Flapless CAD/CAM-guided surgery for staged transition from failing dentition to complete arch implant rehabilitation: A 3-year clinical report

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The transition of patients from failing dentition to complete arch implant rehabilitation often requires that the patient be rendered edentulous and has to wear a complete removable dental prosthesis for varying periods of time. This is objectionable to many patients. A staged treatment approach allows a fixed interim restoration, patient comfort, and prosthodontic control throughout the rehabilitation process. CAD/CAM-guided flapless implant surgery has the advantage of prosthetically driven implant placement and minimal postoperative sequelae. A patient with a failing dentition was treated with this combined protocol and was followed up for 3 years after loading. Implant and prosthesis survival rates were 100%, with no technical complications encountered up to the last recall. The purpose of this clinical report is to describe a combination of CAD/CAM-guided flapless surgery and a staged treatment approach, thereby giving the patient a tooth-supported or implant-supported fixed interim prosthesis during the entire rehabilitation process. The various surgical, laboratory, and prosthetic stages are illustrated for the complete arch prosthetic rehabilitation, and the 3-year follow-up outcome is reported.
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The longitudinal effectiveness of treatment with dental implants has been demonstrated for both partially and completely edentulous patients.[1,2] Currently, there is a growing interest in the medical and dental field for minimally invasive procedures as a standard treatment. Computer-planned, template-guided surgery is one of the new approaches for implant treatment. It includes a combination of computed tomography (CT) high resolution images, 3-dimensional (3-D) planning software, and a computer-aided design/computer-aided manufacturing (CAD/CAM)-generated surgical template.[3-5]

CAD/CAM technology and CT imaging coupled with interactive planning software provides great advantages when planning and executing implant surgery. The benefits of this computer-guided surgical protocol seem superior to existing surgical and prosthodontic procedures and include its minimally invasive nature, prosthetically driven surgery, predictability, and the reduced time required for definitive rehabilitation.[3-8] The benefits of flapless implant placement include reduced healing times, fewer changes in crestal bone levels, less bleeding, and minimal postoperative discomfort and swelling.[9,10]

The rehabilitation of a failing dentition with dental implants often involves the possibility of rendering the patient edentulous for varying periods of time. Many patients object to that and request fixed interim restorations throughout the rehabilitation process.[12] Various treatment approaches have been described pertaining to the rehabilitation of advanced periodontal disease and failing dentition.[11-14] In an attempt to improve patient comfort and avoid the use of a removable prosthesis, immediate implant placement with or without an immediate interim restoration for the rehabilitation of hopeless dentitions has been proposed; however, there are no long-term data regarding the effect on soft tissues.[14]

The staged treatment approach includes the strategic retention of some hopeless teeth to serve as abutments for an interim fixed prosthesis during the osseointegration period.[14-16] A staged approach consists of the following steps: 1) diagnosis and treatment planning; 2) elimination of disease; 3) Strategic extractions and tooth-supported interim restoration; 4) prosthetically driven implant placement followed by healing period; 5) conversion of the tooth-supported to implant-supported interim restoration, followed by extraction of the remaining teeth and soft tissue conditioning; and 6) prosthodontic procedures for definitive rehabilitation. This treatment option has the benefits of having fixed interim restorations throughout the treatment and of providing maximum patient

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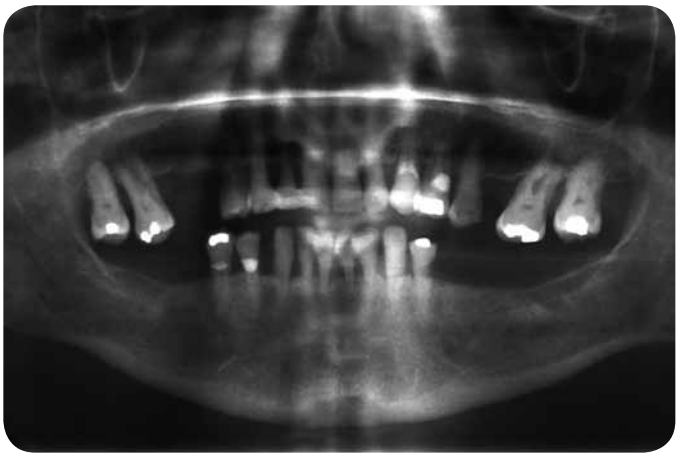
comfort.[9] Additionally, prosthodontic control is enhanced by finalizing guidance and esthetics through the fixed interim restorations, and established landmarks are easy to transfer to the definitive restorations. Limitations may exist, given the extent of the treatment.

