and lower teeth in the mouth using an intraoral scanner.

1-35. One-piece framework and crowns are designed.

Step 3. The scanned image of the interim prosthesis is inverted using dental designer software (3Shape A/S). Next, the images of the inverted interim prosthesis and the opposite teeth are virtually aligned using the bite scan as a reference. In this way, a digital model of the cylinder cap and the base of the interim prosthesis with the opposite teeth mounted in the occlusal relations is obtained.

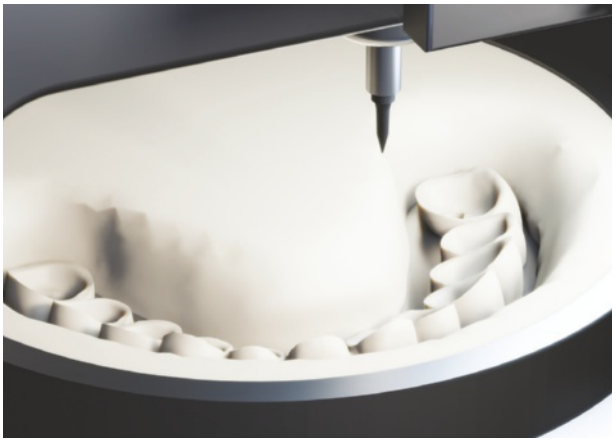
Step 4. The cylinder cap images obtained from the cylinder image libraries and inverted cylinder are merged using semiautomatic 3D object adjustment.

Step 5. The virtual one-piece framework and crowns are designed using design software (Dental Designer, 3Shape A/S) (1-35).

Step 6. The designed framework and crowns are fabricated using the CAD-CAM milling process. (1-36, 37, 38).

Step 7. The final prosthesis is seated and screwed to the abutments (1-39).

1-36. Titanium framework is fabricated using the CAD-CAM milling process.



1-37. Crowns are fabricated using the CAD-CAM milling process.

1-38. Final prosthesis.

1-39. Final prosthesis is seated and screwed to abutments.

Digital workflows for various patient conditions

- **Dentulous patient:** For patients becoming edentulous after the removal of the remaining teeth and undergoing delayed implant placement, the digital workflow includes all the three stages: immediate denture fabrication, delayed implant placement, and provisional and final restoration.
- **Fully edentulous patient:** For fully edentulous patients undergoing immediate provisional restoration, the digital workflow compromises the second and third stages: implant placement and provisional and final restoration.

QR 1-1 QR 1-2

QR 1-1. Digital workflow from before removing remaining teeth to final prosthesis.
QR 1-2. Digital workflow from denture to final prosthesis.

Natural bone healing versus bone graft in extraction socket after teeth extraction

In advanced periodontitis, the alveolar sockets often exhibit severely resorbed buccal bone plates after the removal of teeth (1-40).[2,3] In this situations, surgical procedures such as guided bone regeneration or bone grafting have been suggested to increase the bone volume of the alveolus because the reduction of the alveolar height and width may pose challenges for future implant placements.[4-7] However, contradictory results have reported that significant bone growth in the buccolingual width and a significant vertical increase in the buccal bone plate occur in extraction sockets without the additional use of bone grafts or barrier membranes.[8,9]

1-40. Extraction socket with serious bone defects.

Clinical study

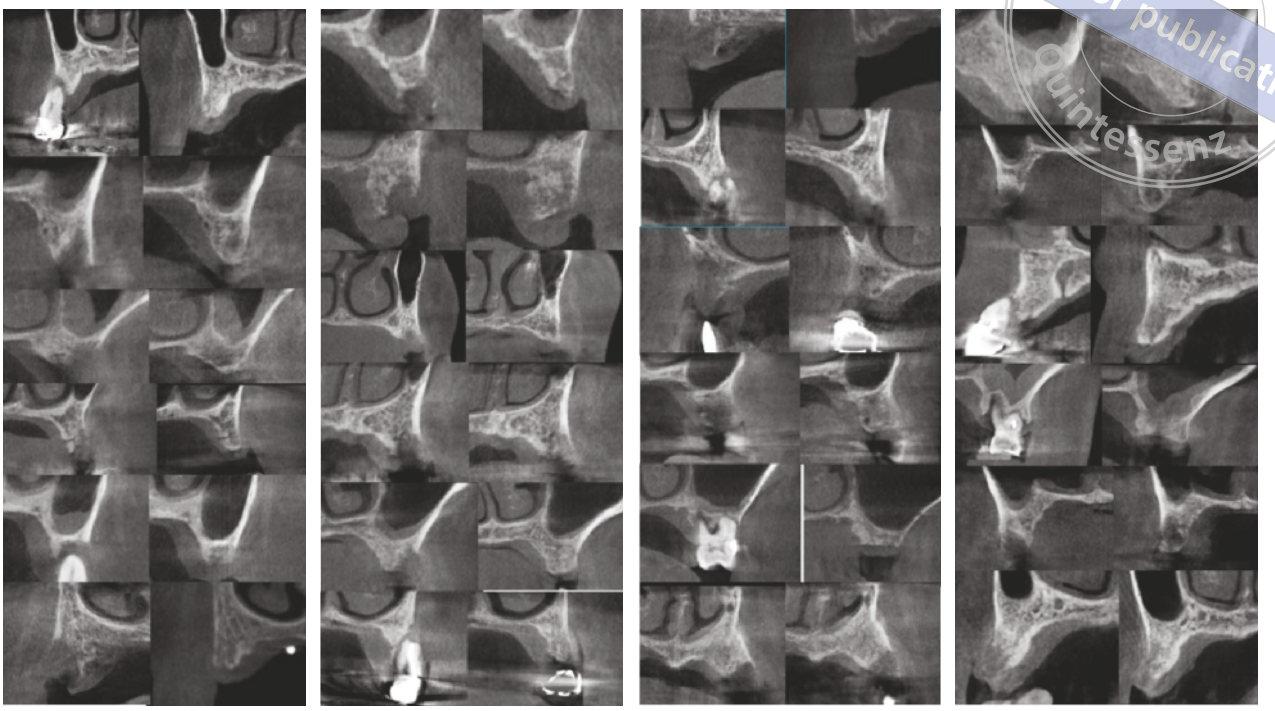
The aforementioned contradictory results prompted this clinical study on the dimensional changes within infected sockets with serious bone defects that occur following the extraction of teeth.

Materials and methods

Forty-eight patients requiring premolar or molar tooth extraction due to bone defects caused by periodontal diseases were selected for this study. Teeth were extracted gently without the elevation of the mucoperiosteal flap using forceps, and a copious saline solution was used to irrigate the socket without socket debridement. No patients received any bone graft after tooth extraction. CBCT scans were obtained before extraction or after 7-10 days following the extraction and at 1 year after the extraction. Vertical and horizontal bone volumes were assessed by overlapping the CBCT scan images. At 1-year after extraction, a prosthetically driven implant plan was developed using virtual implant planning software (1-41, 42).

Results

One year after the extraction, CBCT revealed that the horizontal and vertical bone levels were significantly increased, with an overall mean buccolingual bone width gain of 5.5 ± 2.9 mm and an overall mean vertical bone gain of 3.5 ± 1.8 mm at the level of the buccal bone plate. The overall mean vertical bone gain at the lingual bone plate level was 0.3 ± 1.3 mm (1-43, 44). Statistically significant differences were



1-41. CBCT scans of maxillary tooth extraction sites obtained before extraction or after 7-10 days following extraction and 1 year after extraction.

1-42. CBCT scans of mandibular tooth extraction sites obtained before extraction or after 7-10 days following extraction and 1 year after extraction.

found between the baseline and 1-year results at the horizontal and buccal vertical bone levels. Except for 4 out of 48 sites, implants were virtually positioned within the alveolus. The 4 exposed implant sites were in the maxillary molar area, exhibiting implant exposure only at the coronal portion of the implant (1-45, 46). At these sites, adequate bone height gain was possible for implants with adequate lengths using the maxillary sinus floor augmentation technique (1-47).

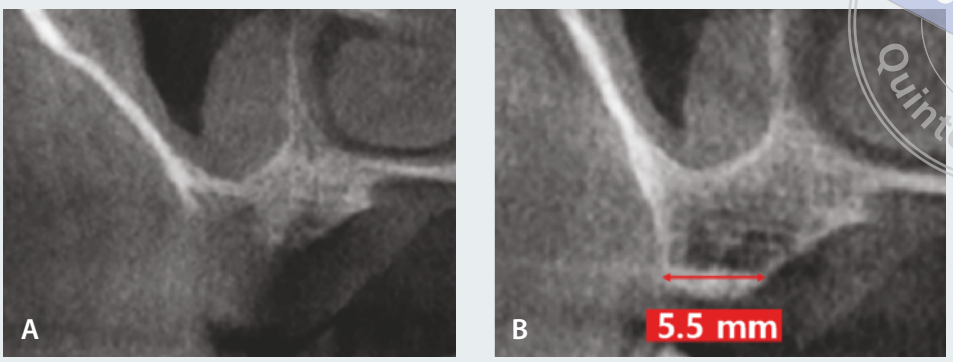
Discussion:

This study demonstrates that the defects caused by periodontal diseases can be filled with new bone, and the bone gain is sufficient to place an implant without the use of bone grafts or barrier membranes in the alveolus. This result is in contrast with the previous reports that claim that defects in the buccal plate do not repair themselves following tooth extraction, and various grafts such as xenograft or alloplastic material should be added to extraction sockets. It is possible to explain the discrepancies with respect to the bone formation in infected large bone defects after tooth extraction, with the key factor being the duration of the observation period. However, most of the previous studies were of comparatively short durations (3 to 6 months) and provided limited information related to the later phases of socket healing. Apparently, bone remodeling in extraction sites is a slow process and cannot be completed in 3-6 months following the extraction of the teeth. Furthermore, bone regeneration occurs more slowly within the infected extraction sockets with bone defects than in disease-free sockets. Therefore, the present study concluded that socket healing occurred over 1 year after the extraction of the teeth.[10] Based on the result of this study, there was new bone regeneration 1 year after tooth extraction in the extraction sockets with bone defects resulting from advanced periodontal diseases.

