Complete arch implant rehabilitation using subtractive rapid prototyping and porcelain fused to zirconia prosthesis: A clinical report

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The applications of various technological advances in implant dentistry and in all aspects of the diagnostic, treatment planning, surgical, and restorative phases are gaining popularity. Additive rapid prototyping and computer-aided design/computer-aided manufacturing (CAD/CAM) technology are used to generate stereolithographic surgical guides and prefabricated interim prostheses to facilitate implant surgery and immediate loading, respectively. Subtractive rapid prototyping is used for fabrication of zirconia frameworks for definitive implant prostheses. This clinical report describes the comprehensive application of these technological advances in implant rehabilitation to optimize surgical and prosthodontic outcomes as well as patient comfort. (J Prosthet Dent 2008;100:165-172)

The use of computer-aided design/computer-aided manufacturing (CAD/CAM) technology has gained popularity in implant dentistry.[1-4] The applications pertain to 3-dimensional (3-D) imaging (computerized tomography scan), 3-D software for treatment planning, fabrication of computer-generated surgical guides using additive rapid prototyping, as well as fabrication of all-ceramic restorations using subtractive rapid prototyping.[5-7] Rapid prototyping technology allows for industrial fabrication of customized 3-D objects from computer-aided design (CAD) data. Additive rapid prototyping pertains to the process of developing an object by deposition of material in layers, whereas subtractive rapid prototyping refers to the machining or milling process that removes material from solid blocks to fabricate customized 3-D objects.[5]

Zirconium oxide, known as zirconia, possesses good chemical and physical properties such as low corrosion potential, low thermal conductivity, high flexural strength (900-1200 MPa), and hardness (1200 Vickers).[8,9] In addition, zirconia is biocompatible, and the adhesion of bacteria on its surface is low.[8-10] Zirconia stabilized with yttrium oxide results in high flexural strength and fracture toughness due to transformation toughening.[8-21] Due to the superior flexural strength compared with aluminum oxide, zirconia frameworks for fixed partial dentures for anterior and posterior teeth and for implant-supported restorations are currently being used.[16-21] Most zirconia-based restorative systems use computer-aided design/computer-aided manufacturing (CAD/CAM) technology for the design and subtractive rapid prototyping technology for the fabrication of the zirconia frameworks.

This clinical report describes the application of various technological advances in comprehensive implant rehabilitation. These include use of CAD/CAM technology and additive rapid prototyping to generate stereolithographic surgical guides using prefabricated interim prostheses to facilitate immediate loading, and the use of subtractive rapid prototyping technology to fabricate a zirconia framework for the definitive implant-supported prosthesis.

CLINICAL REPORT

A 50-year-old woman was referred to the postdoctoral prosthodontic clinic of Columbia University College of Dental Medicine for prosthodontic consultation. The patient's medical history was noncontributory, and there were no contraindications for dental treatment. The patient presented with maxillary and mandibular complete dentures and reported inability to use the existing mandibular complete denture that was fabricated 1 year prior. Comprehensive clinical and radiographic examination revealed a severely resorbed edentulous mandible and atrophic maxilla. According to the Prosthodontic Diagnostic Index (PDI) for classification of complete edentulism, the patient was characterized as Class III, meaning that there was a need for surgical revision of the denture-supporting structures to allow for adequate prosthodontic function (Fig. 1).[22]

Upon intraoral examination, it was determined that the mandibular complete denture did not provide any stability or retention due to the extensive bone loss. The maxillary

