Fabrication of the mandibular implant-supported fixed restoration using CAD/CAM technology: A clinical report

Mamaly Reshad, DDS, MSc,[a] Domenico Cascione, CDT, BS,[b] and Alexandre Amir Aalam, DDS[c]
University of Southern California, School of Dentistry, Los Angeles, Calif

The mandibular implant-supported fixed restoration is an appropriate treatment choice for patients with inadequate bone volume in the posterior mandible. Computer-aided design/computer-aided manufacturing (CAD/CAM) technology has broadened the scope and application for this treatment option. A milled titanium bar retaining individual all-ceramic zirconium oxide crowns, with composite resin replicating gingival tissues, is recommended as an acceptable variation for this type of prosthesis. An alternative method for fabricating a mandibular implant-supported fixed restoration using CAD/CAM technology is described. (J Prosthet Dent 2009;102:271-278)

The mandibular implant-supported fixed restoration has an excellent long-term survival rate.[1-2] It is suitable for the restoration of the edentulous mandible when a fixed prosthesis is required, but there is insufficient bone height in the posterior mandible.[3] Four to 6 dental implants are usually placed in the intraforaminal region to support the restorations with bilateral distal cantilevers.[3] The original design for this restoration used a gold alloy framework which supported acrylic resin teeth. However, due to prohibitive cost factors, complex laboratory procedures, and the advent and development of CAD/CAM technology, newer techniques have been developed.

Contemporary advancement in dental materials and CAD/CAM technology has influenced the evolution and widened the scope of application of the mandibular implant-supported fixed restoration.[4] The prohibitive cost factors associated with complex laboratory procedures coupled with the considerable use of high noble metal alloys for frameworks can be bypassed with CAD/CAM technology. Potential consequences of treatment, such as casting shrinkage resulting from soldering, may also be avoided.

Historical designs for the mandibular implant-supported fixed restoration did not place significant emphasis on esthetics. Newer techniques have been explored to address esthetics, cost, and the insufficient number of dental laboratory technicians with appropriate training in fabrication. Recent literature has explored techniques for the fabrication of this type of restoration, which use artificial teeth and denture base acrylic resin processed onto a CAD/CAM milled titanium framework.[5] Other suggested designs have involved a 1-piece zirconium-oxide framework with porcelain fired directly onto the framework.[5-6] However, repairing a porcelain fracture of a framework that has been in service poses significant risk and can be time consuming. Rehabilitation of an edentulous mandible using a 1-piece cementable zirconium oxide framework has also been described.[7] Similar difficulties may be encountered with this type of prosthesis, as well as potential irretrievability complications.

Esthetically pleasing outcomes may be achieved with the use of all-ceramic restorations for teeth, and composite resins to replicate missing soft tissues. With advancing age, the appearance of the mandibular anterior teeth and surrounding tissues becomes more noticeable.[8] Therefore, the esthetics of the mandibular anterior teeth should not be disregarded, as they become more visible with age.[3] This article describes an alternative method for the fabrication of the mandibular implant-supported fixed restoration using CAD/CAM technology.

CLINICAL REPORT

A 59-year-old man presented to the University of Southern California Faculty Practice (Oral Health Center) complaining of his loose mandibular complete denture. The patient's chief complaint was the inability to adequately function and speak with the prosthesis. Following a thorough evaluation and because of the minimal residual vertical height of the mandible, the patient was classified in the type IV category, according to the classification system for edentulous patients recommended by the American College of Prosthodontists

[a]Co-Chair, Fixed and Operative Dentistry, Division of Primary Oral Health Care.
[b]Clinical Assistant Professor, Division of Primary Oral Health Care.
[c]Clinical Assistant Professor, Division of Primary Oral Health Care.

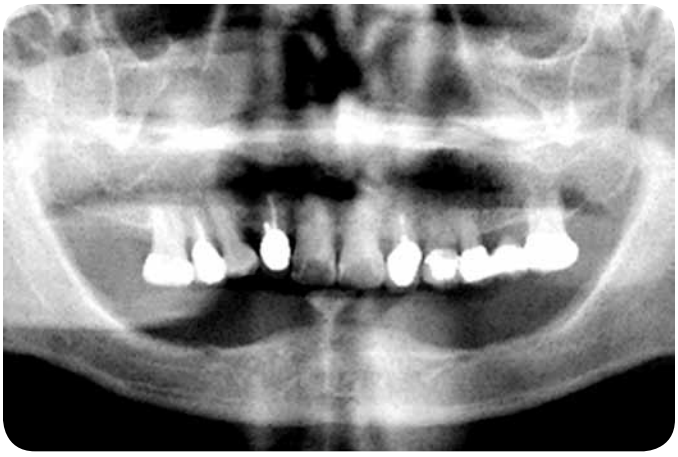
(ACP).[9] The maxillary central incisor teeth presented with dental caries associated with the existing composite resin restorations. The maxillary left lateral incisors displayed dental caries around the metal ceramic crown margin, as well as malposition and inappropriate tooth contour. The maxillary right canine was missing, and the maxillary right first premolar had drifted and tilted into its position. The patient was dissatisfied with the appearance of the maxillary anterior teeth.