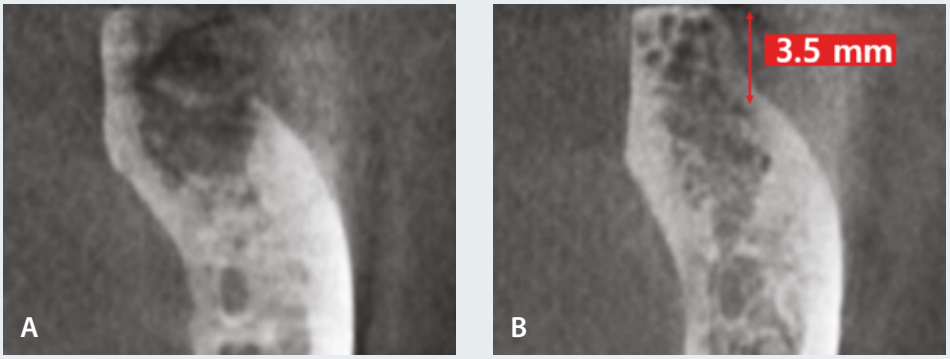
Another factor of consequence might be the extraction procedure. In this study, a simple flapless procedure was used at the time of extraction, socket debridement was not performed, and granulation tissues from chronic periodontal lesions were left in the extraction sockets. According to some authors, socket debridement was particularly necessary when infections were present.[11,12] Granulation tissues in the infected sockets were considered to be obstacles for bone healing; therefore a clean alveolus was obtained with no evidence of the fibrous tissue. However, other authors have reported that the granulation tissue left in situ might be useful for bone healing and volume enhancement in bone defects. It has been demonstrated that multipotent progenitor stem cells are present in infected granulation tissues from chronic periodontitis lesions,[13] which suggests that the removal of the granulation tissue at the time of extraction may result in the removal of stem cells. In the present study, the granulation tissue was left in the defects following the extraction of teeth (1-48), and all 48 sites healed uneventfully while exhibiting acceptable bone healing (1-49, 50, 51). The granulation tissue left in situ seemed to promote a significant bone volume increase within the infected extraction sockets. Furthermore, the flapless tooth extraction procedure might also be an important factor in enhancing bone gain. It is generally accepted that a flapless extraction technique prevents the disruption of the periosteum, blood supply, and source of osteoprogenitor cells on the outer surface of the buccal plate.[14-16] In this context, it must be acknowledged that both the flapless extraction technique and leaving in the granulation tissue may be important factors, which strongly influence bone healing following tooth extraction from the infected extraction sockets.

Conclusions:

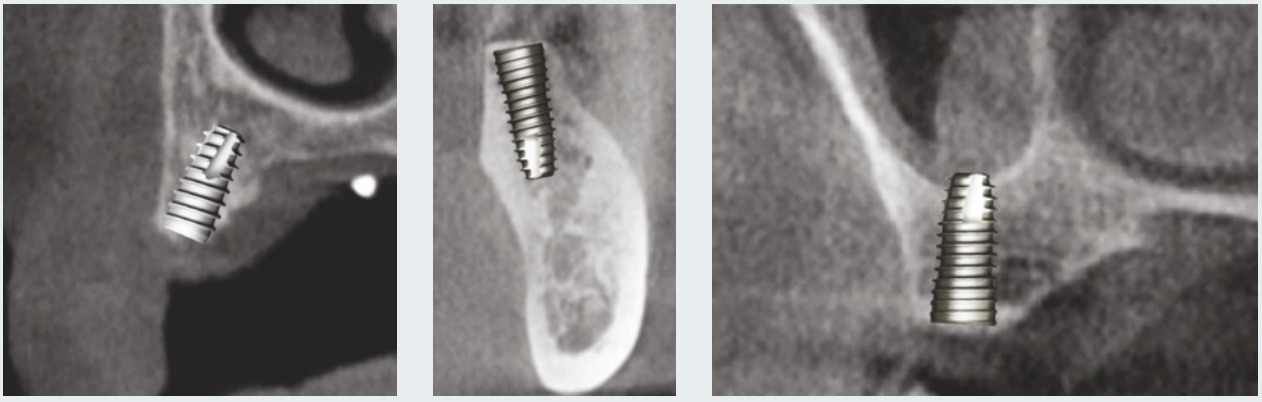
Despite the dimensional changes after the extraction of teeth in compromised extraction sockets, there would be sufficient bone for placing implants with the prosthetic driven approach.



1-43. CBCT at 1 year after extraction indicated that the horizontal bone levels were significantly increased, with an overall mean buccolingual bone width gain of 5.5 mm.



1-44. CBCT at 1 year after extraction indicated that the vertical bone levels were significantly increased, with an overall mean vertical bone gain of 3.5 mm at the level of the buccal bone plate.

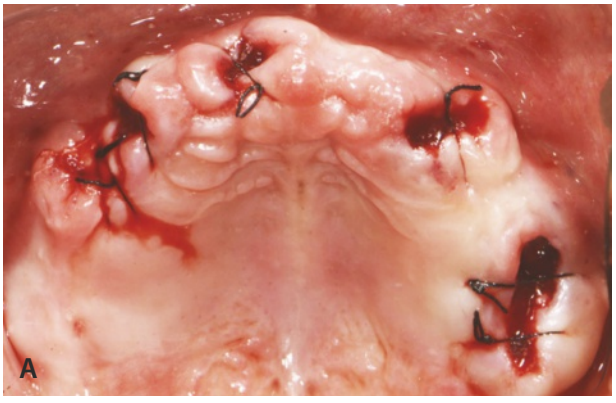


1-45. Bone gain at 1 year after extraction is sufficient to place an implant without the use of bone grafts in the maxilla.
1-46. Bone gain at 1 year after extraction is sufficient to place an implant without the use of bone grafts in the mandible.
1-47. Inspection of the maxillary molar extraction site at 1 year after extraction indicates that adequate bone height gain is possible for an implant with adequate length using the maxillary sinus floor augmentation technique.

1-48. Flapless extraction procedure. A: Before extraction. B: Flapless extraction of the mandibular right first premolar. C: After extraction. Note that socket debridement is not performed, and granulation tissues from chronic periodontal lesions are left in the extraction socket.

1-49. A: Extraction sites in the mandible immediately after flapless extraction. B: One year after extraction. Note that the extraction sties exhibit good bone healing.

1-50. A: Extraction sites in the maxilla immediately after flapless extraction. B: One year after the extraction. Note that the extraction sties exhibit good bone healing.



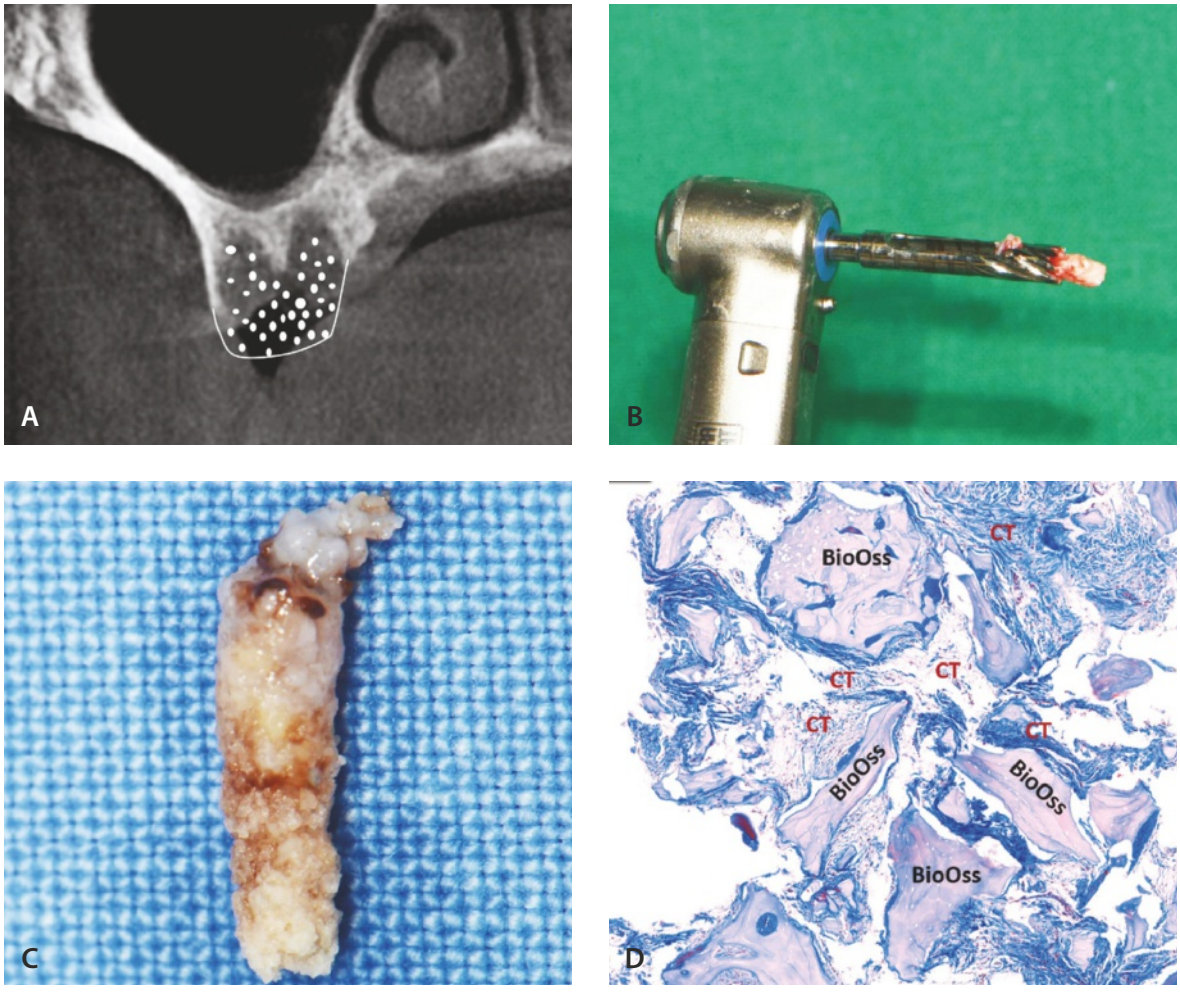
1-51. A: Extraction sites in the maxilla immediately after flapless extraction. B: One year after the extraction. Note that the extraction sties exhibit good bone healing.