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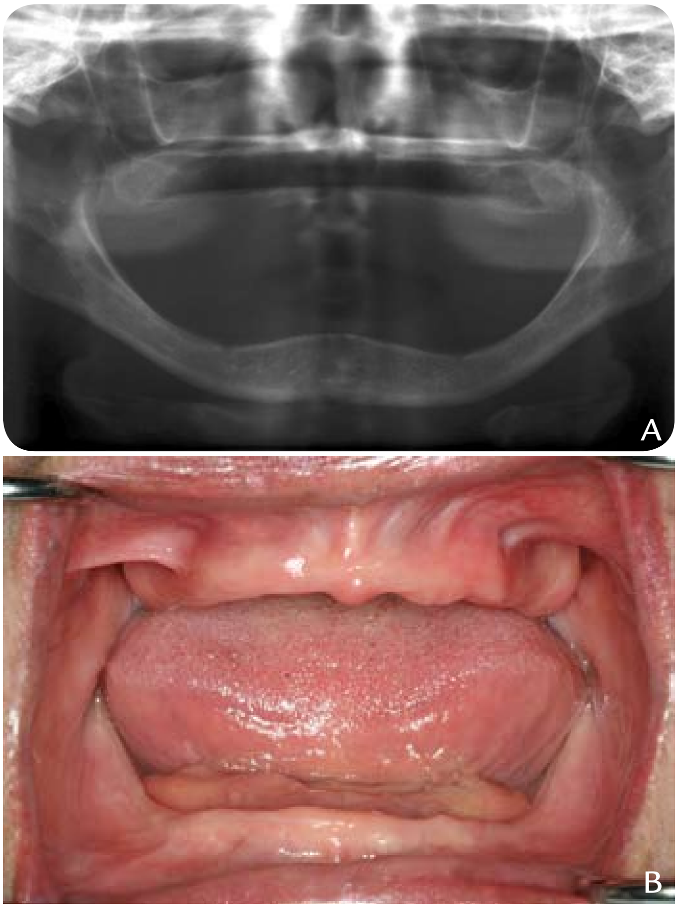
complete denture was acceptable. Esthetics, phonetics, and occlusal vertical dimension (OVD) were evaluated prior to development of the definitive treatment plan.[23] Various treatment options, namely, a new mandibular complete denture, a mandibular overdenture supported by 2 implants, and a fixed complete denture, were presented to the patient. The patient elected to proceed with rehabilitation of the mandibular arch with a fixed complete denture. A minimally invasive approach using computer-guided flapless implant placement followed by immediate loading was planned.

The existing dentures were converted into radiographic templates for the computerized tomography (CT) scan in the following manner. The mandibular removable prosthesis was relined intraorally with resilient relining material (Coe-Soft; GC America, Inc, Alsip, Ill) to obtain properly extended borders and better adaptation to the underlying soft tissues.

The maxillary and mandibular complete dentures were duplicated with autopolymerizing clear acrylic resin (Jet Denture Repair resin; Lang Dental Mfg Co, Wheeling, Ill) in a denture duplicator (Denture Duplicator; Lang Dental Mfg Co) using irreversible hydrocolloid (Jeltrate Plus; Dentsply Caulk, Milford, Del).

Twelve radiopaque markers made of gutta-percha (Gutta Percha; Henry Schein, Inc, Melville, NY) were incorporated into the duplicate dentures. The duplicate dentures were evaluated intraorally to verify accurate seating (Fig. 2). A facebow registration and centric relation (CR) interocclusal record were made, and the dentures were articulated in a semiadjustable articulator (PCH Articulator; Panadent Corp, Grand Terrace, Calif). After raising the incisal pin 4 mm in order to easily separate the mandible from the maxilla while reformatting the CT scan data, a new interocclusal record was made in the articulator with a radiolucent vinyl polysiloxane (VPS) material (Regisil; Dentsply Caulk), and a maxillary and mandibular double CT scan was prescribed.[6,24]