Clinical and radiographic examination revealed an edentulous mandible opposing maxillary natural teeth (Fig. 1). Treating an edentulous mandible with a complete denture opposing an intact maxillary dentition is a challenge.[10] The difficulty arises because the remaining maxillary natural teeth generate substantial force directed towards the mandibular residual ridge. A choice of treatment options, including a new mandibular complete denture, a mandibular overdenture supported by 2 dental implants, and a mandibular implant-supported fixed restoration, were presented to the patient. The patient requested a fixed prosthesis as a definitive restoration.[11] The cross-sectional computerized tomography scan (CT scan) revealed insufficient bone height and width superior to the infra-alveolar nerve in the posterior mandible for dental implant placement. Therefore, a mandibular screw-retained fixed complete denture supported by 5 dental implants, placed in the mandibular symphisis, was determined to be the appropriate treatment option for this patient.[12-13]

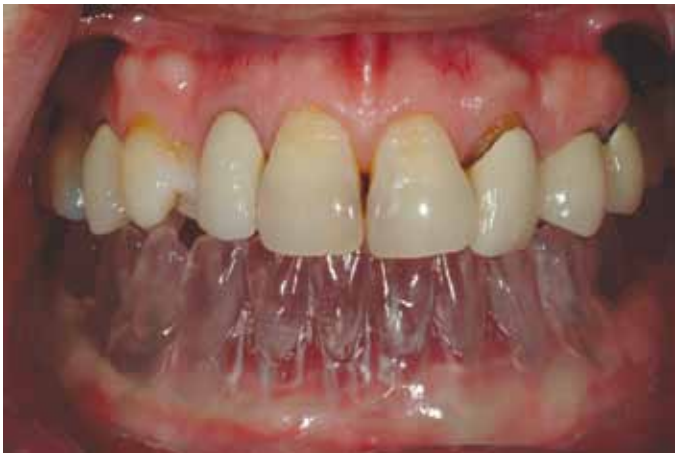
Following prosthetic evaluation and a diagnostic tooth arrangement with denture teeth (VITA Physiodens; Vident, Brea, Calif), radiographic and surgical guides (Fig. 2) were used to assist in the placement of 5 dental implants (Brånemark System; Nobel Biocare USA, Yorba Linda, Calif) in the intraforaminal region. Care was taken to optimize the anterior-posterior spread (A-P spread) to allow a more favorable biomechanical environment for the definitive prosthesis (Fig. 3).[14] The mandibular arch was immediately loaded with a screw-retained fixed provisional restoration on the same day as dental implant placement, following a previously described protocol (Fig. 4).[15]

Three months after the dental implants were placed, customized (Pattern Resin; GC America, Alsip, Ill) pick-up impression copings (Biomet 3i; Palm Beach Gardens, Fla) were fabricated and connected with a flowable composite resin (Venus Flow; Heraeus Kulzer, Armonk, NY) intraorally (Fig. 5). Indexing with flowable composite resin has several benefits. The composite resin is thixotropic during syringing, which allows access to desired areas with less chance of distortion of the coping position on removal. Color contrast and control of polymerization are additional benefits of using this technique for indexing. A custom tray (Triad VLC System; Dentsply Trubyte, York, Pa) pick-up overimpression, using addition-reaction silicone (Extrude Extra; Kerr Corp, Orange, Calif), was made. Five regular platform laboratory analogs (Biomet 3i) were attached to the impression copings, then the impression was boxed and poured with type IV gypsum material (Fujirock EP; GC America). This type of stone is preferred for implant dentistry as it has high strength and low expansion.[16]