Previous reports on staged protocols included the retention of strategic teeth as abutments, implant placement, and extraction of the remaining teeth, followed by additional implant placement.[14] This increased the treatment time and the number of implant surgical procedures. Conversely, during the treatment planning phase of the treatment described in this report, the selection of the retained teeth was made by considering the subsequent implant sites, and all implants were placed in one step at one time, thereby reducing the surgical interventions.

The purpose of this clinical study is to describe a combination of CAD/CAM-guided flapless surgery and a staged treatment approach with which the patient has a tooth-supported or implant-supported fixed interim prosthesis during the entire rehabilitation process. Different loading protocols were applied for the maxilla and mandible. The various surgical, laboratory and prosthetic stages are illustrated for the complete arch prosthetic rehabilitation, and the 3-year post loading outcome is reported.

CLINICAL REPORT

A 68-year-old woman was referred to the postdoctoral Prosthodontics clinic at Columbia University College of Dental Medicine, New York for implant consultation. The patient's medical history was noncontributory, and there were no contraindications for dental treatment. Comprehensive clinical examination revealed partial edentulism and a failing dentition as a result of advanced periodontal disease and caries. All teeth presented with class III mobility. Loss of posterior teeth resulted in the collapse of occlusal vertical dimension (OVD) and splaying of the anterior teeth. Preliminary radiographic screening was performed by using digital panoramic and complete mouth periapical radiographs (Fig. 1).



1 Initial panoramic radiograph showing failing dentition.

Preliminary impressions were made with irreversible hydrocolloid (Jeltrate Plus; Dentsply Caulk, York, Pa). The diagnostic casts were articulated in a semi-adjustable articulator (Panadent; Panadent Corp, Grand Terrace, Calif) with the aid of facebow transfer and a centric relation (CR) interocclusal record. The condylar diagnostic settings were adjusted with the aid of laterotrusive and protrusive interocclusal records. According to the Prosthodontic Diagnostic Index (PDI) Partial Edentulism Classification system, the patient was characterized as class III.[17] The dentition was diagnostically waxed to facilitate the fabrication of an interim prosthesis.

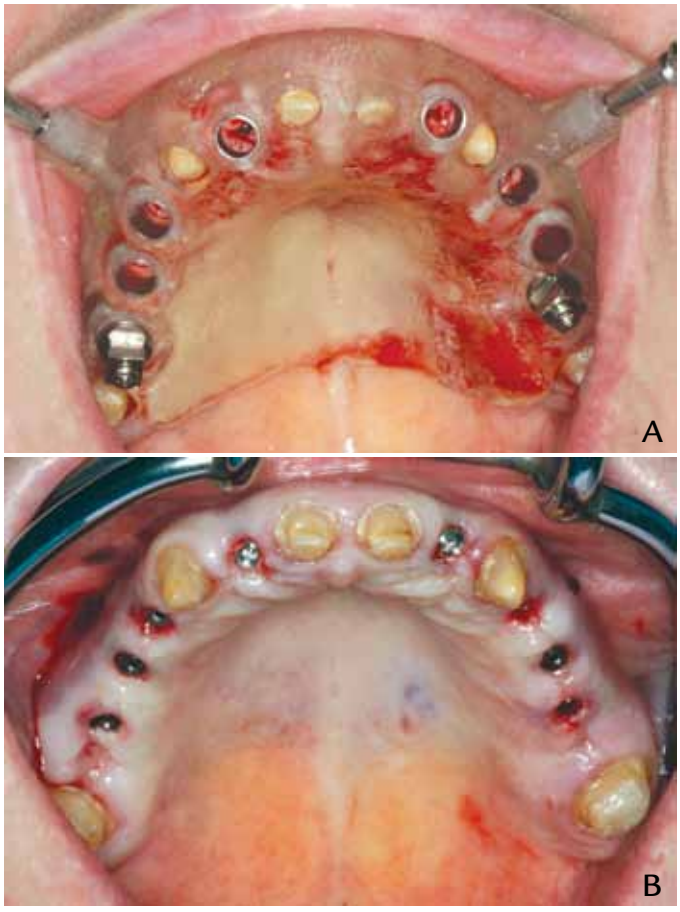
The patient's existing dentition was deemed hopeless as a result of advanced periodontal disease. Treatment goals consisted of 1) restoration of lost OVD, 2) correction of occlusal plane, and 3) restoration of esthetics and function. Various treatment options were presented to the patient.