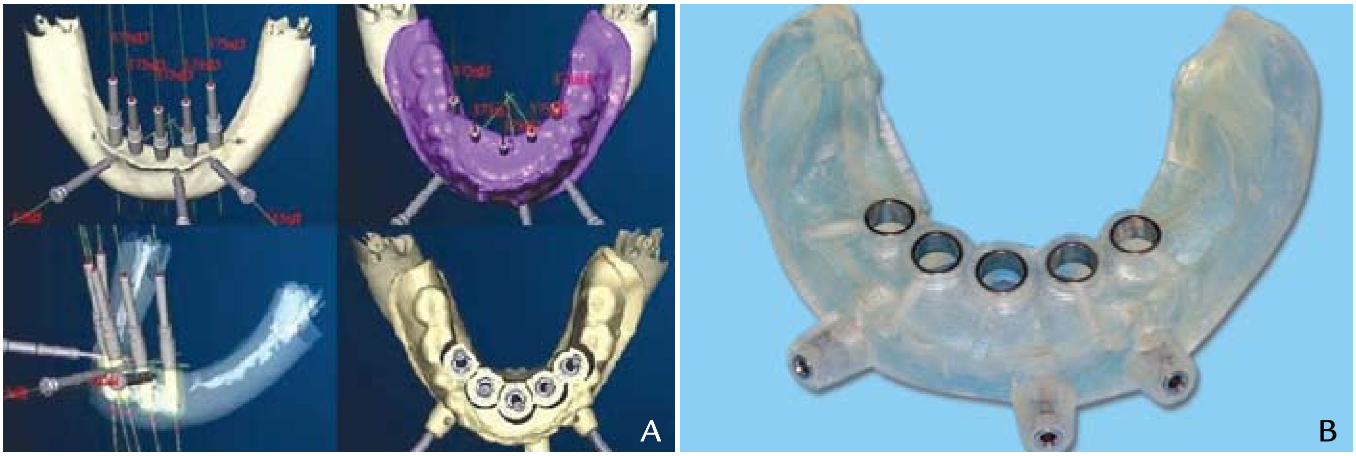


1 A, Preoperative panoramic radiograph. B, Pretreatment intraoral condition.


2 Duplicate dentures as radiographic templates.

The CT scan data was reformatted using a commercially available 3-D implant planning software (Procera; Nobel Biocare USA, Yorba Linda, Calif). The maxilla was severely resorbed with extensive sinus pneumatization and could not be treated without bone grafting procedures. The mandible was also severely resorbed. Through the 3-D planning software, 5 regular platform implants, 13 mm long (Branemark Mk III TiUnite; Nobel Biocare USA), were planned in the interforaminal area of the mandible. The virtual implant plan was sent to a rapid prototyping manufacturing facility (Procera; Nobel Biocare AB, Goteborg, Sweden) for fabrication of the stereolithographic surgical template (Fig. 3).

After the mandibular stereolithographic surgical template was received, a definitive cast and a CAD/CAM prefabricated interim prosthesis, screw-retained at the implant