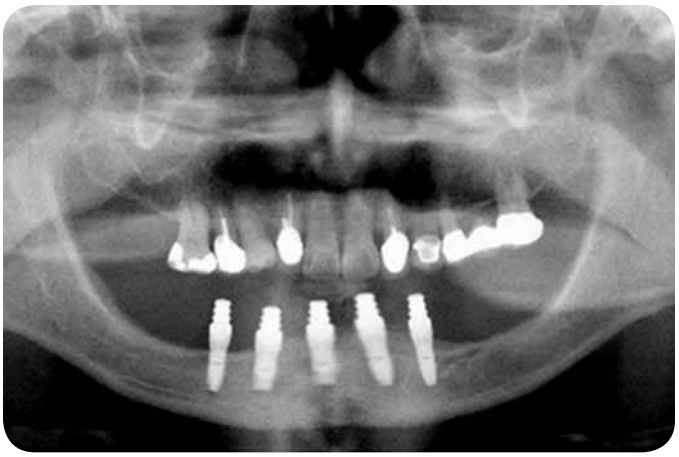
The mandibular cast was trimmed, and healing abutments (Brånemark System; Nobel Biocare USA) were used to stabilize the record base for accurate maxillomandibular relationship registration and mounting. Denture teeth (VITA Physiodens; Vident) were arranged on the wax rim (Fig. 6). It was necessary to be able to convert the denture tooth arrangement into a material that could easily be cut back. A polyurethane epoxy resin material (Polyurock; Metalor Dental USA, Inc, North Attleboro, Mass) was selected. Epoxy resin materials are easily cut with rotary instruments without fracture, burning, or deformation. A duplicate of the diagnostic arrangement on the definitive cast was made with a light-bodied addition-reaction silicone material (Elite Double 22 Fast; Zhermack, Inc, Eatontown, NJ). The silicone duplicating material was vacuum mixed, poured onto the boxed diagnostic cast, and placed in a pressure pot (60 psi). After polymerization, the silicone duplicating



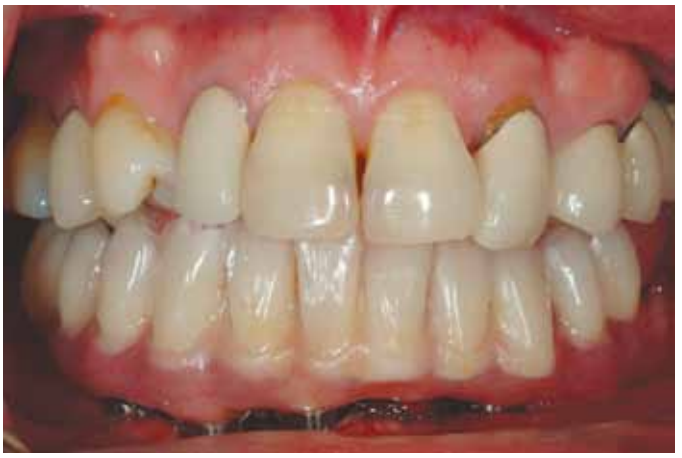
1 Preoperative panoramic radiograph.



2 Mandibular surgical guide in occlusion.



3 Panoramic radiograph of dental implants immediately after placement.



4 Immediately loaded mandibular prosthesis in occlusion.

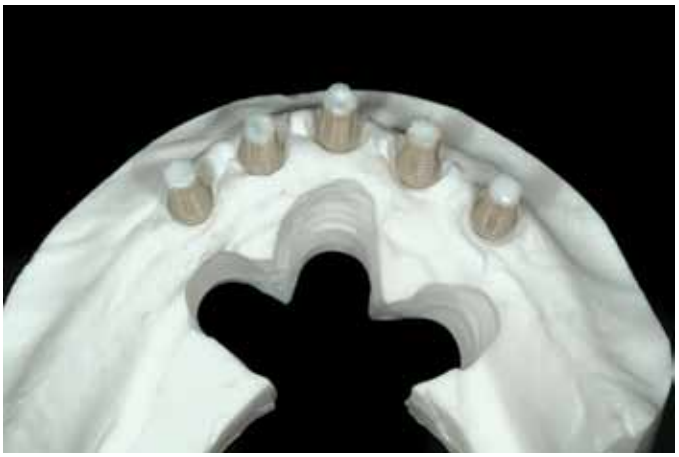
5 Indexed impression copings.

