Complete-arch maxillary rehabilitation using a custom-designed and manufactured titanium framework: A clinical report

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Fabrication of a passive framework when restoring multiple implants in an edentulous maxilla may be an important requisite for long-term implant survival. The development of computer-aided design and manufacturing techniques for fabricating custom 1-piece titanium frameworks can simplify that challenge. This article reports on a treatment in which a custom-milled titanium complete-arch maxillary framework was used to restore a compromised maxillary arch. A 4-year follow-up demonstrated a steady state of bone and no prostodontic complications. (J Prosthet Dent 2008;99:8-13)

Several factors can compromise the long-term survival of implants in the maxilla. Residual bone in this area often tends to be less dense than that of the mandible. In addition, anatomical structures, such as the sinus and nasal cavities, can preclude the use of longer implants and create angulation problems with those placed. Winkler et al1 suggested that success in the maxilla depends on the length of the implants used, with the most vulnerable implants being the shortest.

After placement and osseointegration of implants, it is the responsibility of the restorative dentist to maintain that status with a properly designed and fitted prosthesis. An accurate and passive fit is a desirable goal. Achieving this becomes more important when the prosthesis is supported by implants.2,3 Unlike teeth, which have a periodontal ligament and slight mobility, implants are fixed to the bone and, therefore, cannot accommodate minor discrepancies in fit between the framework and the implant. The preservation of osseointegration is based not only on the bone-tissue interface, but also on the precise fit of the prosthesis.2 The more implants that are placed, the more difficult it is to achieve a passive framework fit. If the framework does not fit passively, complications may ensue within a relatively short period of time, including screw loosening, abutment and implant fracture, or loss of bone due to overload.4

These considerations may lead to the conclusion that maxillary implants should be restored with several short-span segments, rather than being completely splinted. However, cross-arch stabilization, recommended by early investigators of complete-arch implant-supported prosthesis treatment, reduces the likelihood that undue stress will be placed on any single implant.5 Therefore, fabrication of a 1-piece metal substructure remains a desirable treatment objective. Achieving a passive fit and decreasing the mechanical stresses should improve the success of posterior implants in areas of poorer bone quality and quantity.3

The ability to fabricate custom titanium copings by using computer-aided design and computer-aided manufacturing (CAD/CAM) technology in conjunction with computernumerically controlled (CNC) milling machines has existed since the early 1980s. By the late 1990s, this technology had evolved to include production of multiple-unit implant frameworks milled from homogeneous pieces of titanium.6 This type of framework, intended for screw-retained implant-supported prostheses for partially and completely edentulous patients, can be veneered with porcelain, composite resin, or acrylic resin teeth, according to the manufacturer.

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With this technology, abutment interfaces are precision-milled and become an integral part of the prosthesis, eliminating the need for individual gold cylinders. It has been shown that the gold cylinders of gold-alloy frameworks are subject to potential distortion in the casting process. Several studies have demonstrated that CNC-milled titanium implant frameworks have comparable precision of fit to that of cast frameworks. The CNC fabrication process is automated and depends less on manual laboratory procedures than do conventional casting protocols, theoretically allowing for higher control of a precise fit. Jemt, in a study of gold alloy frameworks, found a wide range of distortion, while another study showed that the use of the conventional lost-wax technique is imprecise and inaccurate, as judged in terms of passive fit. Additional evidence indicates an overall shrinkage of the framework when using silver-palladium alloy. Titanium frameworks are reproductions of an acrylic resin framework pattern created by the dental laboratory after a dentist has produced an accurate definitive cast. If properly fabricated, the titanium framework has the potential of true passivity. Traditional fit verification techniques confirm this.

The advantages of titanium include its known biocompatibility, a benefit for patients concerned about metal toxicity or allergy. Titanium is approximately one fourth of the weight of gold, and, therefore, a complete-arch framework that would normally weigh 20 dwt to 35 dwt prior to porcelain or acrylic resin placement typically weighs no more than 5 dwt when fabricated in milled titanium. Questions have arisen regarding the esthetics and durability of porcelain fused to titanium. This article describes the use of a custom-milled titanium complete-arch maxillary framework to achieve a precise and passive fit.

CLINICAL REPORT

A 73-year-old white man with a history of myocardial infarction and hypertension, as well as mitral valve prolapse, presented for treatment at the private practice site in New York. He had undergone coronary bypass surgery 8 years earlier. In addition, Bell’s palsy had left a profound left-side facial paralysis.