Rehabilitation of edentulous patients without bone graft

In dentate or partially edentulous patients with one or several teeth missing or a tooth-only defect with minimum resorption of the supporting structures, the exact placement of the implant at the site of the missing tooth provides an esthetic replacement of the missing tooth with an implant-supported prosthesis. However, in completely edentulous patients who present with varying degrees of horizontal and vertical composite defects, the implant position can be modified depending on the shape of the bone so that four or six implants of optimal lengths can be installed and considered to be treated without bone grafting.

The surgical procedures to correct the deficiencies in severely resorbed edentulous ridges are the major obstacles faced by both patients and dentists. Over the past decades, bone grafts have been utilized to augment deficient areas of the maxilla and mandible for the preparation of implant sites. However, the grafting procedures pose difficulties in ascertaining the biologic quality of the new bone at the graft sites in atrophic edentulous jaws. Often, the lost tissue may be replaced

by fibrous tissue rather than the functional bone and implants fail due to their failure to integrate (1-52).[17] In addition, the financial burden on the patient and the pain morbidity associated with grafting procedures are major obstacles to the treatment. Dentists must justify the rationale for expensive and invasive procedures when cheaper and less invasive procedures are equally effective. There is growing evidence that edentulous patients with severely resorbed ridges can be treated with implant-supported fixed prostheses with four or six dental implants while avoiding bone grafting procedures. Furthermore, the procedure without bone grafting has been reported to have a higher success rates than that with bone grafting. Therefore, the less invasive surgical concepts that rehabilitate the edentulous patient without bone grafts could be the treatment of choice for edentulous patients.



1-52. A: GBR (guided bone regeneration) with bone graft. B: Specimen collection six months after GBR. C: Specimen. D: Tissue is filled with fibrous tissue rather than functional bone.

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CHAPTER 2

Treatment planning of the fully edentulous patient

Introduction

There are several factors that must be considered in the treatment planning for fully edentulous patients. Implant placement without considering the smile line could result in an unpleasant esthetic outcome due to the showing of the transition line and alveolar mucosa. Implants placed without assessing the inter-arch spaces may increase the technical difficulties of fabricating the implant-supported prosthesis, or fabrication of the prosthesis might even be impossible, requiring removal of the implants. Therefore, these issues should be intercepted during the diagnostic phase. This chapter describes the factors that must be reviewed in the treatment planning of edentulous patients.

Implant treatment options for edentulous patients

Treatment alternatives for the rehabilitation of edentulous patients include implant-retained overdentures, implant-supported overdentures, cement-retained implant-supported fixed prostheses, and screw-retained implant-supported fixed prostheses.

i. Implant-retained overdenture

In implant-retained overdentures, retention to the dental prosthesis is provided by the dental implants, and most of the support is gained from the coverage of the alveolar ridge. These prostheses use locator-type attachments. The most common protocol used in the implant-retained overdenture treatment involves placement of 2 implants in the mandible and 4 implants in the maxilla. The implants are placed in the canine or first premolar regions (2-1).

ii. Implant-supported overdenture

In case of implant-supported overdentures, the implants receive 100% of the masticatory load and provide retention for the denture. The number of implants needed for this type of prosthesis is similar to that of a fixed implant-supported prosthesis.[1] The treatment involves placement of 4 or 6 implants. The prosthesis is retained by a bar (2-2).

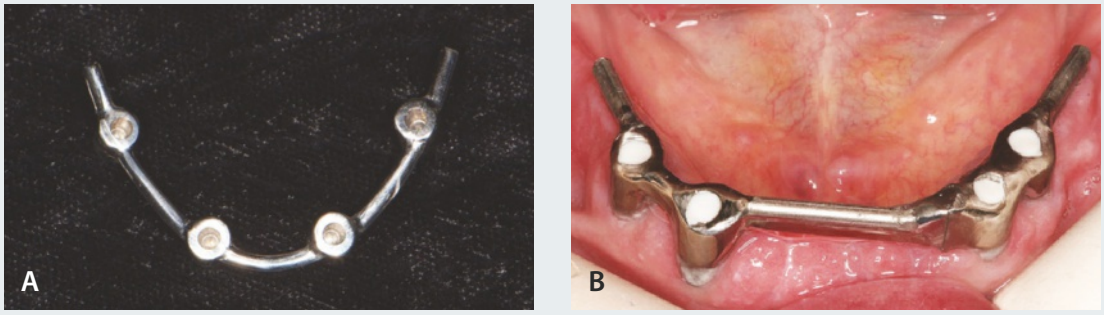
iii. Cement-retained implant-supported fixed prosthesis

The most commonly chosen protocol includes placement of 8 to 10 implants in the maxilla and 6 to 8 implants in the mandible. The prostheses are fabricated in sections, including 3- or 4-piece bridges, using customized or commercial abutments. In an atrophic ridge, cement-retained prostheses are esthetically compromised because of extended crown heights since interproximal papillae and proper emergence profile cannot be designed (2-3). An illusion of interdental papilla can be created prosthetically using pink porcelain or pink acrylic (2-4). However, patients with advanced ridge resorption may not be satisfied esthetically with the prosthesis (2-5).

iv. All-on-6 screw-retained implant-supported fixed prosthesis

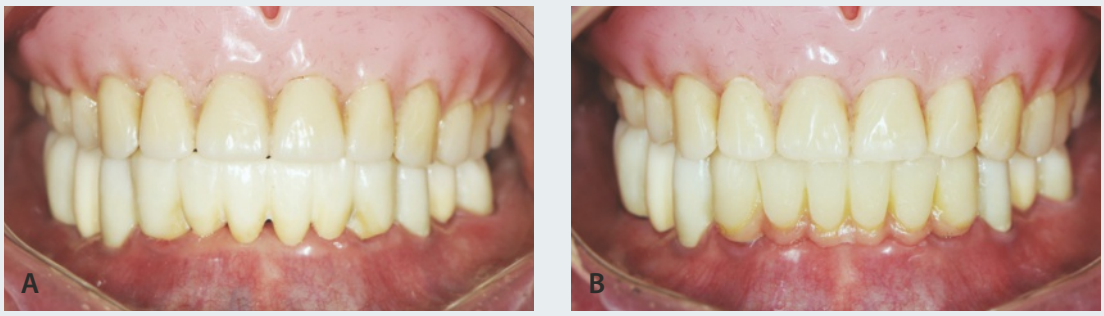
All-on-6 implant treatment is a procedure that makes a screw-retained implant-supported fixed 1-piece prosthesis using 6 implants and multi-unit abutments. The teeth and gingival areas, interproximal papillae, and emergence profile can be designed in the prosthesis. Therefore, it provides acceptable esthetics and function (2-6).

2-1. Locator attachment for retaining implant-retained overdenture.



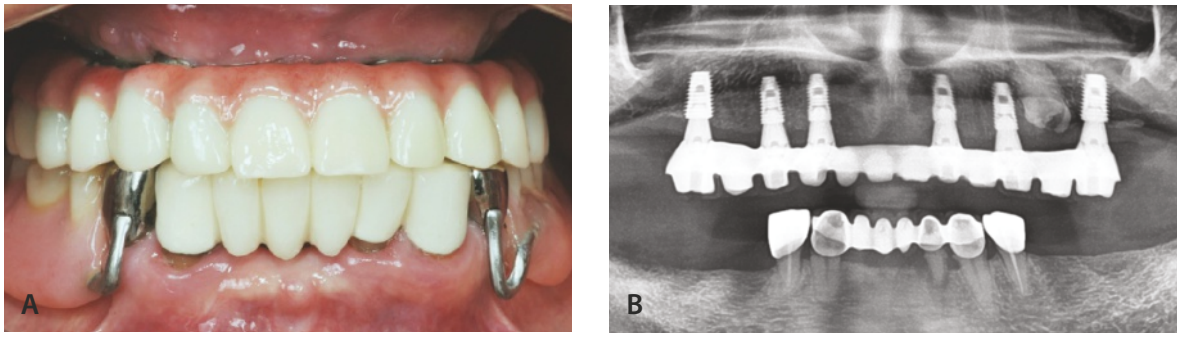
2-2. A: Bar attachment for retaining implant-supported overdenture. B: Bar attachment for retaining implant supported-overdenture in the mouth.