6 Denture teeth arranged on wax rim.

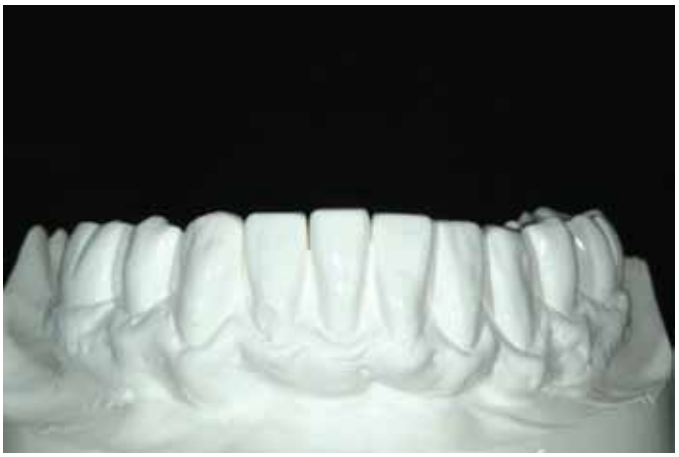
material was separated from the cast for evaluation of detail reproduction. Temporary plastic implant cylinders (Brånemark System; Nobel Biocare USA) were placed on a duplicate of the definitive cast. Temporary plastic cylinder access holes were sealed with cotton and soft wax (ABF-wax; Metalor Dental USA, Inc) (Fig. 7). An additional silicone index (Platinum 85; Zhermack, Inc) of the diagnostic arrangement on the definitive cast was used to verify appropriate clearance with temporary plastic cylinders.

A polyurethane epoxy resin (Polyurock; Metalor Dental USA, Inc) was vacuum-mixed, according to the manufacturer's instructions, to a fluid consistency and poured into the silicone duplicating material using a vibrator. The duplicate of the definitive cast with the temporary cylinders was placed into the silicone mold (Elite Double 22 Fast; Zhermack, Inc) containing the epoxy resin and placed in a pressure pot (60 psi). According to the manufacturer's instructions, the resin is fully polymerized at 90 minutes, allowing the removal of the silicone duplicating material (Elite Double 22 Fast; Zhermack, Inc). Temporary cylinder chimneys were accessed with a small round bur (H1-021; Brasseler USA, Savannah, Ga), and the epoxy resin framework was removed and trimmed to resemble the definitive restoration. Figure 8 shows the trimmed epoxy resin framework design on the definitive cast. The silicone index (Platinum 85; Zhermack, Inc), which was made to evaluate the clearance of the temporary plastic cylinders, was used again to help with the controlled cut-back of the epoxy resin framework.

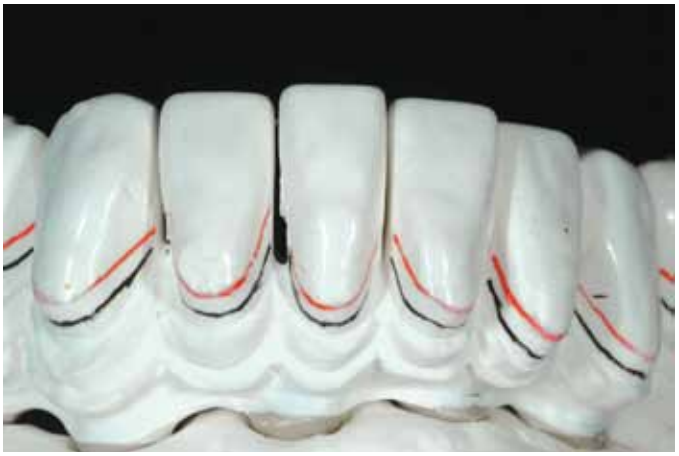
A 1.5- to 2-mm controlled cut-back of the epoxy resin was performed in the gingival areas (Fig. 9). Peaks and troughs were designed to facilitate retention of the composite resin to the future titanium framework. Red and black lines were drawn on the epoxy resin (Fig. 9). It was imperative not to begin the cut-back until reference points had been established on the epoxy resin. The red line indicated the future gingival margin position, and the black line represented the crown margins for the definitive restorations. These additional steps helped secure appropriate crown height and contour, and gingival esthetics for the definitive restoration. Figure 10 shows the complete controlled cut-back for the framework. Principals of tooth preparation were respected for the preparation design. The retainers were prepared with adequate resistance and retention form.[17] Rounded internal line angles were used to avoid the initiation of cracks in the porcelain.[18] Clearly defined shoulder finish



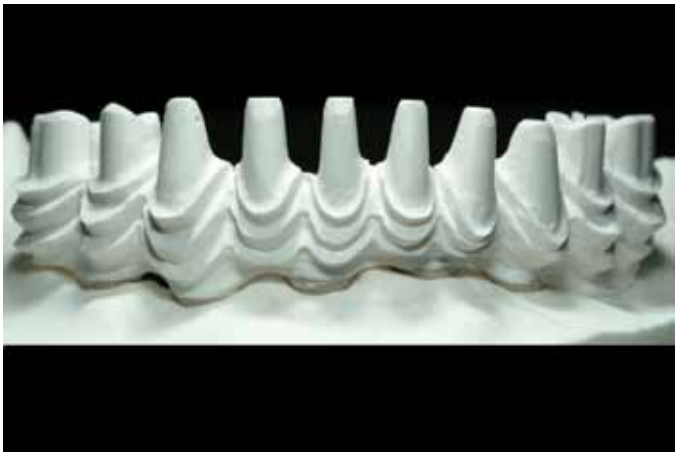
7 Temporary plastic cylinders on duplicate of definitive cast.