The patient refused to wear a removable prosthesis at any time during the treatment. The decision was made to proceed with a staged treatment approach since the patient presented with residual teeth able to serve as temporary abutments for an interim fixed dental prosthesis (FDP). A minimally invasive approach with computer-guided flapless implant placement and staged interim restorations with tooth and implant retention was chosen as the treatment of choice.

After an appointment with the periodontist for scaling and root planing, strategically positioned abutment teeth were prepared (central incisors, canines, and third molars in the maxilla; canines and left first and right second premolars in the mandible). Subsequently, the remaining mandibular and maxillary teeth were extracted serially. After the extractions, a laboratory-processed interim maxillary FDP with lingual metal reinforcement and a mandibular FDP with lingual wire reinforcement were placed intraorally and positioned with the aid of vacuum-formed templates. The interim FDPs were relined with autopolymerizing acrylic resin (Alike; GC America Inc, Alsip, Ill) and cemented with provisional cement (Tempbond NE; Kerr Manufacturing Co, Romulus, Mich). The pontics at the extraction sites were shaped to an ovate design. Minor occlusal adjustment was performed to maximize comfort, and analgesic medication was prescribed (Advil; Wyeth, Los Angeles, Calif) to control postoperative pain. At the second week recall appointment, the patient expressed satisfaction and comfort with the new fixed interim prostheses (Fig. 2).