2-3. Cement-retained full-arch prosthesis design. Note that it cannot reproduce interproximal papillae and proper emergence profile since they have extended crown heights.



2-4. Cement-retained implant-supported full-arch fixed prosthesis in the mandible. A: Before designing interdental papilla. B: After designing interdental papilla.

2-5. Cement-retained implant-supported full-arch fixed prosthesis in the maxilla. It has extended crown height.

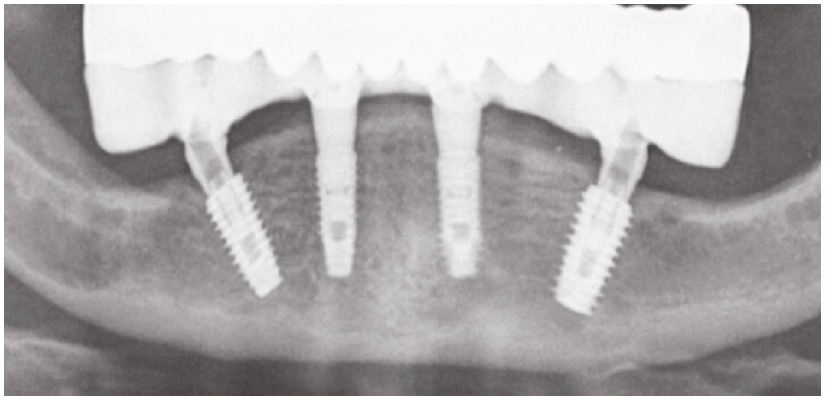


2-6. All-on-6 screw-retained implant-supported fixed prosthesis in the maxilla. A: Frontal view. B: Panoramic radiograph.

v. All-on-4 screw-retained implant-supported fixed prosthesis

All-on-4 implant treatment is a procedure that includes a screw-retained implant-supported fixed 1-piece prosthesis using 4 implants and multi-unit abutments. It uses 2 straight implants and multi-unit straight abutments in the anterior area, and 2 tilted implants and mullti-unit angulated abutments in the posterior area (2-7).

In an extremely atrophic edentulous ridge, it is possible to rehabilitate the completely edentulous jaw by placing 4 implants anterior to the anterior sinus wall of the maxillary sinus, and anterior to the mental foramen in the mandible without bone grafting.



2-7. All-on-4 screw-retained implant-supported fixed prosthesis in the mandible.

Factors to consider when choosing a treatment option

Several factors play a role in the decision-making for the treatment option that best suits the patient. The following factors must be assessed in the treatment planning of edentulous patients:

1. Lip support
2. Smile line
3. Amount of resorption
4. Interarch space
5. Number of implants
6. Implant position
7. Opposite dentition
8. Mandibular dynamics
9. Patient preference
10. Cost

1. Lip support

One of the most important selection criteria is the need for support to the upper lip. Lip support is determined by the shape of the alveolar ridge. The maxillary alveolar process presents a resorption pattern that proceeds cranially and medially, resulting in a loss of vertical dimension and lip support.[2] Patients should be assessed for requirement of a flange in the prosthesis for lip support.

One of the best diagnostic tools is the patient's existing maxillary denture. Removing the dentures will allow assessment as to whether a flange is essential to provide support for proper lip contour. An overdenture may be necessary for patients requiring more lip support closer to the base of the nose since the flange on the overdenture may assist in supporting the contours of the face.

- Horizontal bone resorption of the maxillary alveolar ridge affects the support of the columella, leaving the patient with a completely unsupported upper lip. The prosthetic option that may accurately restore the esthetics, providing sufficient lip support, is implant-supported or implant-retained overdenture that permits fabrication of an acrylic flange (2-8).

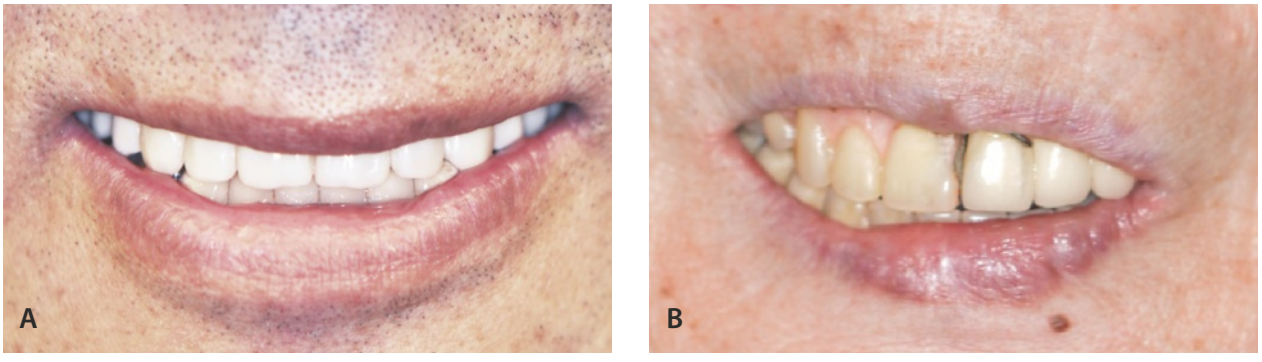
- If the columella is well supported and does not sink in and there is no need for an acrylic flange, a fixed-type of restoration might be indicated (2-9).

2-8. Profile image of the patient without denture in the mouth. Lip support with labial flange should be considered for treatment planning of the fully edentulous maxilla.

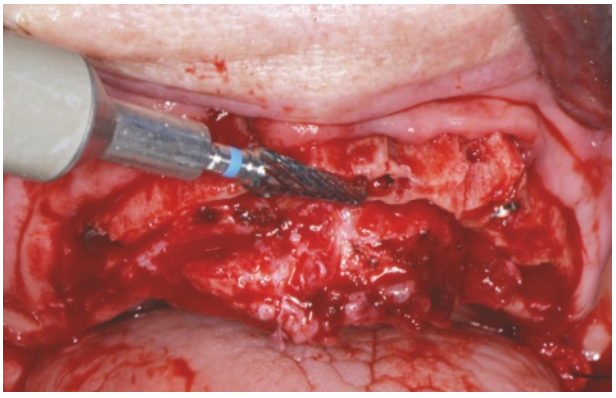
2-9. A: Profile image of the patient without denture in the mouth. B: All-on-4 screw-retained implant-supported fixed prosthesis in the maxilla. C: Profile image of the patient with the screw-retained fixed prosthesis in the mouth. Note that there is no need of a labial denture flange to support the lip.

2. Smile line

When the junction of the prosthesis and alveolar mucosa is visible, it could result in an unpleasant esthetic outcome. This is primarily because of the difficulty in matching the color of the prosthetic gingiva with the natural gingival tissues. Therefore, smile line should be appraised in the treatment planning of edentulous patients. Patients should be asked to smile without the denture in place to determine the display of the alveolar ridge during smiling. If it is exposed during smiling, the esthetics of a fixed implant-supported restoration could be compromised since the junction between the restoration and the gingiva (transition line) would be visible (2-10). This can be corrected with surgical alveoloplasty at the time of implant placement. The amount of alveolar ridge visible while smiling is measured preoperatively and a corresponding amount of bone is removed during the surgical procedure using a bone reduction guide (2-11). By locating the prosthesis-tissue junction a minimum of 2 mm beyond the visible gingiva, the junction can be concealed. An alternative option could be an overdenture which can cover the junction with its flange. It is not necessary to consider the smile line in the lower jaw, as the junction is covered by the lower lip.



2-10. A: Alveolar ridge is not displayed during smiling. B: Alveolar ridge is displayed during smiling. Note that if it is exposed during smiling, smile line should be the basis for treatment planning of the fully edentulous maxilla.



2-11. Alveoloplasty

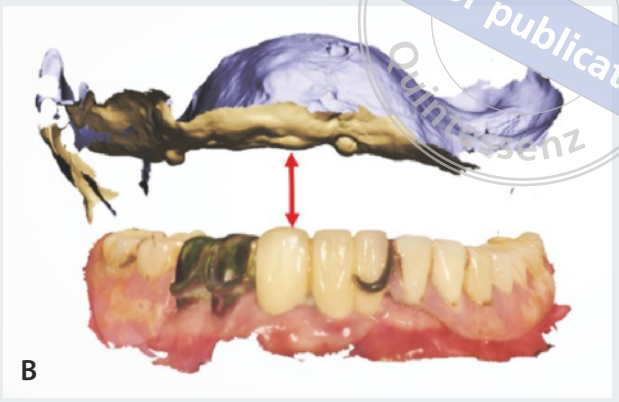
3. Amount of ridge resorption

The amount of ridge resorption dictates the type of prosthesis to be fabricated. It is necessary to determine if the patient exhibits minimal, moderate or advanced resorption since each type of prosthesis has a unique dimensional tolerance (2-12).