3 A, 3-D implant planning. B, Stereolithographic surgical template.

4 Surgical template fixed intraorally with implant mounts.

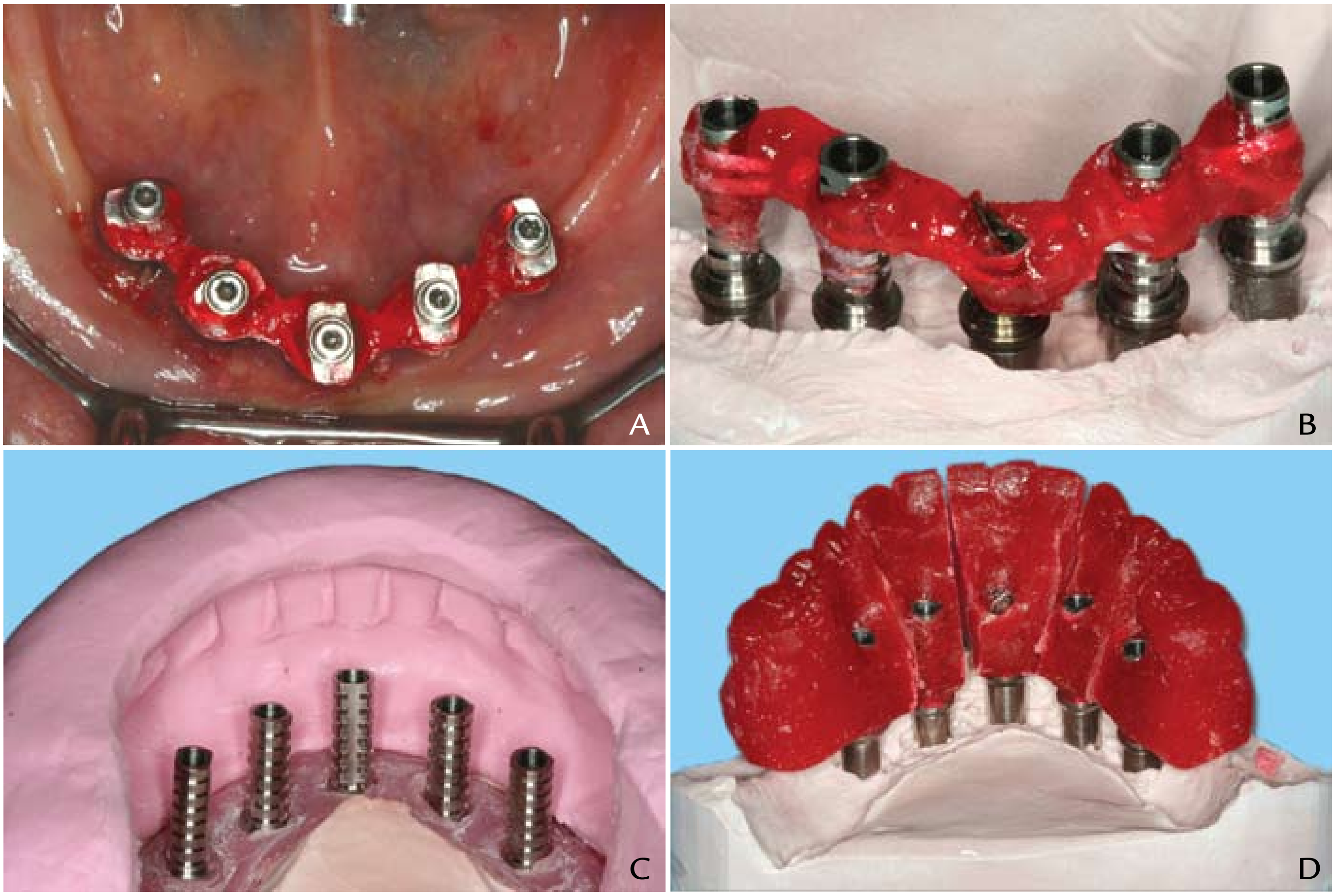
level, with expandable abutments (Guided Abutment; Nobel Biocare USA) were retro-generated through the surgical template using previously described procedures.[25-27] These abutments consist of a cylinder with 4 vertical slots enabling outward movement. When the abutment screw is tightened, the screw head forces the 4 walls of the cylinder to expand and engage a corresponding metal sleeve which is incorporated in the intaglio surface of the prosthesis.

The definitive cast with the surgical template was cross mounted on the articulator to the maxillary cast of the existing complete denture, and an interocclusal CR record was made to ensure the accurate positioning of the stereolithographic template during the implant surgery. The prefabricated interim prosthesis was also cross mounted at the established OVD on the articulator. Flapless implant surgery was performed with strict adherence to the surgical protocol.[25] All implants achieved primary stability of 35 Ncm, thus allowing for immediate loading (Fig. 4).[28]

Following the flapless surgical placement of the implants, the implant mounts were unscrewed, the surgical template was removed, and the prefabricated screw-retained interim prosthesis for immediate loading of the implants was inserted. Minimal occlusal adjustments were needed to achieve cross-arch centric relation contacts. Screw access openings were filled with VPS (Imprint III Light Body; 3M ESPE, St. Paul, Minn) impression material (Fig. 5). The patient was placed on a soft diet for 8 weeks and was prescribed medication for control of postoperative pain. Use of an oral irrigator (Waterpik Ultra Dental Water Jet, WP-100W; Water Pik Technologies, Inc, Newport Beach, Calif) twice each day for maintenance of oral hygiene was advised.

At the 1-week recall, the patient reported no postoperative swelling, minimal pain, and increased satisfaction with the surgical, esthetic, and functional outcome. After an uneventful healing of 3 months, a definitive impression was made. The interim prosthesis was removed and impression copings were connected to the implants and splinted to each other with dental floss and autopolymerizing acrylic resin (GC Pattern Resin; GC America, Inc). Radiographs were made to verify seating of the impression copings. The acrylic resin-impression copings assembly was sectioned and reconnected with acrylic resin to compensate for polymerization shrinkage (Fig. 6, A). An open tray definitive impression was made with a custom tray and polyether impression material (Impregum; 3M ESPE). After removal of the impression, healing abutments were connected to the implants to prevent soft tissue collapse, while the interim prosthesis was cleaned. After cleaning, the prosthesis was inserted intraorally.

