

# Treatment Using a Porcelain-Fused-to-Titanium Crown

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## Patient History

Initial presentation date: December 7, 2009

Age at initial presentation: 41

## Chief Complaint

A 41-year-old male presented on emergency with a fractured left maxillary second premolar. The patient had moderate parafunctional forces.

## Medical History

The patient had no remarkable medical history.

## Dental History

The patient routinely visited the dental office for recall examinations and restorative needs. He recently had a root canal on the left second molar. He was planning to receive an implant in the first molar area in next 6 months. The patient wanted to complete the crown in order to protect the second molar during healing.

## Diagnostic Findings: Intraoral

Maxillary and mandibular teeth were in Class I occlusion. The patient exhibited wear facets caused by his parafunctional

grinding and had no evidence of fremitus on any teeth. He was missing the upper left first molar.

## Diagnosis

The fractured cusp upper left second premolar had a previous root canal requiring crown coverage. The patient opted for placement of a porcelain-fused-to-metal crown to support the remaining teeth. (An amalgam had been already in place.)

## Background

Alternative methods for fabrication of milled titanium crown and bridge copings have recently become available. New optical scanning technology followed by computer-designed and computer-aided milling has improved the performance and fit of titanium porcelain-fused-to-metal crowns (TiPFM) (Figure 1 and Figure 2). The porcelain systems and bonding protocols have been enhanced to increase the longevity of these restorations.<sup>1,2</sup> Long-term clinical results are limited; however, the performance of this new method of fabrication appears promising. Since the early 1960s, gold has been used to cast excellent crown and bridge substructures. With the increasing cost of gold alloys, research has focused on finding suitable metal coping alternatives. The use of gold substructures has proven to be quality-oriented; however, it is difficult to predict the relative weight and subsequent cost of the gold and/or precious metals used in the restoration. In the past few decades, researchers have been searching for the ideal semiprecious and nonprecious metals to create an affordable,



**Figure 1** Porcelain-fused-to-titanium crown.



**Figure 2** TiPFM showing the intaglio surface of the titanium alloy core.

long-lasting, and well-fitting restoration. It is thought that a fixed cost can be assigned to this type of framework design, minimizing expense and improving predictability.

Shokry et al suggested that the challenges for titanium alloy coping fabrication had been in the manufacturing process.<sup>3</sup> Titanium alloy has been used as a “castable metal,” providing a semiprecious alternative to expensive precious metal alloys.<sup>4</sup> The casting of titanium alloy can cause many challenges for the dental technician because the material is extremely light and does not flow well after reaching its high melting temperature (1640° C).<sup>3</sup> In addition, many concerns have been raised about the casting and firing procedure leading to unacceptable margins.<sup>3</sup> For example, the porcelain firing could cause the metal to change from an alpha phase to a beta phase, affecting the marginal accuracy.<sup>5</sup> Furthermore, casting led to the creation of a “reactive layer” that inhibited the bond between the porcelain systems and titanium.<sup>5,6</sup> Casting titanium was difficult due to the spontaneous oxidization of the metal during casting. This oxidization caused an unwanted darkened layer that made predictable esthetics challenging during the porcelain firing. These initial trials<sup>5,6</sup> found that the fracture of porcelain from the titanium coping was the most common problem. These issues led the titanium alloy to fall from favor.

Recently, there has been renewed interest in titanium as a core substructure due to optical scanning followed by CAD/CAM fabrication of crown copings (Figure 3 and Figure 4). The titanium copings can be “milled” from a prefabricated titanium block. Milling produces excellent fitting margins to less than 10 µm (Figure 5). Research has demonstrated marked improvements in marginal fit using the milled fabrication process. For example, Shokry et al compared casting versus milling processes and concluded that titanium copings fabricated by CAD/CAM methods showed the least marginal discrepancy among all groups.<sup>3</sup>

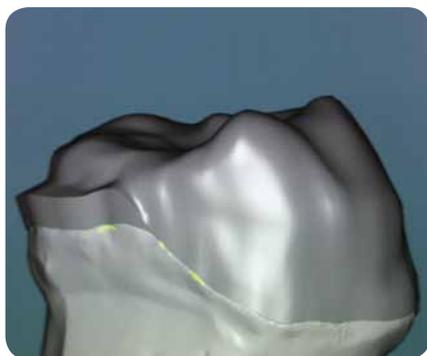
Some researchers believe titanium alloy is the ideal gold replacement because it has a thermal expansion coefficient of  $9.6 \times 10^{-6} \text{ K}^{-1}$  and a low thermal conductivity.<sup>7</sup> This allows the alloy to perform well in the oral cavity. Widely used in dentistry for decades, the semiprecious material has demonstrated