Eight weeks after the extractions,

2 Fixed interim restoration after extraction of failing teeth.

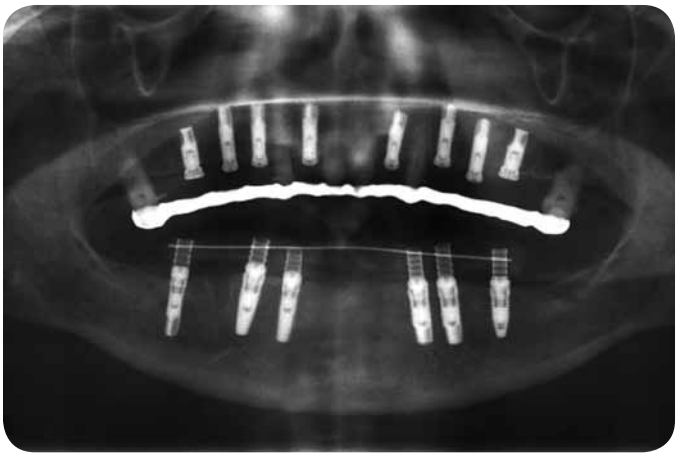


3 A, Computer-planned, CAD/CAM-guided implant surgery with stereolithographic template. B, Flapless implant placement.

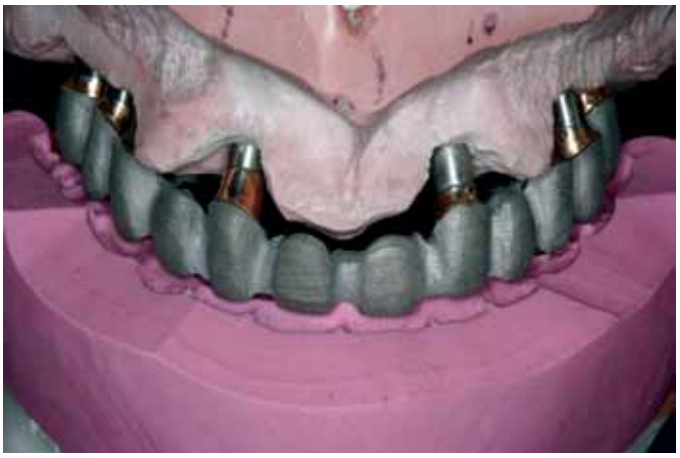
the patient presented for the fabrication of the radiographic templates required for the computerized tomography (CT) scan. Impressions of the interim prostheses as well as of the partially edentulous jaws were generated with irreversible hydrocolloid (Jeltrate Plus; Dentsply Caulk), and casts were cross-mounted on the articulator (Panadent; Panadent Corp) with a facebow transfer and CR interocclusal record. Maxillary and mandibular radiographic templates with 12 radiopaque gutta-percha markers were fabricated with clear acrylic resin (Ortho Resin; GC America Inc, Alsip, Ill) as previously described.[9] An occlusal index registration was made with vinyl polysiloxane PVS material (Regisil; Dentsply Caulk, Milford, Del) on the articulator, and the radiographic templates were evaluated and adjusted intraorally. At the evaluation appointment, a double CT scan was prescribed. The data from the patient's CT scan were reformatted, and a 3-D implant planning software (Nobel Guide; Nobel Biocare USA, Yorba Linda, Calif) was used to plan the ideal implant locations virtually. In the virtual surgical planning, the maxilla presented with sufficient width and length to accommodate 6 Narrow Platform (NP) and 2 Regular Platform (RP) implants (Brånemark Mk III TiUnite; Nobel Biocare USA), while the mandible presented with adequate crest width at the coronal part of certain sites. However it was not possible to accommodate implants without minor ridge reduction. Subsequently, the virtual implant planning was sent via email to a rapid prototyping manufacturing facility (Procera; Nobel Biocare USA) for fabrication of the maxillary stereolithographic surgical template. After explaining the various treatment options to the patient, she consented to proceed with conventional flap implant placement in the mandible with simultaneous ridge reduction.

After receipt of the stereolithographic template and associated laboratory prosthodontic procedures, the maxillary CAD/CAM-guided flapless implant surgery was scheduled and performed with strict adherence to the surgical protocol (Fig. 3).[5,6] Upon completion of the surgery, the maxillary interim fixed prosthesis was recemented. Chlorhexidine (Peridex; Zila Inc, Phoenix, Ariz) mouth rinse was prescribed. At the 1 week postoperative appointment, the patient expressed her satisfaction with the outcome as well as minimal postoperative pain and swelling.

Four weeks after the maxillary implant surgery, the mandibular implant surgery was performed. At that visit, 4 RP and 2 NP implants (Replace TiUnite; Nobel Biocare USA) were placed in the sites planned from the CT scan. An insertion torque of 45 Ncm was reached, thus allowing for



4 Postoperative panoramic radiograph after mandibular implant surgery, fixed interim restoration with conversion prosthesis technique, and immediate loading after extraction of remaining teeth.



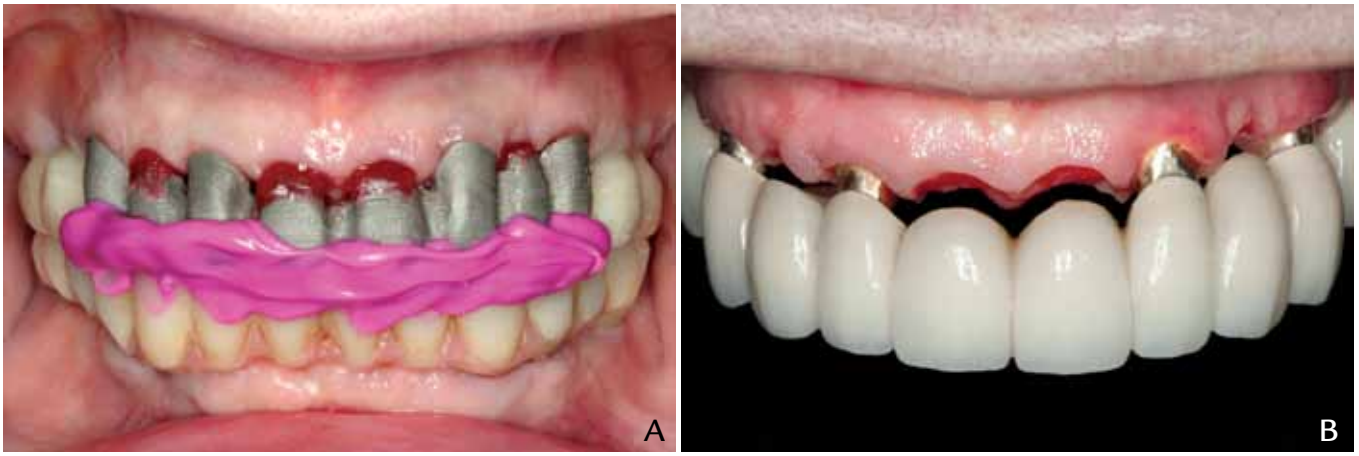
5 Metal frameworks' contour dictated by silicone index from cross-articulated interim restorations.