8 Trimmed epoxy resin framework design on definitive cast.



9 Red and black lines on epoxy resin. Red line represents gingival margin and black line represents crown margin for all-ceramic restorations.



10 Controlled cut back of epoxy resin on definitive cast.

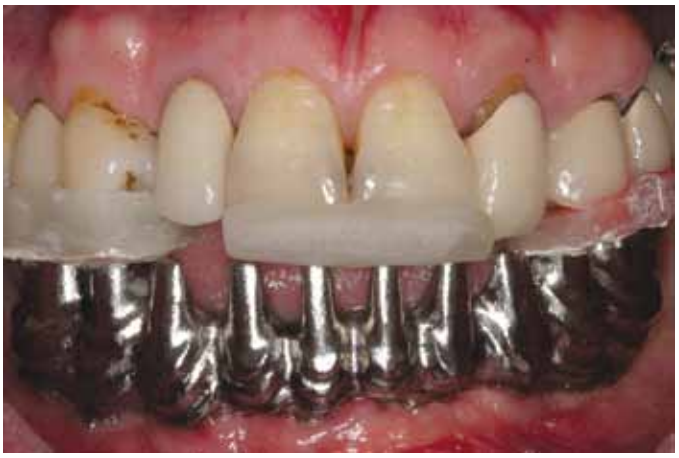
lines were prepared for all retainers.[19] The epoxy resin framework, as well as the definitive cast (Fujirock EP; GC America), was sent to a dental implant manufacturer (Biomet 3i) for milled titanium framework fabrication. To allow for proper scanning, the stone did not cover the coronal third of the laboratory analogs; this was facilitated through a removable "soft tissue" cast (Gingifast; Zhermack, Inc). Instructions were given to scan the stone cast for the implant positions and the epoxy resin for the titanium framework design. Figure 11 shows proper adaptation and seating of the titanium framework on the definitive cast. Current advancement in CAD/CAM technology facilitated an almost identical reproduction of the scanned object. As the titanium alloy was cut without melting of the alloy, investing, and casting, dimensional changes or alteration of the physical and mechanical properties were avoided.

Radiographs confirmed seating of the metal framework intraorally. Prefabricated jigs and carriers were used to confirm centric relation records. The anterior deprogrammer and posterior rigid carriers (Triad VLC System; Dentsply Trubyte) were made at the planned vertical dimension on the titanium framework, which was attached to the mounted casts as shown in Figure 6. Once centric relation position was confirmed using an anterior deprogrammer, a zinc oxide material (TempBond; Kerr Corp) was used as a recording medium on the posterior carriers (Fig. 12).

At the same appointment, a customized shade tab was created on a white background to match the soft tissue color (Ceramage Primer; Shofu Dental Corp, San Marcos, Calif). Four different shades of pink-colored composite resin (Ceramage; Shofu Dental Corp) were photographed at different vertical positions intraorally. The photos were evaluated on a computer screen (VAIO; Sony Corp, New York, NY) before mixing different composite resin shades to create a shade that more closely resembled the tissue color at different heights. Tooth color match was determined (Vitapan Classical shade guide; Vident).

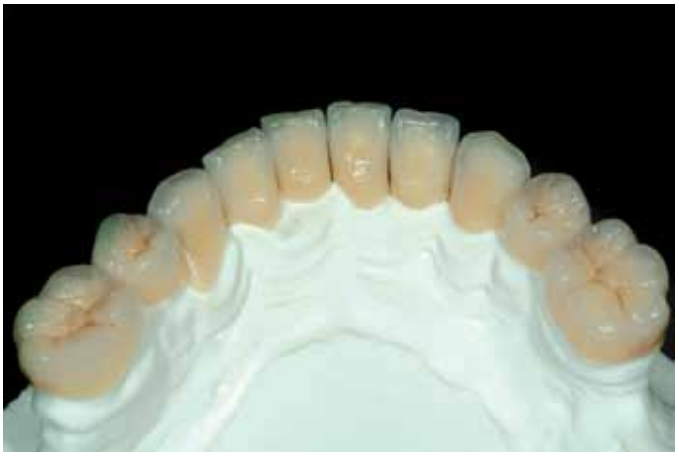
The titanium framework was sent to a manufacturer (Vident) for scanning and fabrication of the zirconium oxide copings. Instructions were given for a coping thickness of 0.6 mm for the posterior and 0.4 mm for the anterior teeth. The manufacturer was also instructed with respect to the desired final tooth color. The decision to use zirconium oxide copings