- Minimal resorption: In such cases, when the virtual teeth are designed as per the residual alveolar ridge, the discrepancy between the cervical portion of the teeth and the surface of the underlying alveolar mucosa is minimal (within 1 to 2 mm). Several treatment modalities are available for the patients with minimal ridge resorption, including implant-retained overdenture, cement-, or screw-retained implant-supported fixed prosthesis (2-13).

- Moderate resorption: In the maxillary alveolar ridge with moderate resorption, the posterior alveolar ridge presents a reduced vertical height and the placement of implants is not possible without sinus bone augmentation surgery. Similarly, in the mandible, moderate bone resorption does not permit placement of implants distal to the mental foramen without bone grafting. However, the ridge in the canine and premolar sites is mostly preserved. Treatment options are All-on-4 or All-on-6 screw-retained implant-supported fixed prosthesis or overdenture (2-14).

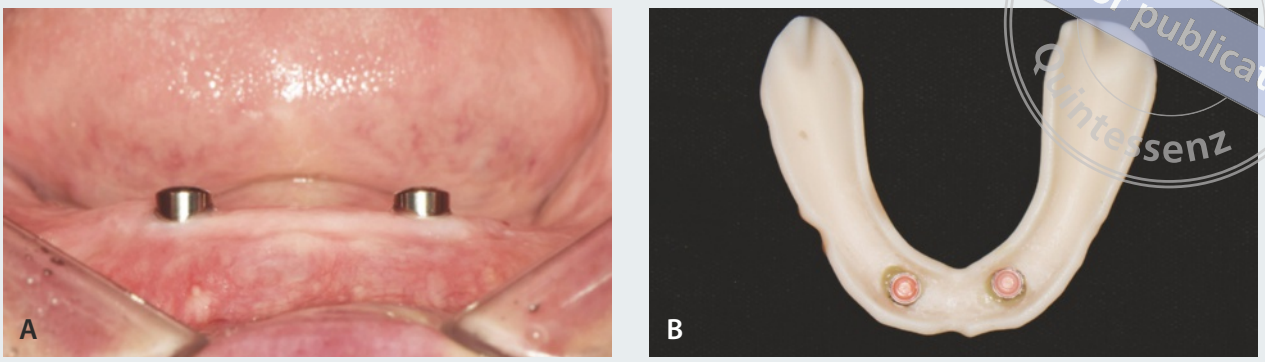
- Advanced resorption: In advanced resorption, the ridge undergoes substantial vertical and horizontal resorption to the extent that the support to the upper lip is insufficient. It is possible to place implants anterior to the anterior sinus wall in the maxilla and anterior to the mental foramen in the mandible without bone grafting. Treatment alternatives are implant-retained overdentures or All-on-4 screw-retained implant-supported fixed prostheses.
  Implant-retained overdenture: It includes placement of 2 implants in the mandible and 4 implants in the maxilla and the use of locator-type attachment (2-15).
  All-on-4 screw-retained implant-supported fixed prosthesis: It includes placement of 4 implants in the pterygoid process, anterior to the anterior sinus wall, or in close approximation to the piriform rim in the maxilla, and between the mental foramen in the mandible (2-16, 17).



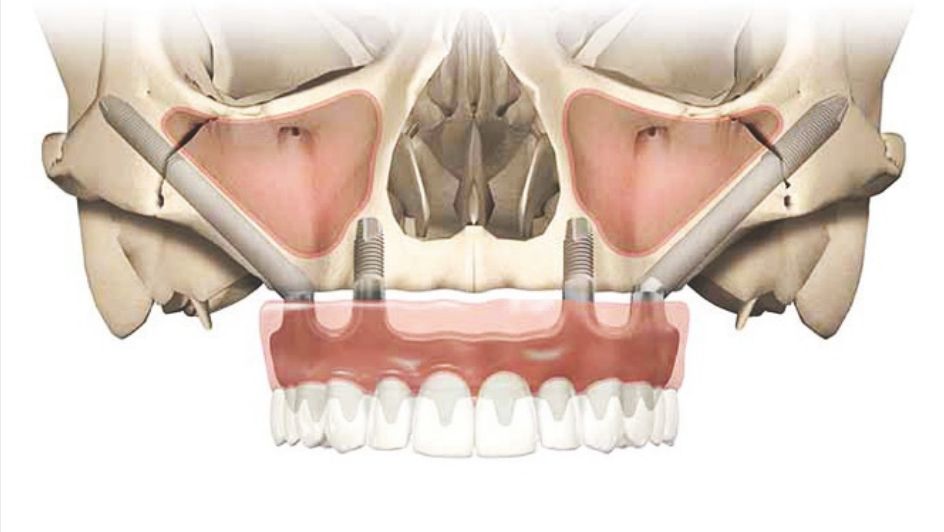
2-12. A: Virtual full-arch prosthesis design. B: Evaluation of the amount of ridge resorption. Note that it is necessary to evaluate if the patient exhibits sufficient interarch space for the type of prosthesis.

2-13. A: Patient with minimal ridge resorption. B: Cement-retained implant-supported fixed prosthesis.

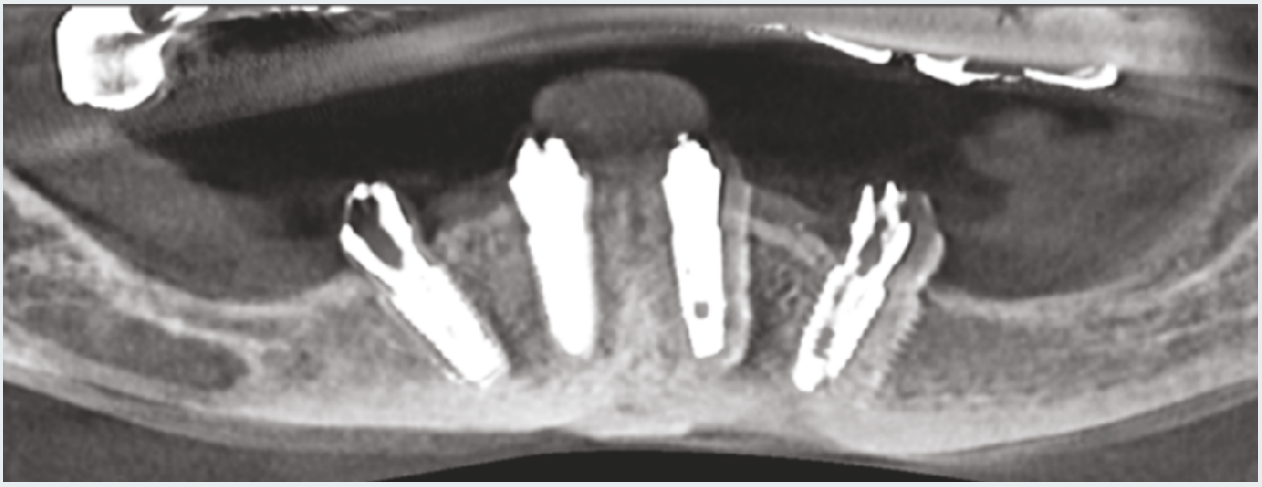
2-14. A: Patient with moderate ridge resorption. B. All-on-6 screw-retained implant-supported fixed prosthesis.



2-15. A: For a patient with advanced ridge resorption, two implants are placed for implant-retained overdenture treatment. B: Implant-retained overdenture with locator-type attachment.



2-16. All-on-4 treatment plan for patients with advanced ridge resorption in the maxilla.



2-17. All-on-4 treatment for patients with advanced ridge resorption in the mandible.

4. Interarch space

Interarch space is the distance between the edentulous ridge and the opposite occlusal plane. It dictates the type of prosthesis to be fabricated. It is important to ascertain if the available interarch space is sufficient to allow the placement of various prosthetic components necessary for implant rehabilitation.[3] The minimum space required varies, depending on type of prostheses to be delivered. A screw-retained prosthesis requires space for abutments, frameworks and prosthetic teeth. An overdenture requires space for a denture base, prosthetic teeth and an attachment. An efficient method for evaluating interarch space is to design the final restoration virtually on the edentulous ridge image (2-18). The virtual prosthesis design can be used to evaluate the available interarch space and decisions can be made regarding the anticipated prosthesis design (2-19).

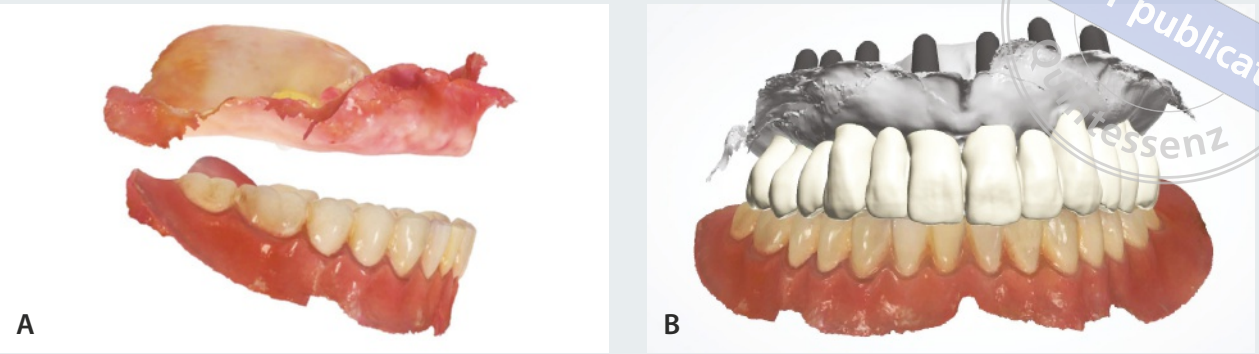
(1) Overdenture: A minimum of 9 mm space is required for locator attachment and 14 mm for bar attachment.