the application of immediate load. The interim wire-reinforced FDP was relieved with an acrylic bur (H79EF; Brasseler USA, Savannah, Ga) to allow temporary nonengaging abutments to be tightened on the implants. Autopolymerizing polymethyl methacrylate resin (Alike; GC America Inc) was mixed to a light consistency, and a syringe was loaded with the acrylic resin. Then, the acrylic resin was injected to connect the abutments to the FDP with the conversion prosthesis technique.[12] The 1-piece screw-retained FDP was finished and polished in the laboratory and subsequently inserted after the remaining teeth were extracted. A postoperative panoramic radiograph was made and nonsteroid antiinflammatory medication (Advil; Wyeth Pharmaceuticals Inc) and chlorhexidine (Peridex; Zila Inc) mouth rinse were prescribed to control postoperative pain (Fig. 4). At the recall appointment 1 week later, the patient expressed satisfaction with the functional and esthetic outcome. When asked which procedure was more comfortable, the patient said she preferred the flapless surgical procedure.

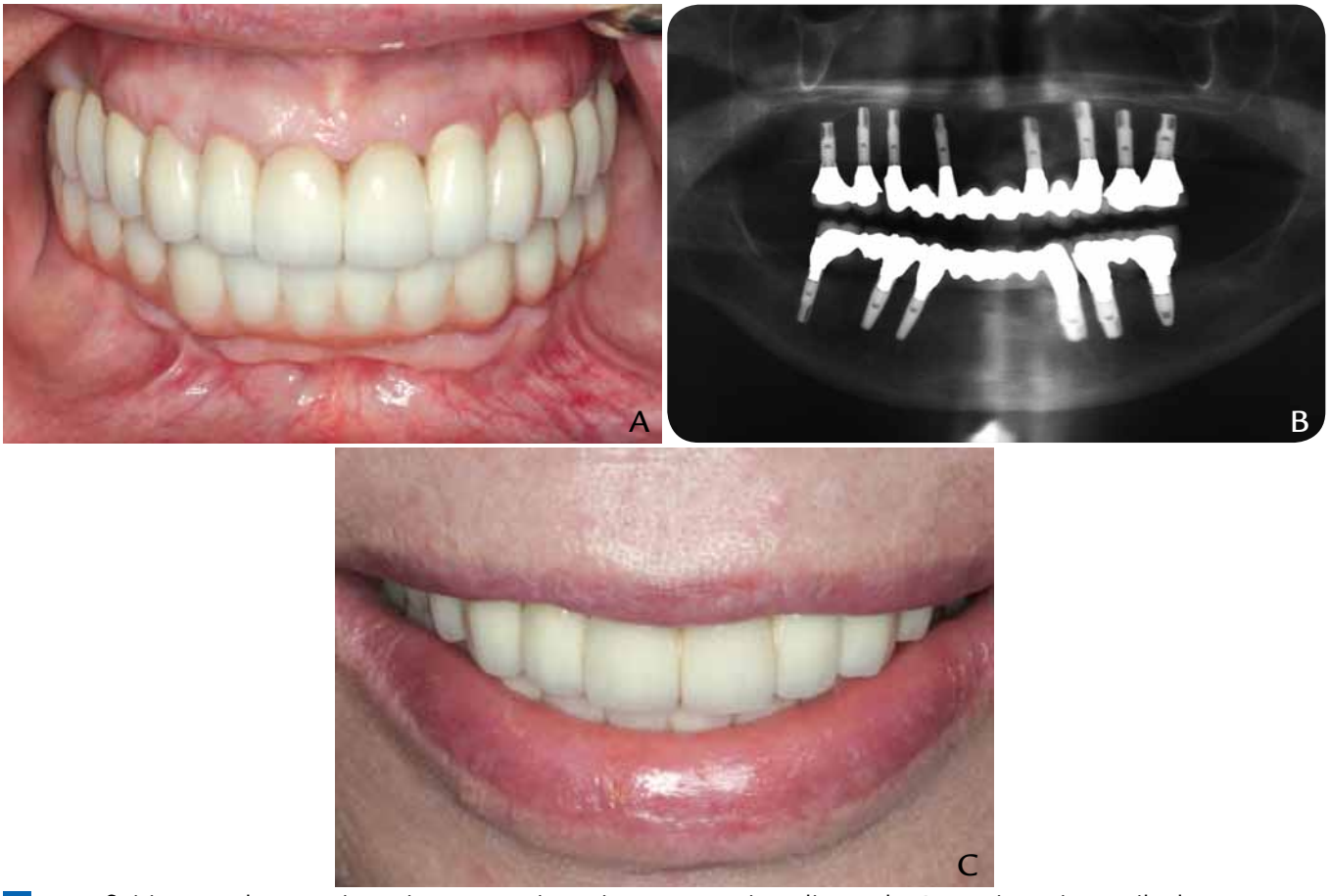
Four months after implant placement, the maxillary second stage surgery was performed, and healing abutments were connected to the implants. A minimally invasive procedure done with a tissue punch was used to expose the implants. After 2 weeks, the tooth-supported interim FDP was relieved at the midpontic area to accommodate the temporary abutments.[16] Temporary nonengaging abutments were connected to the maxillary implants, and the screw access channels were protected with wax. For the 2 implants at the lateral incisor area, the inclination did not allow for screw retention, and so the healing abutments were left in place. With the same technique as previously described for the mandible, the temporary abutments were connected to the tooth-supported FDP with acrylic resin (Alike; GC America Inc) to fabricate a screw-retained FDP. At this point, the remaining hopeless abutment teeth were extracted, and the extractions sites received ovate pontics to condition the soft tissues.