5 A, Prefabricated interim prosthesis in place. B, Postoperative panoramic radiograph confirming fit of prosthesis at expandable abutment level.



6 A, Impression copings connected with acrylic resin before definitive implant level impression. B, Verification index placed on definitive cast. C, Silicone index generated from interim prosthesis. D, Complete contour acrylic resin pattern sectioned to compensate for polymerization shrinkage.

The definitive cast was poured with type IV stone (Silky-Rock; Whip Mix Corp, Louisville, Ky) in 2 increments to minimize the volumetric expansion of dental stone.

At the next appointment, a verification index was fabricated intraorally to evaluate the accuracy of the definitive cast before proceeding with fabrication of the definitive prosthesis.[29] Impression copings were connected to the implants and splinted to each other with dental floss and visible light-polymerizing acrylic resin (Triad Gel Clear Pink; Dentsply Caulk). After sectioning and reconnection, this verification index was unscrewed and transferred to the definitive cast. Passive fit of the index on the definitive cast was confirmed, verifying its accuracy (Fig. 6, B).

Subsequently, the mandibular complete arch zirconia framework was fabricated. While the verification index was transferred to the definitive cast, the interim prosthesis was screwed in place intraorally and a CR interocclusal record was generated. The interim prosthesis was then connected to the definitive implant cast.

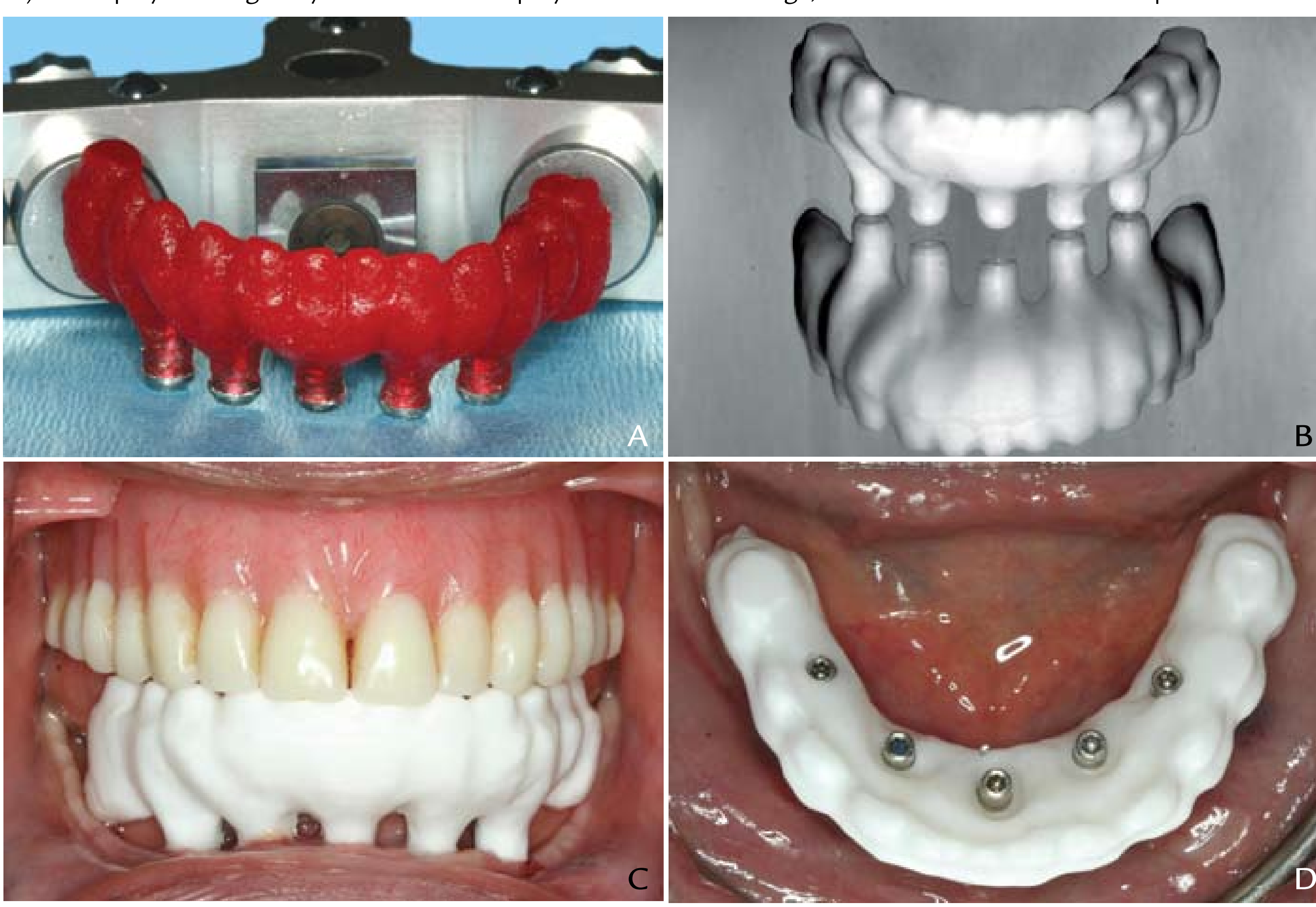
The CR interocclusal record was used to articulate the mandibular definitive cast to the maxillary cast of the existing complete denture on the articulator. The maxillary cast of the complete denture had been previously mounted in the articulator with a facebow transfer during fabrication of the interim prosthesis used for immediate loading. In addition, buccal and lingual indices of the articulated interim prosthesis were made with VPS material (Lab Putty; Coltene/Whaledent, Inc, Cuyahoga Falls, Ohio) to aid in determining available space and guide the fabrication of the definitive prosthesis within the confines of this index (Fig. 6, C).[30,31]