(2) Cement-retained implant-supported fixed prosthesis: This prosthesis requires a minimum space of 7 mm. However, a minimum of 10 mm space is necessary when considering the average tooth height.

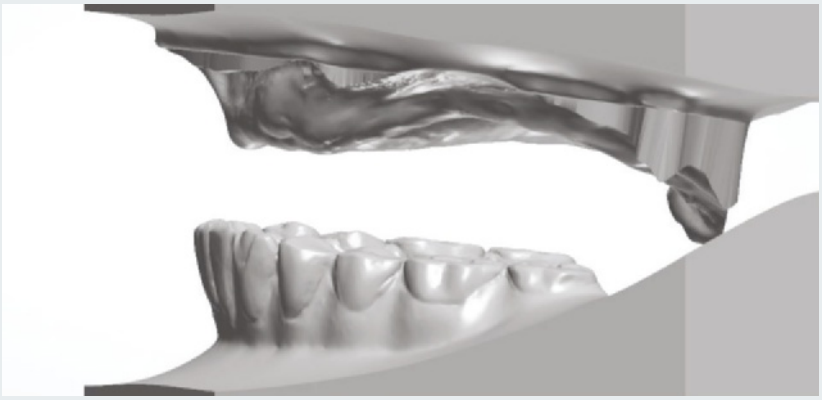
(3) Screw-retained implant-supported fixed prosthesis: A minimum of 12 mm space is required in the maxilla and 10 mm in the mandible.

When insufficient interarch space is diagnosed during implant planning, it can be corrected with an alveoloplasty or by increasing occlusal vertical dimension (OVD) (2-20). If the OVD is increased by 6 mm or more, it may exceed the patient's ability to adapt. Such a magnitude of change can result in increased masticatory stress and pain in the muscles of mastication. Abduo reported that, whenever indicated, a permanent increase in the OVD up to 5 mm is a safe and predictable procedure without detrimental consequences.[4] If the interarch space is severely limited, it should be corrected with an alveoloplasty. If the interarch space is moderately limited, it can be corrected by increasing the OVD (2-21A-G). (QR 2-1)

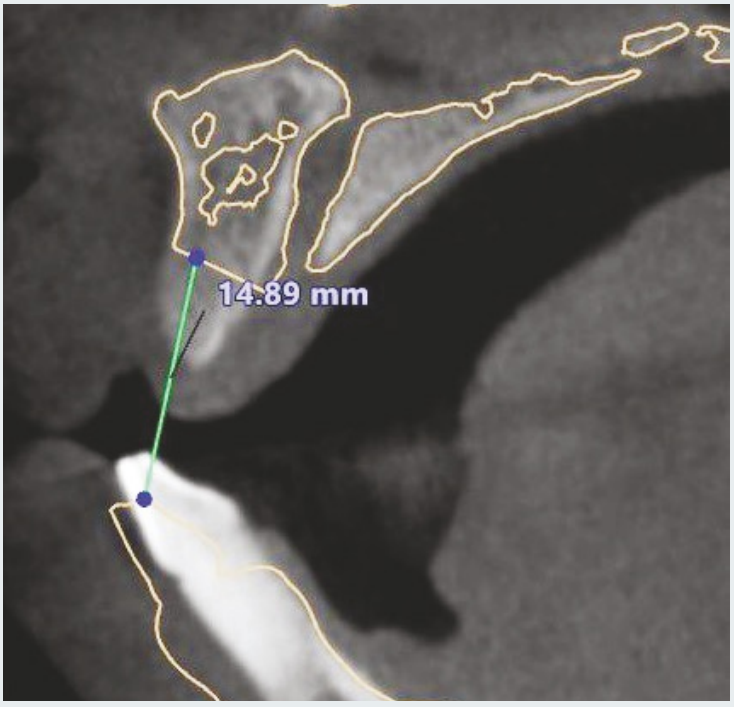
QR 2-1. Case where limited inter-arch space was corrected by increasing occlusal vertical dimension.



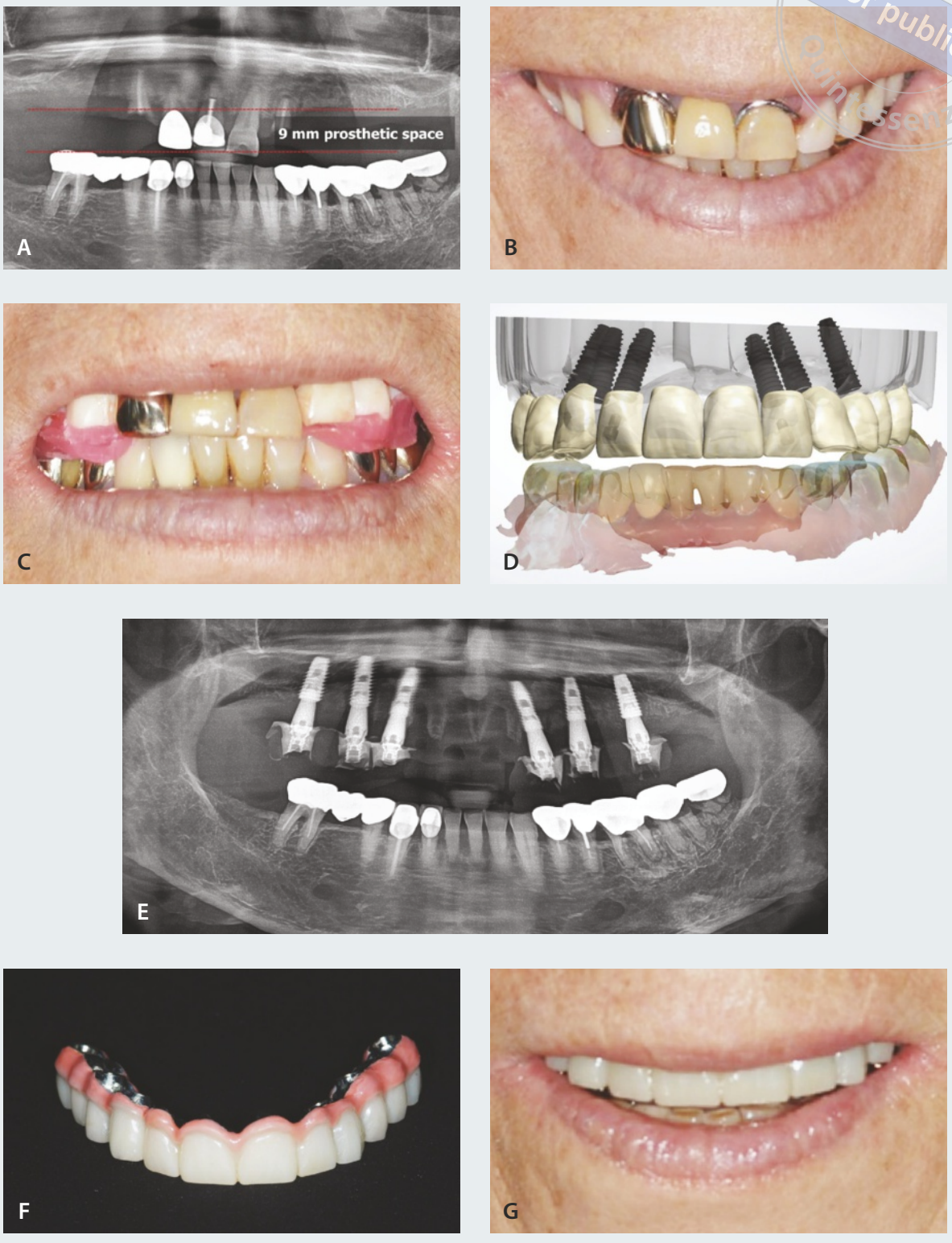
2-18. A: Interarch space. B: Virtual full-arch prosthesis design.



2-19. Interarch space between the edentulous ridge and the opposite occlusal plane.



2-20. Limited interarch space can be corrected with an alveoloplasty.



2-21. Case where limited interarch space was corrected by increasing occlusal vertical dimension. A: The distance between the alveolar crest and the opposite occlusal plane was 9 mm. B: High smile line. C: Frontal image of the patient after increasing occlusal vertical dimension by 3 mm. D: All-on-6 screw-retained implant-supported fixed prosthesis planning. E: Posttreatment panoramic radiograph. F: Provisional screw-retained full-arch prosthesis. G: Frontal image of the patient with the prosthesis.