proven biocompatible properties. Titanium is considered to be “the most biocompatible metal used for dental casting.”<sup>3</sup> The titanium alloy is corrosive-resistant in addition to having a neutral taste and a Vickers hardness of 180 to 250.<sup>8</sup> Its high mechanical strength is unique given its relative light weight, which is four times lighter than gold. The material is hypoallergenic, making it very desirable for use in those with metal allergies. Crown and bridge frameworks are milled from larger monoblocs of solid alloy.<sup>11</sup> The milling process developed using CAD/CAM technology enables the laboratory technician to fabricate an extremely well-fitting crown and bridge substructure with a well-controlled alpha oxidization layer. The monobloc enables the manufacturer to control the uniformity of the alloy composition.

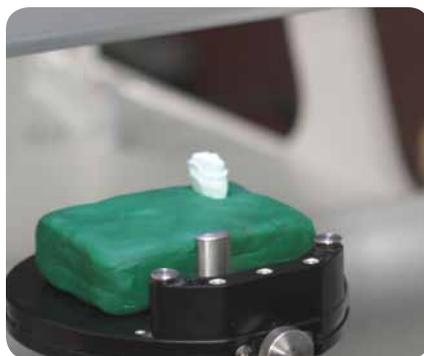
In the present case, a crown coping was produced using titanium aluminum vanadium alloy (Ti-6Al-4V) (Nobel Biocare)<sup>7</sup> (Figure 6). The manufacturer lists a tensile strength of 860 MPa and yield strength of 795 MPa.<sup>3</sup> Coping fabrication typically occurs after a dental laboratory scans the die or impression, designs the coping on the computer, and then ships it to the central manufacturing plant (Nobel Biocare). Once the coping has been verified to fit on a die, it is returned to the laboratory for porcelain firing.

The titanium coping was milled, using a monobloc of titanium alloy (Nobel Biocare). The alloy fulfils the requirements of ASTM F136 for a wrought material suitable for use in surgical implants.<sup>11</sup> Its mechanical properties also make it ideal for high-precision milling of crown and bridge substructures.

Crown preparations for TiPFM follow similar guidelines as other metal copings. The clinician must ensure adequate removal of the tooth structure to provide porcelain plus the coping thickness of 0.4 mm to 0.5 mm<sup>1</sup> (Figure 7). The crown preparation is similar to a porcelain-fused-to-gold preparation in reduction; however, the porcelain butt margins should have a rounded axial preparation with rounded cusp angles to aid in computer milling. The buccal surface can be designed on the computer-generated die to allow for porcelain butt marginal adaptation via virtual cutbacks (Figure 8). When designing the coping, the laboratory



**Figure 3** CAD design of the titanium alloy coping.



**Figure 4** CAD/CAM scanner.



**Figure 5** Excellent fit of the titanium crown die.

technician must ensure the proper thickness of porcelain over the titanium framework. The porcelain must be less than 2-mm thick to ensure proper strength.

Historically, it was suggested that porcelain chipping can occur if the porcelain thickness was not ideal.<sup>10</sup> Improvements in the CAD/CAM software have enabled the dental technician to automatically create and visualize the virtual height of the coping to see the space for veneering of the porcelain. With the new CAD/CAM processes, the technician can minimize veneering thickness issues by creating full anatomic crowns with automated computer-generated cutbacks.<sup>10</sup> To ensure a uniform ideal thickness, the framework can be reduced from the full-contour virtual wax-up. The software has a “relative cutback feature” that makes the space for porcelain uniform from the opposing dentition. To provide marginal stability of the titanium alloy during porcelain firing, the manufacturer’s minimal thickness restrictions must be followed. This is especially important in the marginal ridge area. Boeckler et al found that some porcelain fractures occurred if the copings were created using a CAD/CAM program that did not start with cutbacks on anatomic copings. They concluded that “CAD/CAM titanium ceramic copings over 3 years were acceptable, with no biologic complications and a high cumulative survival rate.”<sup>4</sup>

Hobo and Shillingburg have reported that milled alloy copings oxidize less during milling than during casting. This creates a more polished finish, allowing for the porcelain to bond more effectively and predictably.<sup>10</sup>

The more recent porcelain bonding success has been attributed to the strict protocol for porcelain bonding to titanium. The porcelain manufacturers (Vita) recommend certain preconditioning steps. The porcelain systems “exceed all international standard demands EN ISO 9693 (25 MPa).”<sup>2</sup> Typically, the bond strength is as high as 42 MPa. The steps are as follows:<sup>1,2</sup>

- Unidirectional grinding of the coping with a specialized bur is used for roughening the surface. Do not overheat the framework.