After 8 months of soft tissue maturation, the patient presented for the definitive impressions. Financial restraints demanded that the waiting period be extended. Secondly, time was given to address potential gingival recession after the extractions and the second stage surgery. Modifications of the interim FDPs were made during this period to finalize and idealize the tooth proportions and spatial orientation. A new facebow registration was made to articulate the maxillary cast. Irreverisible hydrocolloid (Jeltrate Plus; Dentsply Caulk) impressions of the maxillary and mandibular prostheses were also made to cross articulate the casts of the interim restorations with the definitive implant casts for maximum prosthodontic control. Furthermore, the patient's envelope of anterior guidance was recorded on the articulator by using the cross-articulated casts of the patient's existing interim restorations. Acrylic resin (Alike; GC America Inc) was used to make a custom anterior guide table on the articulator.

Silicone putty (Lab Putty; Coltene/Whaledent Inc, Cuyahoga Falls, Ohio) was adapted around the buccal surfaces of the articulated casts of the interim restorations to form an index which would provide the spatial orientation of the teeth and aid in the selection of abutments and framework design.[4] The maxillary and mandibular implant level impressions were made with perforated custom tray and polyether impression material (Impregum; 3M ESPE, St Paul, Minn). Impression copings were connected to the implants and splinted together with dental floss and autopolymerizing acrylic resin (GC Pattern Resin; GC America Inc).[4] The assembly was sectioned and rejoined to allow for the polymerization shrinkage of the resin to occur. The definitive



6 A, Sequential interocclusal records with segmented interim restorations. Acrylic resin was used to capture soft tissue morphology created by ovate pontics. B, Conditioned soft tissues before insertion of definitive prostheses



7 A, Definitive prostheses at insertion. B, Postinsertion panoramic radiograph. C, Postinsertion smile demonstrating pleasant symmetry and esthetics.

implant casts were poured with Type IV dental stone (Silky Rock; Whip Mix Corp, Louisville, Ky) with a double pouring technique.[18-20]

The maxillary interim FDP was sectioned in the 2 areas between the first and second premolar, bilaterally, and sequential CR records were obtained by injecting VPS registration material, maintaining at the same time the established OVD. The mandibular FDP was kept as 1-piece and interocclusal records were made against it. After cross-mounting all casts in the articulator, the decision was made to rehabilitate the patient with segmented cement-retained implant restorations with 3 FDPs in the maxillary arch (right first molar and second premolar, first premolar to first premolar, and left first molar and second premolar) and 2 FDPs in the mandible (left first molar to first premolar and left canine to right first molar).