Nonengaging temporary abutments (Nobel Biocare USA) were placed onto the implant analogs on the definitive cast and trimmed to fit within the confines of the VPS index. Screw access openings were blocked out with utility wax (Plastic Wax Sticks; Coltene/Whaledent, Inc). Autopolymerizing acrylic resin (GC Pattern Resin; GC America, Inc) was injected with a syringe inside the VPS index. Once the acrylic resin polymerized, the screw access openings were cleared and the full contour acrylic resin pattern prosthesis was retrieved.[7] For the fabrication of a zirconia implant-supported prosthesis, an acrylic resin pattern of the framework was designed, scanned, and milled into a zirconia framework, then veneered with feldspathic porcelain. This zirconia framework was designed by developing a full contour acrylic resin pattern that was cut back appropriately.[7]

A wide variety of techniques have been proposed in the dental literature to achieve accuracy and passivity of fit of implant prostheses.[32-38] Therefore, an additional step to maximize the framework's accuracy of fit was taken before final scanning. The full contour acrylic resin pattern was placed onto the definitive cast, sectioned again to allow for compensation of acrylic resin polymerization shrinkage, and reconnected with additional acrylic resin (Fig. 6, D).

This full contour resin pattern was then cut back to allow for 2 mm of veneering porcelain with respect to the confines of the VPS indices and the established tooth position and alignment. The acrylic resin framework was designed to allow for adequate connector height and for uniform thickness and support of the veneering porcelain to optimize the strength of the prosthesis.[7,39] A scanner (Procera Forte; Nobel Biocare USA) was used to scan the acrylic resin pattern and generate a 3-D CAD file (Fig. 7, A). The data were transferred to a CAM milling center (Nobel Biocare USA, Mahwah, NJ), and a zirconia block was milled accordingly into a zirconia framework and sintered (Fig. 7, B).