11 Titanium metal framework on definitive cast.



12 Centric relation record at desired occlusal vertical dimension.

13 Zirconium oxide copings on titanium framework.

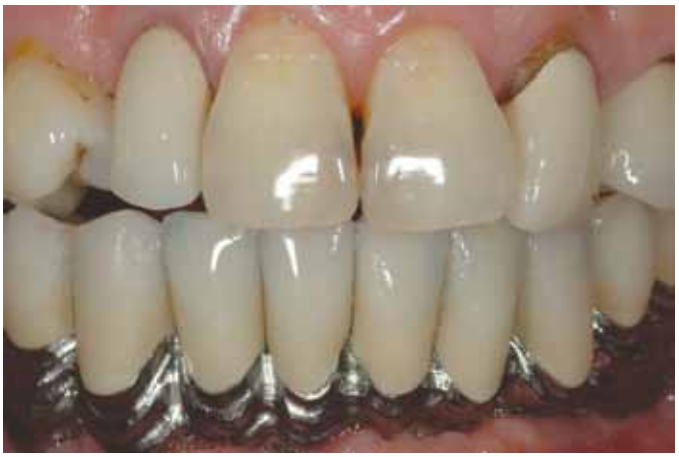


14 Porcelain application.

was based largely on the reduction of laboratory costs and time, and the ability of an opaque core to block out the underlying metallic color of the titanium framework (Fig. 13). A veneering porcelain material (Vita VM9; Vident) that is compatible with the zirconium oxide copings was applied. Manufacturer's instructions were strictly followed to avoid failure due to delamination of the veneering porcelain from the coping. A duplicate of the titanium framework in stone (Fujirock; EP; GC America) was used for positioning of the zirconium oxide coping for veneering porcelain application (Fig. 14). Occlusion was evaluated and adjusted intraorally at the bisque-bake stage (Fig. 15).

The application of pink composite resin followed porcelain bisque-bake trial insertion. The titanium framework was airborne-particle abraded with 50-μm aluminum oxide particles (Danville Materials; San Ramon, Calif) and steam cleaned. A primer was applied (Ceramage Primer; Shofu Dental Corp), followed by light-polymerizing preopaque material (Ceramage Pre-opaque; Shofu Dental Corp). Light polymerization was performed for 3 minutes (Allegro,1000 mW/cm^2; Den-Mat Holdings LLC, Santa Maria, Calif). A translucent composite resin material (Ceramage; Shofu Dental Corp) was applied, followed by the final opaque layer of light-polymerizing material (Fig. 16). Light polymerization was performed for 3 minutes (Allegro, 1000 mW/cm^2; Den-Mat Holdings LLC). Figure 17 shows the definitive restoration after the completion of pink composite resin application and polishing. Polishing was performed following the manufacturer's instructions (Ceramage; Shofu Dental Corp). The gingival margin of the individual crowns terminated 1 mm below the pink composite resin height circumferentially to achieve an esthetically pleasing result (Fig. 17). The all-ceramic individual restorations were glazed, and a silicone material (Fit Checker Black; GC America) was used to confirm placement.[20]

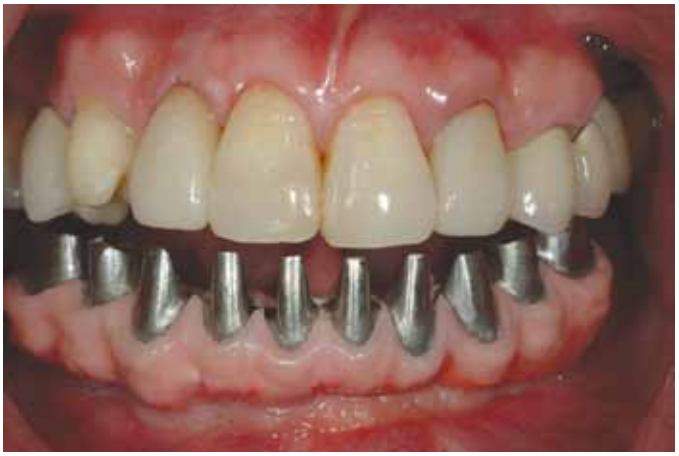
The definitive restoration was inserted in a sequence of steps and in a single appointment. First, the titanium framework, which was a screw-retained restoration, was inserted (Fig. 18). Gold screws (Biomet 3i) were used, and a torque of 32 N was applied. A period of 1 hour was allowed to elapse before a further torque of 32 N was applied to the gold screws. Access holes were closed with cotton pellets and composite resin (Ceramage; Shofu Dental Corp). The individ-