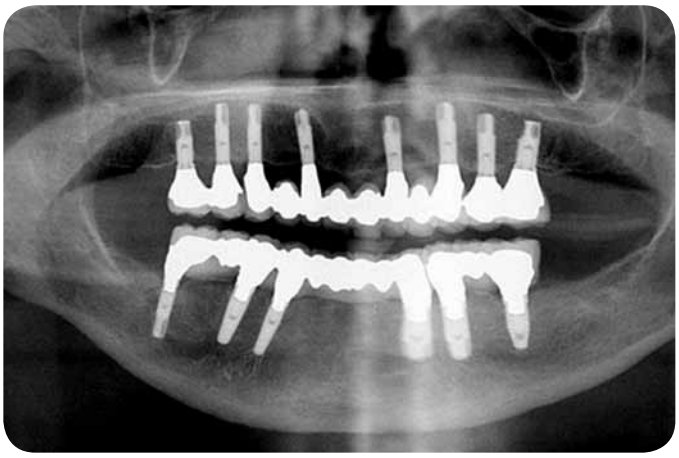
The dental laboratory technician was instructed to wax and cast all customized abutments and frameworks for the maxilla and mandible (Fig. 5). It was requested that the transmucosal part of the customized

abutments be straight and not excessively contoured and the facial finishing lines of the abutments be placed 1 mm subgingivally for esthetic reasons.

At the following clinical visit, the abutments and metal frameworks for both maxillary and mandibular arch were evaluated (Fig. 6A). The accuracy of fit was confirmed clinically and with periapical radiographs. Acrylic resin (Pattern Resin; GC America Inc) was used to capture soft tissue morphology created by ovate pontics. New CR records were made with the aid of segmented interim restorations to enable cross articulation, followed by framework transfer impressions with polyether (Impregum; 3M ESPE) to capture the framework-soft tissue relationship.

In the dental laboratory, the metal frameworks were veneered with feldspathic porcelain (Willi Geller Creation; Jensen Dental, North Haven, Conn) by using the silicone index as a guide. Mutually protected occlusion with anterior guidance was the prescribed occlusal scheme. Three weeks later, the segmented FDPs were evaluated at the bisque stage, and minor occlusal adjustments were made. Articulating paper (AccuFilm II; Parkell Inc, Edgewood, NY), and shimstock foil (GMH; Hanel Medizinal, Nürtingen, Germany) were used for occlusal assessment. A new CR record was made, and all the prostheses were sent out for final glaze.

At the final insertion appointment, the custom abutments were torqued at 35 Ncm, and the screw access channels were sealed with cotton and composite resin (Z250; 3M ESPE) before the prostheses were evaluated (Fig. 6B). Subsequently, the segmented FDPs were cemented with provisional cement (Improv; Nobel Biocare USA), and a panoramic radiograph was made (Fig. 7). One week later the patient expressed satisfaction with the esthetics and function. A nightguard was provided to protect the prostheses from porcelain chipping and parafunctional activity. At the recall appointment 3 years after loading, the patient remained satisfied with the quality of the implant rehabilitation. Upon clinical and radiological examination, no biological or technical complications were noted (Fig. 8).



8 Panoramic radiograph at 3 years after loading.

DISCUSSION

The patient expressed satisfaction with the transition from tooth-supported to implant-supported prosthesis since fixed interim restorations had been strongly requested. This clinical report integrates various techniques and new technological advances in the treatment of the failing dentition to maximize patient comfort and prosthodontic control.

Previous reports on staged protocols included retention of strategic teeth as abutments, implant placement, and extraction of the remaining teeth, followed by additional implants.[14] Conversely, during the treatment of this patient all the implants were placed at the same appointment, reducing the surgical interventions. This is more efficient and less invasive for the patient since only a single implant surgical procedure is performed. However, it must be mentioned that the condition of the remaining teeth and the envisioned design play a significant role in the decision as to which teeth to use as interim abutments for fixed interim restorations.