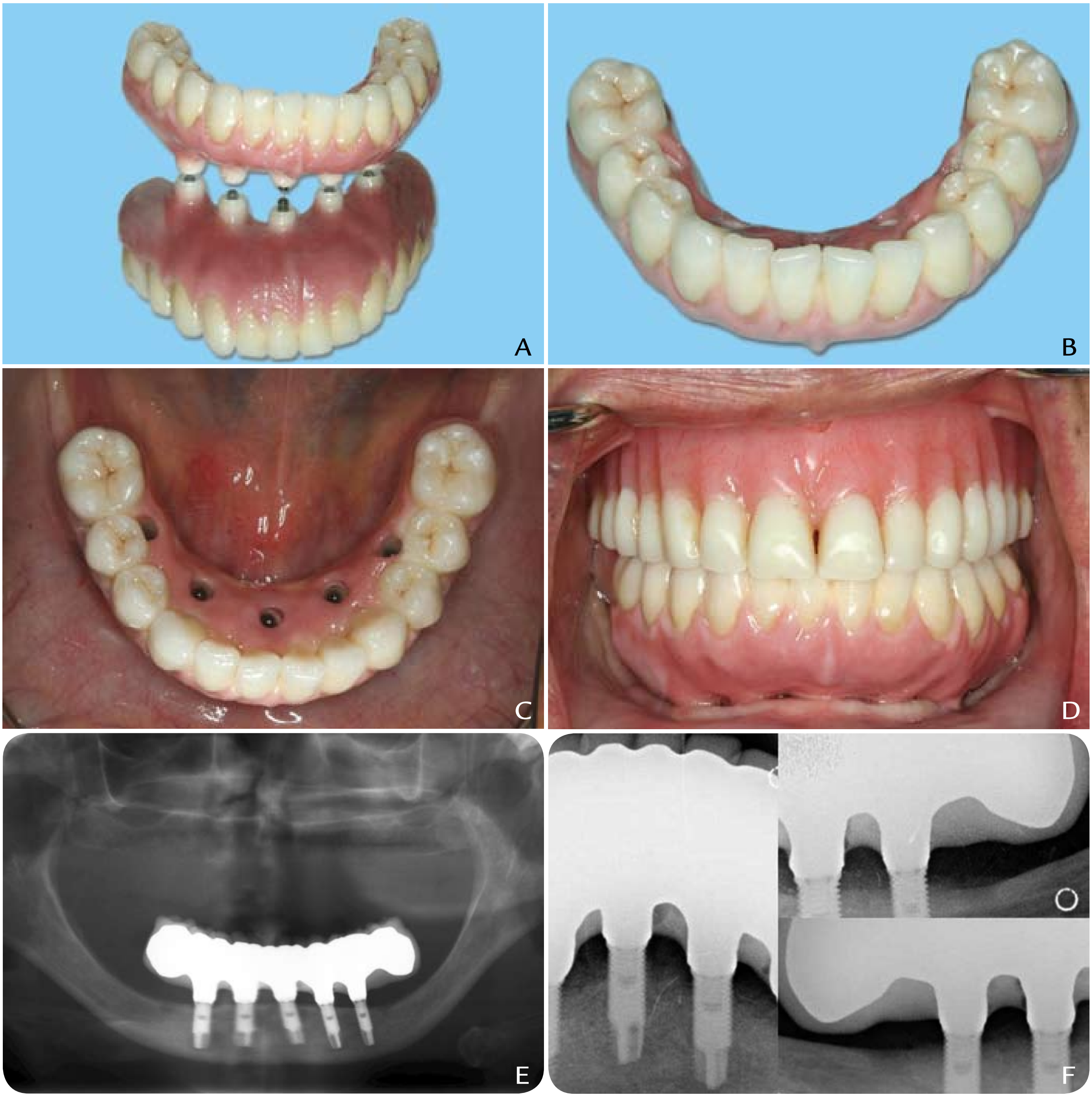
At the next appointment, the complete arch zirconia screw-retained framework was evaluated for accuracy and passivity of fit (Fig. 7, C and D). Periapical radiographs were made and fit at the implant-abutment



7 A, Cut back of acrylic resin pattern, ready to be scanned with stylus-based scanner. B, Zirconia framework. C, Intraoral evaluation of framework (labial view). D, Intraoral evaluation of framework (occlusal view).

interface was verified. A new centric relation record was made to transfer the maxillomandibular relation to the articulator, a transfer impression with polyether material (Impregum; 3M ESPE) was made, and the shade was selected. It should be noted that during the treatment of this patient, different shades for the zirconia framework were not yet commercially available. Subsequently, the zirconia framework was veneered with feldspathic porcelain, and a balanced occlusion scheme was established for the definitive prosthesis to prevent dislodgement of the maxillary complete denture in function.[40]