- Some manufacturers recommend decontamination of the coping by placing it in an ultrasonic bath of either alcohol or acetone for 30 mins. This is a precautionary step because titanium copings and bridges are milled under a mixture of water and oil to keep the milling unit’s burs cool. Because they do not undergo sintering, it is logical to conclude that a light coating of oil may remain on the coping, which could affect the reaction with porcelain under the firing sequences.
- Sandblasting of the coping surface with aluminum oxide 120- $\mu$ m to 150- $\mu$ m grit is performed.
- Passivation. The coping must be allowed to interact with the open air for 5 to 10 minutes, but no more than 30 minutes. The coping is ready to be layered.
- The bonding agent is applied first.
- Then the opaque dentin is applied.
- Then a second opaque dentin layer.
- The main buildup occurs, followed by optional stain and glazing.

The alpha oxidation layer must be removed prior to porcelain veneering.<sup>1,2</sup> The framework can be prepared using “titanium cutters”(crosscut burs)—always cutting unidirectionally. This refinement should be performed with slow speed and low pressure. Diamonds and stones should not be used. Typically, after sandblasting and before steam cleaning, the titanium coping must be passivated for approximately 10 minutes before applying the bonder. At room temperature, titanium has a strong tendency to spontaneously form a very fine oxide layer. This layer prevents corrosion and therefore is responsible for the biocompatibility of the material. Passivating the surface means airing for 5 to 10 mins but not more than 30 minutes. This is a critical step prior to adding the bonding agent. Manufacturers do not suggest the use of acid or etching agents.<sup>1,2</sup>

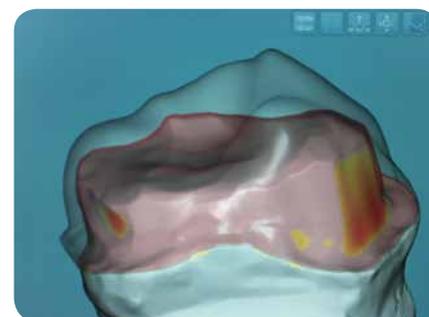
The manufacturer recommends spraying the bonding agent on the titanium oxide to obtain the best coverage and surface



**Figure 6** TiPFM crown cemented on the second molar.



**Figure 7** Reduction of the tooth structure to ensure adequate thickness.



**Figure 8** The virtual design allows the technician to see the thickness of the titanium and porcelain.

wetting. The bonding agent must completely cover the marginal area in order to obtain excellent adhesion of the porcelain. The titanium substructure can be veneered with either porcelain or composites.

Titanium requires a low-fusing porcelain with a firing temperature below 880° C because heating above this temperature causes the titanium to change from the hexagonal alpha phase to the cubic beta phase. This can cause ill-fitting copings. Furthermore, the firing of porcelain higher than the 880° C can cause the oxide reactive layer to form, inhibiting porcelain adhesion.<sup>5</sup> During the beta titanium phase, the porcelain will form a white dioxide layer that is unsuitable for bonding. The beta phase leads to impurity and brittleness.<sup>1</sup> The intaglio surface can also develop an oxide layer. Using sandblasting with aluminum oxide, the dental laboratory removed this.

The crown was fabricated to be protected with canine guidance influencing the posterior disclusion during working and nonworking movements. Centric contacts were adjusted intraorally to maintain vertical dimension of occlusion on the lingual cusp and the central fossa. Any crown and bridge cement can be used with a TiPFM. The crown should not be etched. In this case study, the crown was cemented with a self-adhesive resin cement (RelyX™ Unicem, 3M ESPE) (Figure 9). The resin cement was cured completely prior to cleanup. A sickle scaler was used to easily remove the excess resin after curing. The resin cleaved off at the margin due to the precision of the fit (Figure 10). The radiolucency of the titanium helps enable the dental team to view the underlying tooth structure for caries detection (Figure 11). The metal can also be highly polished to help reduce tartar accumulation.

Prior to the development of current technologies, Loevgren et al reported that with all the shortcomings of casting titanium alloy, the clinical outcomes in a 5-year period for ceramic-veneered titanium restorations with the Procera™ system were favorable.<sup>12</sup> With the improvements in CAD/CAM technology and bonding porcelain techniques, titanium alloy is expected to offer strong, long-term esthetic performance. It appears that the important steps remain in the methods of crown fabrication

by using CAD/CAM technology plus in the close adherence of following the manufacturers' steps for porcelain bonding.

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**Figure 9** Resin cement was cured completely prior to cleanup.



**Figure 10** Final crown in place after cleanup.



**Figure 11** X-ray of final crown placement showing the translucency.