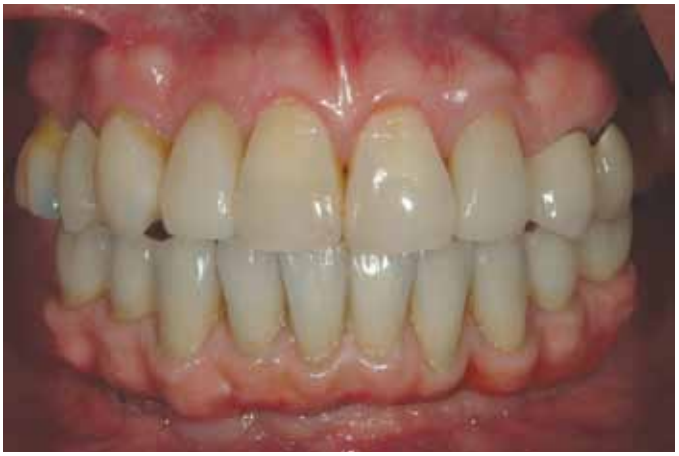
15 Bisque-bake trial insertion.

16 Opaque layer for pink composite resin.

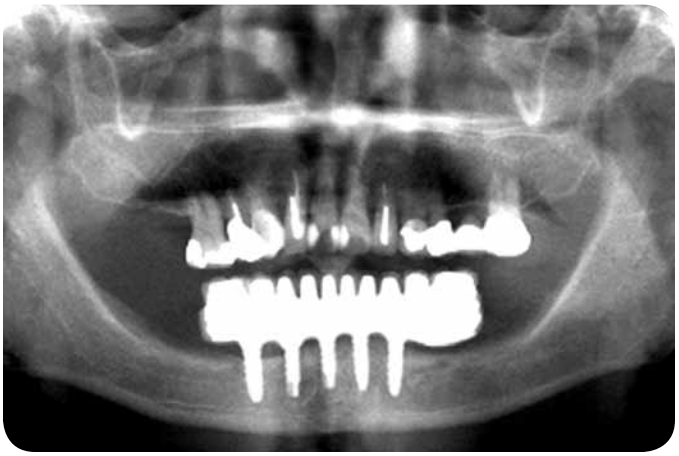
17 Gingival margin of individual crowns terminating 1 mm below pink composite resin tissue height circumferentially.



18 Insertion of screw-retained titanium framework.



19 Definitive restorations at 12 months.



20 Postoperative panoramic radiograph.

ual crowns were evaluated to confirm seating, and the occlusion was reevaluated. The crowns were subsequently luted with dual-polymerizing resin cement (Panavia F2.0; Kuraray America, Inc, New York, NY).[21] Prior to luting, the intaglio surface of each coping was etched with 37% phosphoric acid for 5 seconds and washed under copious water irrigation. The intaglio surface of the coping was primed with a ceramic primer (Clearfil Ceramic Primer; Kuraray America, Inc) which contains the chemical 10-methacryloyloxyl-dimethyl phosphate (MDP). MDP is a phosphate monomer which links metal oxides (zirconium oxide).[22] The titanium surface was also primed with a metal primer (Alloy Primer; Kuraray America, Inc). Panavia cement was mixed and the restorations were luted individually. Care was taken to remove excess cement after luting each unit. Once each unit was fully seated and excess cement was removed, polymerization (Allegro, 1000 mW/cm^2; Den-Mat Holdings

LLC) was performed for 20 seconds. Once all of the restorations were inserted, an additional polymerization cycle through a layer of glycerin jelly (Oxyguard; Kuraray America, Inc) was performed. The restoration of the maxillary anterior teeth commenced after the bisque-bake trial insertion. The maxillary central incisors were restored with composite resin (Venus Flow; Heraeus Kulzer) and the maxillary lateral incisors with luted (Venus Flow; Heraeus Kulzer) all-ceramic restorations. The latter was a leucite-reinforced castable ceramic (HT high temperature; Swiss NF Metals, Inc, Toronto, Canada) which was stained and glazed (Glaze; Swiss NF Metals, Inc). The malpositoned maxillary right first premolar was restored with composite resin to resemble a canine tooth and to contribute to the right working disclusion. An occlusal device was fabricated for the patient to avoid tooth wear and ceramic fractures. The patient was instructed on maintenance of interproximal gingival health with the aid of dental floss (Super Floss; Oral-B, Boston, Mass). Figures 19 and 20 show the definitive restoration after 12 months. No clinical complications were observed at the 12-month follow-up examination, and the patient remained satisfied with the function and esthetics of the mandibular restoration.