At the insertion appointment, the definitive screw-retained mandibular zirconia prosthesis was evaluated intraorally, and the abutment screws were torqued to 35 Ncm. A panoramic radiograph was made to confirm seating of the definitive prosthesis. The patient was given home oral health care instructions, including use of floss threader, interproximal brushes, and an oral irrigator. The patient was satisfied with the final esthetic and functional outcome. At the 6-month recall appointment, the prosthesis was stable, and periapical radiographs verified stable marginal bone levels compared to postinsertion baseline periapical radiographs (Fig. 8).



8 A, Definitive porcelain fused to zirconia prosthesis. B, Definitive porcelain fused to zirconia prosthesis (occlusal view). C, Intraoral evaluation of zirconia prosthesis (occlusal view). D, Intraoral evaluation of zirconia prosthesis (labial view). E, Postinsertion panoramic radiograph verifying accurate fit of definitive zirconia prosthesis. F, Posttreatment periapical radiographs 6 months after insertion of definitive zirconia prosthesis.

DISCUSSION

CAD/CAM-guided flapless implant placement with ideal implant positioning highlights the merits of rapid prototyping technology in the field of implant dentistry, whereas subtractive rapid prototyping is used for fabrication of zirconia prostheses.[5]

Zirconia is currently used as a core material for fabrication of frameworks for tooth and implant-supported fixed partial dentures (FPD). Esthetics are optimized with zirconia restorations due to the natural shade of the substrate, thus eliminating the problem of the gray effect, especially at the cervical area, of implant prostheses with metal alloy substructures.[18] Control of the opacity of these zirconia frameworks has been recently attempted with the introduction of a variety of shades for the substrate zirconium oxide framework.[18]

Several in vitro reports have demonstrated the superior flexural strength of zirconia compared to other ceramic materials, such as aluminum oxide.[11-16,20,41] However, stress concentration inside a framework may induce cracking of the veneer porcelain. Studies of all-ceramic FPDs with a zirconium oxide framework reported that the majority of fractures occurred at the framework and layering porcelain interface and extended along the interface.[41-45]

Few long-term clinical studies evaluating systems with zirconium oxide frameworks have been performed.[7,10,17,19] Moreover, these clinical studies[7,10,17,19,42] included tooth-supported 3- and 4-unit posterior FPDs, and only 1 identified clinical report[46] included rehabilitation with a 10-unit anterior tooth-supported zirconia FPD. To the authors' knowledge, no clinical reports have been published on rehabilitation with an implant-supported zirconia fixed complete denture. Clinical data on longevity of zirconia prostheses are lacking. Further clinical studies investigating the longevity and bond strength between the zirconia framework and the veneering porcelain are needed.

SUMMARY

The process of restoring an edentulous patient with endosseous implants and porcelain fused to a zirconia prosthesis using CAD/CAM and subtractive rapid prototyping technology has been described. This protocol allows for minimally invasive implant surgery, as well as functional and esthetic restoration of edentulous patients with various amounts of bone resorption. The advantages include minimally invasive flapless implant placement with ideal implant positioning, immediate occlusal loading for maximum patient comfort, and esthetic and biocompatible restoration with a definitive implant-supported zirconia prosthesis.

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Noteworthy Abstracts of the Current Literature

Display of mandibular and maxillary anterior teeth during smiling and speech: Age and sex correlations

Sackstein M.
Int J Prosthodont 2008;21:149-51.

This study aimed to measure mandibular and maxillary anterior tooth display during smiling and speech and to evaluate correlation with age and sex. Ninety-four subjects were video recorded when smiling and when saying “ah” or “shesh.” Anterior tooth display was measured using individual video frames. Average mandibular and maxillary anterior tooth display showed opposing trends. The former increased with age, had a tendency to be greater in men, and was greater during speech than during smiling. The latter decreased with age, was greater in women than in men, and was greater during smiling than during speech. Anterior dental esthetic evaluation, especially for the mandible, should include observation of speech.