In the maxillary arch, the root tips or fragments remained for the maxillary right and left first molars and right second molar, as well as for the first premolars and both canines. These functioned as abutments for an overdenture. Due to extensive decay, only the gold copings for the first molars remained (Fig. 1, A). Caries and periodontal breakdown rendered these unusable as future abutments. Since ample bone appeared to be present, and the patient did not want a conventional complete denture, the patient indicated a desire for an implant-supported prosthesis (Fig. 1, B).

In the mandible, fractured roots were present in the left first premolar and canine sites. The patient had cantilever fixed partial dentures extending from the mandibular first premolars to the mesial of the first molars. The remaining 5 mandibular anterior teeth demonstrated cervical caries and gingivitis (Fig. 1, B). At the time, the patient requested that the mandible be treated palliatively. An understanding was reached that the mandible would be restored with implants and fixed partial dentures when finances permitted.

Due to the history of mitral valve prolapse, the patient’s physician recommended antibiotic prophylaxis for all treatment, along with limited use of vasoconstrictors whenever local anesthesia was administered. Accordingly, the patient received 2000

![1 A, Intraoral preoperative view of compromised maxilla. B, Preoperative radiograph.](image-url)
mg of amoxicillin (Ranbaxy Pharmaceuticals, Princeton, NJ) 1 hour prior to all procedures. The remaining 7 maxillary teeth were extracted, and after the extraction sites had healed adequately, the patient was referred back to the surgeon for placement of 8 implants (five 4 x 13 mm, one 4 x 8.5 mm, one 4 x 10 mm, and one 4 x 15 mm) (Branemark System; Nobel Biocare USA, Yorba Linda, Calif).

Clinical examination and evaluation of the patient revealed that the existing plane of occlusion was appropriate. With this established, and using the existing overdenture and the principles of complete denture prosthodontics as a guide, a diagnostic waxing on a trial record base was fabricated to determine tooth arrangement prior to surgery. Centric relation, vertical dimension of occlusion, anterior function, and esthetics were all verified at the trial insertion visit. Having established these parameters and determining that the existing prosthesis met them, a decision was made to reline and reuse the existing denture as a provisional prosthesis during the 6-month healing period. The patient returned several times throughout this interval for additional relines to ensure that any load on the healing implants was minimized. A duplicate denture and complete-arch custom tray (Triad VLC Custom Tray Material; Dentsply Ltd, Weybridge, UK) were fabricated in advance for use following stage II surgery.

Six months after the initial surgery, the implants were uncovered and healing abutments (Nobel Biocare USA) were placed. Following a 4-week healing period, the definitive restorative treatment commenced, and the patient returned for placement of 8 titanium abutments (Estheticone; Nobel Biocare USA) (Fig. 2). The fit of the abutments was verified using radiographs as well as visual and tactile inspection with a dental explorer. A complete-arch closed-tray transfer impression of the abutments was made using abutment impression copings (SDCA #099; Nobel Biocare USA) and polyether impression material (Permadyne; 3M ESPE, St. Paul, Minn).

In addition, the duplicate denture, modified with a cutout allowing complete access to the implant copings, was positioned, and abutment copings with guide pins (DCB #106; Nobel Biocare USA) were placed over the implant abutments. Acrylic resin (DuraLay; Reliance Dental Mfg Co, Worth, Ill) was applied to the copings, luting them to the denture (Fig. 3). After the acrylic resin polymerized, the guide pins were removed, and the denture with the copings joined to it was withdrawn. The original denture was relieved with a rotary instrument at the location of each abutment and was then relined with a soft-tissue conditioning material (Viscogel; Dentsply Ltd, Weybridge, UK) to accommodate the new implant abutments.

Abutment replicas (DCB #176; Nobel Biocare USA) were placed in both the complete-arch impression and the duplicate denture index. Two casts were generated. A polyether interocclusal record (Ramitec; 3M ESPE) with the existing dentition in the mandible was made. This was forwarded to the dental laboratory, along with the duplicate denture index, to communicate an accurate maxillomandibular relationship and tooth position to the dental laboratory technician. In addition, this index provided a definitive cast of the implant positions. The complete-arch impression served to provide the dental laboratory technician with a soft tissue cast.