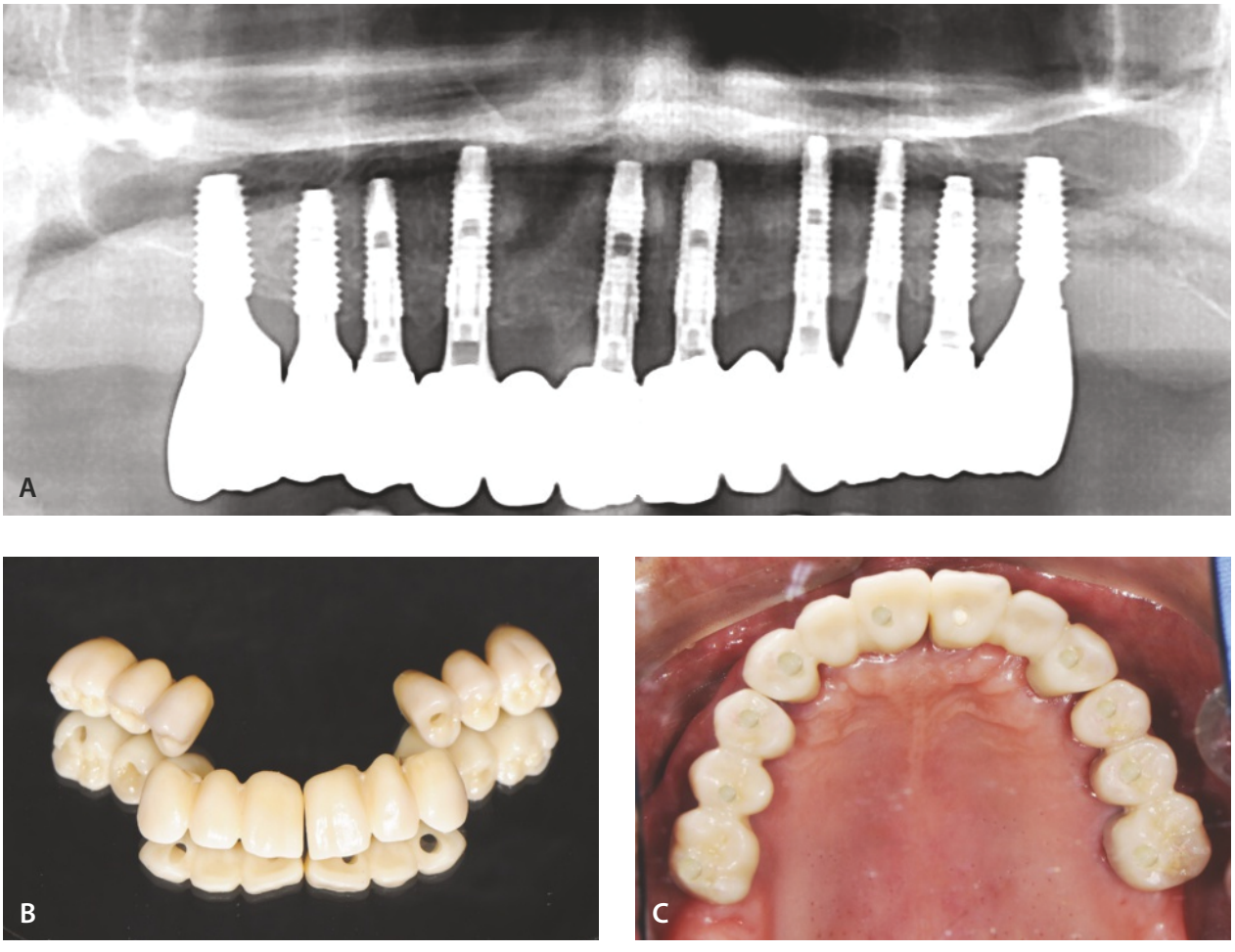
5. Number of implants

The number of implants may vary according to the type of prosthesis.

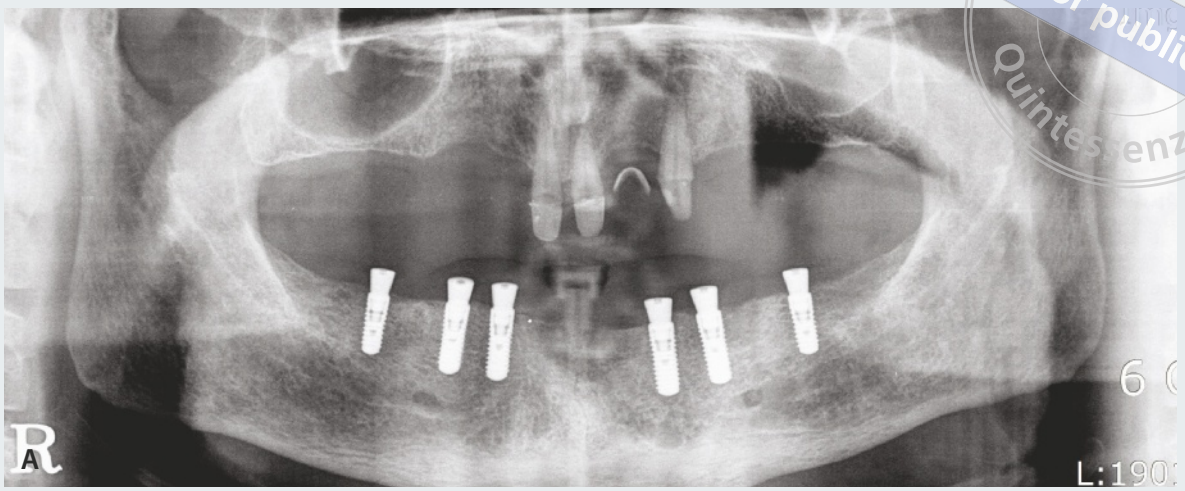
(1) Cement-retained implant-supported fixed prosthesis:
Eight to 10 implants are placed in the maxilla, which allow fabrication of 3 or 4 separate 3-unit bridges (2-22). In the mandible 6 to 8 implants are placed, which aid in fabrication of 3 separate 3-unit bridges (2-23).

(2) Screw-retained implant-supported fixed prosthesis:
Six (All-on-6) or 4 implants (All-on-4) are placed and their prostheses are always in a single piece (2-24).

(3) Overdenture:
Implant-retained overdenture: Four implants are used in the maxilla and 2 implants in the mandible.
Implant-supported overdenture: Four or 6 implants are used (2-25).

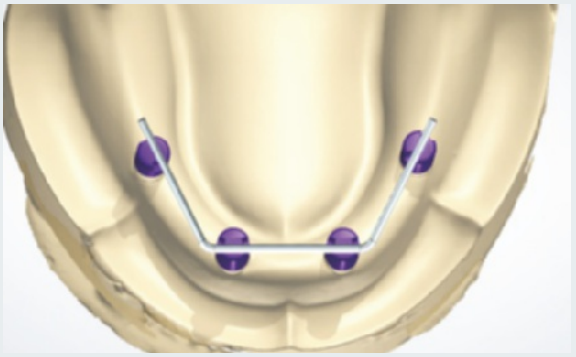


2-22. Cement-retained implant-supported full-arch fixed prosthesis in the maxilla. A: Panoramic radiograph. B: Four separate bridges. C: Occlusal view.



2-23. Cement-retained implant-supported full-arch fixed prosthesis in the mandible. A: Panoramic radiograph. B: Three separate bridges. C: Occlusal view.

2-24. Screw-retained implant-supported full-arch titanium framework.

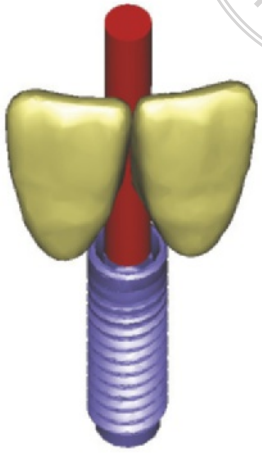


2-25. Implant-supported overdenture planning.

6. Implant position

i. Cement-retained implant-supported fixed prosthesis:

Implant position is critical in order to obtain optimum emergence profile for cement-retained implant-supported fixed prostheses. If implants are placed in interproximal positions, they can cause problems from both an esthetic and hygiene perspective (2-26). Precise implant placement is imperative and should be performed by the use of a surgical guide based on virtual implant planning. Commonly used implant positions are the first molar, first premolar, canine, and central incisor areas in the maxilla, and the first molar, first premolar, and canine areas in the mandible (2-27, 28).



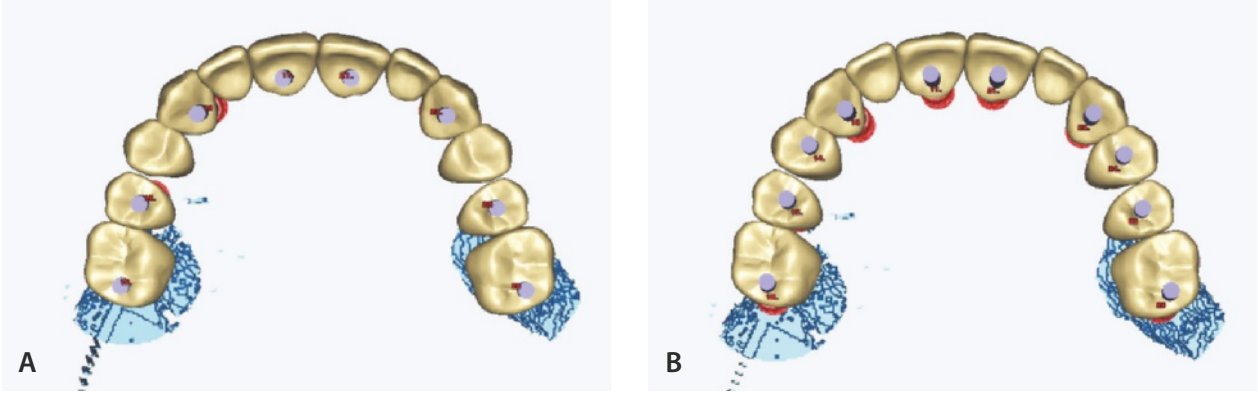
2-26. If implants are placed in interproximal positions, they can cause problems from both an esthetic and hygiene perspective in cement-retained implant-supported fixed prosthesis.