DISCUSSION

This article describes the clinical and laboratory procedures for the fabrication of a mandibular implant-supported fixed restoration using CAD/CAM technology. The advantages of this technique include significant reduction in laboratory time and complexity when compared to more traditional approaches involving investment and casting of dental alloys. As the casting of gold alloys is eliminated, none of the problems associated with the cost of alloy, control of investment expansion, and shrinkage of the alloy remain relevant.

However, this type of prosthesis may present some disadvantages. Using all-ceramic teeth rather than denture teeth increases the risk for fracture. It may be argued that denture teeth are a safer choice because fracture is less likely. The progressive wear of the denture teeth is not likely to present as a dental emergency. However, the use of all-ceramic restorations for this situation in the mandibular arch may be justified because the restorations remain predominantly under compressive forces.[18] Attaining a mutually protective occlusal scheme will facilitate the avoidance of tensile forces on the all-ceramic restorations.[23] Luting of all-ceramic restorations onto a rigid metal substructure with a high modulus of elasticity (titanium framework) is likely to prevent crack initiation and propagation.[24]

Staining at the junction between the composite resin and all-ceramic restoration is a potential problem with the prosthetic design. However, at the 1-year recall, staining was not observed. Arguably, the primary disadvantage with this prosthetic design is its potential irretrievability. Implant access holes are covered with either composite resin or an all-ceramic restoration. When the prosthesis needs to be removed completely, a few of the all-ceramic restorations may need to be replaced to gain access to the retaining screws. If only a single restoration fails, it may easily be removed, refabricated, and replaced. Repair of the pink-colored composite resin can be performed intraorally without removal of the prosthesis. Finally, another disadvantage may be the more time-consuming procedure of luting with resin cement (Panavia 21; Kuraray America, Inc). The latter is probably offset by faster and simpler occlusal evaluation and adjustment, as single cementable units are used. Esthetics may be enhanced as individual all-ceramic restorations may be fired without concern for potential sagging of the ceramic used in a 1-piece metal ceramic restoration.

SUMMARY

An alternative technique using CAD/CAM technology for the fabrication of implant-supported fixed restorations was proposed. A milled titanium bar retaining individual all-ceramic zirconium oxide crowns, with composite resin replicating gingival tissues, is recommended as an acceptable option for this type of prosthesis.

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Corresponding author:
Dr Mamaly Reshad
Division of Primary Oral Health Care
School of Dentistry, University of Souther California
925 West 34th St
Los Angeles, CA 90089-0641
Fax: 213-740-1209
E-mail: Reshad@usc.edu

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NOTEWORTHY ABSTRACTS OF THE CURRENT LITERATURE

Clinical parameters influencing the accuracy of 1- and 2-stage impressions: a randomized controlled trial

Luthardt RG, Walter MH, Weber A, Koch R, Rudolph H.
Int J Prosthodont 2008;21:322-7.

Purpose: The clinical success of fixed restorations is linked to the precise reproduction of the prepared teeth by dental impressions. The hypothesis under examination was that neither clinical parameters nor the impression technique influenced the reproduction of the finishing line during impression making.

Materials and Methods: For 48 patients who needed a fixed restoration, a 1-stage putty-wash, 2-stage putty-wash, and monophase impression were made after preparation in a randomized order. Clinical parameters (Plaque Index, probing depth, bleeding on probing, Gingival Index, location of the finishing line, bleeding during impression taking, and blood at the impression) were recorded. Master casts were manufactured and optically digitized. Using the data of the 1-stage putty-wash impression as reference, the reproduction of the finishing line was measured 3-dimensionally. Linear models were used for statistical analysis.

Results: The finishing line was reproduced most precisely by the 1-stage putty-wash technique. Variables with significant influence were the impression technique, blood at the impression, and probing depth. The 2-stage putty-wash impressions showed significantly reduced accuracy compared with the 1-stage impressions.

Conclusion: Clinical parameters and the impression techniques determine the reproduction of the finishing line. The benefit of 2-stage putty-wash impressions with regard to a more complete rendering of subgingival finishing lines should be questioned in light of these results.