The staged approach eliminated the need for removable prostheses and maximized patient comfort and prosthodontic control. Limitations pertain to a longer treatment time than with the option of removing the hopeless dentition and inserting a removable prosthesis. However, the extension of treatment may be favorable for the patient's finances since complete arch implant therapy has a significant cost.

CT imaging coupled with interactive planning software provides advantages for the planning and execution of the implant surgery. CAD/CAM-guided flapless implant surgery has the benefits of prosthetically driven implant placement and minimal postoperative sequelae.[3-10] Compared with conventional techniques, guided surgery facilitates the implant placement by reducing the duration of the surgical procedure and improving patient recovery and postoperative sequelae. The ability to place endosseous implants by using 3-D planning, computer manufactured surgical guides, and flapless surgery results in ideal surgical and prosthetic implant placement. This enables the clinician to decide the final position of the implants with a prosthodontically driven approach before surgery.

The limitations of computer-guided surgery include the additional cost of the planning software, special surgical inventory, and fabrication of the stereolithographic template. Another issue is the accuracy of com-

puter-guided surgery with mucosally-supported and tooth-supported stereolithographic templates. This topic is currently under investigation.[21-24] These deviations include a mean of 0.8 mm at the entry point (range of 0.1 mm to 2.68 mm), a mean of 1.09 mm at the apex (range of 0.24 mm to 3.62 mm), a mean of -0.15 mm for depth (range of -2.33 mm to 2.05 mm), and a mean of 2.26 degrees for angle (range of 0.24 degrees to 11.74 degrees).[21] These linear differences at the level of entry point, the apex, and the depth can cause inaccurate placement of implants outside the existent bony confines, with subsequent catastrophic failures. It can also cause potential implant placement close to anatomic structures such as the inferior alveolar nerve.

For this clinical report, a tooth-supported and tissue-supported stereolithographic template was used. It has been shown that tooth-supported templates are more accurate than tissue-supported templates because of the resiliency of the soft tissue.[24] As with every new technique, there is a learning curve. For the present treatment, the planning, laboratory, and surgical steps were supervised by clinicians who were experienced in this protocol.

In the maxillary anterior region, the placement of adjacent implants was avoided because of the unfavorable esthetic outcomes that have been reported in the literature.[25] The ovate pontic technique was used for soft tissue conditioning and site development. Other techniques described in the literature included the root submergence technique and the preservation of the alveolar ridge with xenografts and growth factors.[26,27]

In the mandibular arch, the decision was made to perform conventional flap surgery for implant placement based on the results of the preoperative CT scan analysis. Alveolar ridge recontouring was necessary to create appropriate implant sites. Interestingly, a recent report presented a novel technique for planning and performing guided surgery with simultaneous alveoloplasty.[28] A flap procedure was part of this new protocol. After implant placement and because all implants achieved a high insertion torque of 45 Ncm, a decision was made to immediately load them with the conversion prosthesis technique. Immediate loading in the mandible is a well-documented procedure with high long-term success rates comparable to conventional loading protocols.[29]

For the final prosthetic design, a segmented approach with multiple cement-retained FDPs was chosen. The implant site selection was based on the envisioned prosthetic design during the treatment planning phase. The rationale for segmenting the complete arch rehabilitation included ease of fabrication and ease of maintenance in case of complications. After 3 years of prosthetic loading, no complications were encountered. The significance of retrievability and ease of maintenance was highlighted in a systematic review which showed that biological and technical complications are not rare with fixed implant prostheses.[30]

SUMMARY

As the computer-guided surgery protocols continue to evolve and improve, further clinical studies are necessary to assess accuracy and make this new technology even safer and more user-friendly for the average clinician. The clinical significance of this report lies in the treatment sequence combined with cutting edge technology for maximum patient comfort and prosthodontic control. Computer-guided flapless surgery with prosthetically driven placement led to predictable implant rehabilitation with no adverse events. Different loading protocols, namely conventional loading for the maxilla and immediate loading for the mandible were applied successfully. In summary, a staged approach with fixed interim restorations was used throughout the entire rehabilitation period, optimizing patient satisfaction.

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