Subsequently, an acrylic resin (Biolon; Dentsply Intl) fixed partial denture was fabricated by the labo-

![Implant abutments in place.](image)

![Abutment copings luted to duplicate denture.](image)
laboratory and returned to the dentist to be evaluated intraorally. This implant-supported provisional prosthesis consisted of a heat-polymerized acrylic resin processed to cast metal restoration (Lite-Cast; Ivoclar Vivadent, Amherst, NY) supported by 8 temporary implant cylinders (DCA# 157; Nobel Biocare USA). Following the guidelines defined by the duplicate denture, this prosthesis, most importantly, enabled verification of the accuracy of the definitive cast. It was determined that the complete-arch restoration fit the patient and the definitive cast identically. Centric occlusion, tooth position, and tooth mold were satisfactory, and the patient left the dental office with the interim implant-supported prosthesis in place.

With the accuracy of the definitive cast now confirmed, the cast was returned to the dental laboratory along with directions for fabrication of a custom-milled titanium framework (Procera Implant Bridge; Nobel Biocare USA). Using acrylic resin (Biolon C&B Resin; Dentsply Intl), an individually designed framework pattern was fabricated directly on temporary implant cylinders. Temporary cylinders were used instead of definitive abutments because the temporary implant cylinders are less expensive than final gold cylinders and accomplish the same goal for this procedure (DCA#157; Nobel Biocare USA) (Fig. 4, A). The acrylic resin framework pattern and the verified definitive cast were then sent to the titanium framework production center in Karlskoga, Sweden. There a digital model of the framework pattern was created from data obtained by a laser scanner (Laser-Scanner One Design; Nobel Biocare AB, Goteborg, Sweden) (Fig. 4, B). A coordinate-measuring machine (Zeiss Prismo Vast; Zeiss, Oberkochen, Germany) was also used to register the position and orientation of the abutment replicas.

The CNC machinery milled the framework out of a solid piece of grade 2 titanium. The abutment interfaces were also precisely milled. To confirm its accuracy, the framework was measured in the coordinate measuring machine, and the measurements were compared to the manufacturing input. The manufacturer purports that no positional error of greater than 0.03 mm is accepted within the custom-milled implant fixed partial denture process. The framework was then returned to the laboratory in the United States, where it was adjusted, refined, and polished before being delivered to the dentist.

The patient returned, the provisional restoration was removed, and the 1-piece multi-unit implant framework was evaluated intraorally (Fig. 5). Framework fit verification techniques...
included alternate finger pressure, visual inspection, evaluation with an explorer, and radiographs. A polyether interocclusal record (Ramitec; 3M ESPE) was made, and a definitive porcelain shade was selected. The provisional restoration was replaced, and the titanium framework was returned to the laboratory for application of porcelain (Triceram; Esprident GmbH, Ispringen, Germany). The definitive prosthesis was inserted at the next visit. Fit, occlusion, contours, and esthetics were assessed, and all parameters indicated that a passive fit had been obtained. Regular follow-up over a 4-year period confirmed the overall success of the implants. No significant changes in the prosthesis were noted. There were no incidences of screw loosening or any other complications, and no adjustments were necessary during this period (Figs. 6 and 7).

**DISCUSSION**

Creation of an accurate definitive cast is essential to ensuring that implant-supported frameworks fit accurately and passively. This article describes a method whereby the accuracy of the definitive cast can be confirmed. This method can be used regardless of whether the framework is milled out of titanium by a CNC machine or cast with a gold alloy using the lost-wax process.

If an error is somehow introduced into the definitive cast and reproduced in the framework, a milled titanium framework should not be sectioned and repaired, as is commonly done with long-span cast frameworks. Rather, a new, accurate, definitive cast must be generated, along with a new framework. When the definitive cast is accurate, a milled titanium framework will fit precisely, making it likely that the overall cost and chair time for the patient will be less than it would be if a cast framework were fabricated. The material cost of a milled titanium framework is also typically less than a cast gold alloy framework, though this comparison may fluctuate with variations in the price of gold. CNC-milled frameworks can only be screw-retained and, thus, are not an option for a dentist who desires to create a cement-retained prosthesis.

**SUMMARY**

This clinical report presents a method of confirming definitive cast accuracy by using a processed acrylic resin, metal-reinforced interim restoration. CAD/CAM technology is then used to produce a 1-piece titanium framework for a complete maxillary screw-retained implant restoration. Office visits, chair time, and laboratory costs may be reduced.

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