ii. Screw-retained implant-supported fixed prosthesis:

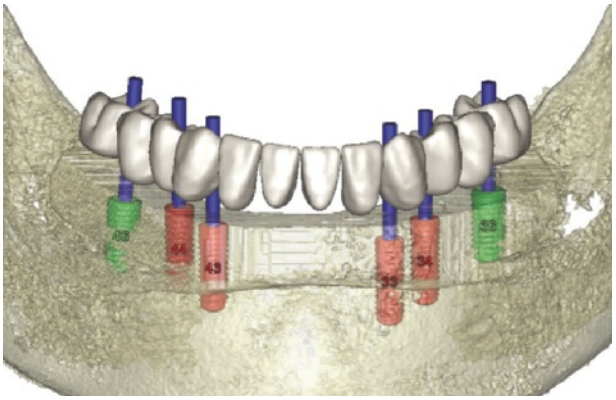
Implant position is not critical for screw-retained implant-supported fixed prostheses. If implants are placed in interproximal tooth positions, it does not impact the esthetics since they are disguised by the gingival areas of the prosthesis. Implant distribution is critical since the implants need to be placed so that the load can be shared equally (2-29). Splinting the implants is also important to improve the biomechanics of the prosthesis.

iii. Overdenture:

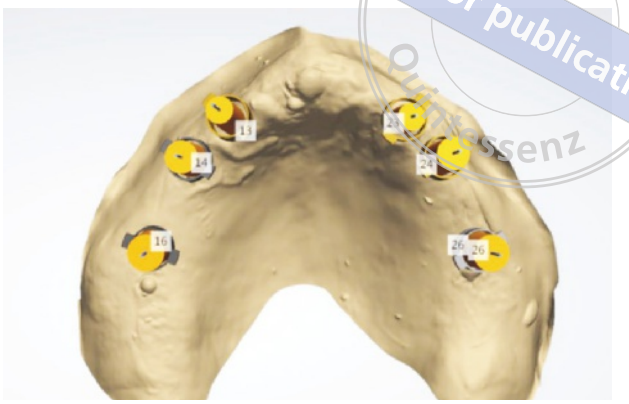
In overdentures, implant position is not critical but implant distribution is important. Implants need to be placed with a sufficient antero-posterior spread so that the load can be distributed over a wide area and cantilever length is minimized. When a bar is used, it should have a straight-line connection between the implants. The implant position should also ensure adequate room for the cap.[5,6]



2-27. For cement-retained implant-supported fixed prosthesis, the most commonly chosen protocol includes placement of 8 (A) or 10 (B) implants in the maxilla



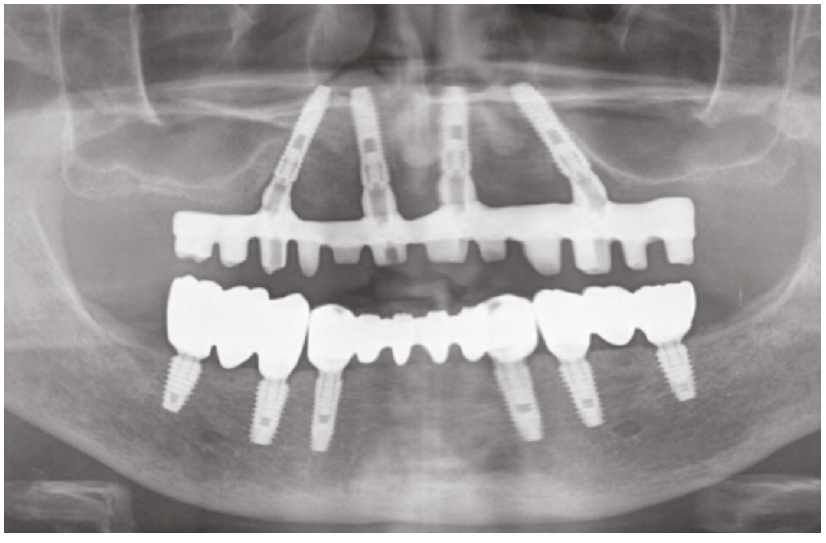
2-28. The most commonly used implant positions for cement-retained implant-supported fixed prosthesis in the mandible are the first molar, first premolar, and canine areas.



2-29. Implant positions for screw-retained implant-supported fixed prosthesis. Note that implant position is not critical for the screw-retained implant-supported fixed prosthesis.

7. Opposite dentition

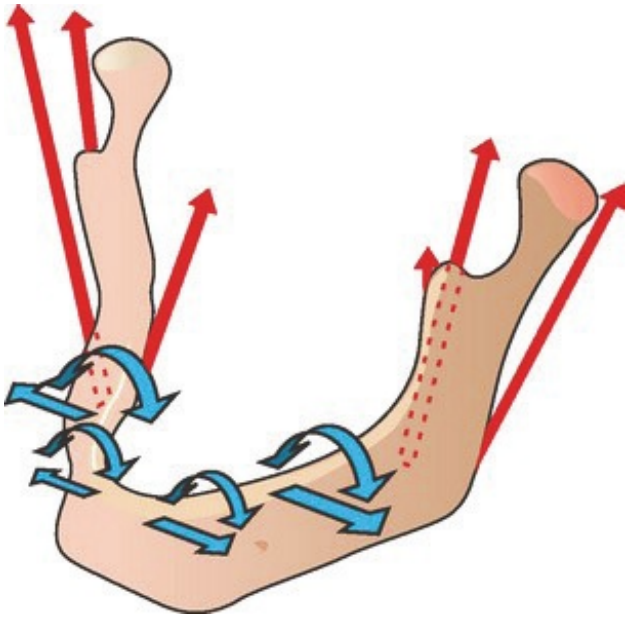
The opposite detention must also be examined in determining the optimal prosthetic choice. In a situation where only one arch is rendered edentulous, the natural teeth generate high occlusal forces and exert excessive load on the prosthesis, which may result in screw loosening and screw fracture, bone loss around the implant, or prosthesis fracture. Therefore, patients who generate heavy occlusal forces need more implants and greater stability of prosthesis. For patients who have a history of frequent fractures of the prosthesis, severe dental attrition, or strong masticatory muscles, increase in number and size of implants should be planned. Patients with an edentulous ridge in both jaws may experience less problems with implant-supported prostheses than those with only one edentulous arch (2-30).



2-30. Patients with an edentulous ridge in both jaws experience less problems with implant-supported prostheses than patients with only one edentulous arch.

8. Mandibular dynamics

The maxilla and mandible present different biomechanics. Many reports have addressed the dimensional changes of the mandible during jaw movement as a result of masticatory muscle action. Flexure and torsion of the mandible has been observed during jaw movements (2-31). The mandibular bone between the mental foramen is relatively stable in terms of flexure and torsion. However, distal to the foramen, the mandible exhibits significant movement.[7] Consequently, implant-supported full-arch fixed prostheses with cross-arch connection of posterior mandibular implants may cause bone loss around the implants, implant loosening, fracture of implant or prosthesis components, and discomfort upon opening. Therefore, full-arch splinted restorations joining bilateral molar implants in the mandible should not be a treatment of choice. However, when splinting 4 implants (All-on-4) between the mental foramina in the mandible with a full-arch splinted fixed restoration, mandibular dynamics may not influence the implants or prognosis of the prosthesis.[8]



2-31. Mandibular dynamics.

9. Patient preference

Meeting patients' expectations is paramount during treatment planning. Esthetics is a major cause of failure. Patient communication at the outset is of utmost importance. To avoid any unexpected surprises sufficient time must be devoted in educating the patient about the relative advantages and disadvantages of proposed treatment. Patients' desire for a fixed reconstruction should be assessed. Patients can be satisfied with the esthetic appearance of a denture that replicates the appearance of the soft tissues and interdental papillae between the denture teeth. Therefore, treatment should be customized to meet the patient needs.

10. Cost

Full-arch fixed reconstructions require more laboratory assistance and implant parts, hence, are a lot more expensive than overdentures. However, cost needs to be considered not only during the fabrication of the prosthesis but also during maintenance.

Overdentures seem to require more postinsertion maintenance than their fixed counterparts.[9] The patient must be made aware that maintenance costs for removable prostheses on implants will be higher than that of a fixed prosthesis.

Steps to choose treatment option in fully edentulous patients:

Step 1: Ascertain the need for fixed or removable prosthesis. A removable solution is chosen for patients requiring a denture flange or who are unable to maintain adequate oral hygiene. If the esthetic and functional challenges cannot be overcome with fixed prostheses in a severely resorbed alveolar ridge, a removable one is selected. If a high smile line cannot be corrected with a fixed prosthesis, a removable option is advised.

Step 2: If a fixed prosthesis option is chosen, evaluate whether screw- or cement-retained fixed prosthesis is required.

Step 3: If a screw-retained fixed prosthesis is chosen, evaluate whether All-on-6 or All-on-4 prosthesis is required.

Step 4: If a removable option is chosen, determine the type of attachments required in the removable prosthesis: bar, magnet, or ball.

Step 5: Identify whether alveoloplasty is indicated.

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