The CAD/CAM Compound Prosthesis: Digital Workflow for Fabricating Cement-Retained Zirconia Prosthesis Over Screw-Retained Milled Titanium Bars

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The computer-assisted design/computer-assisted manufactured compound prosthesis involves designing and milling a cement-retained prosthesis over milled titanium bars. In the presented clinical case report, a diagnostic wax pattern was made to assess esthetics, contours, and occlusion. A total of eight maxillary root-form implants were restored by following the combined prosthesis design concept. The mandibular arch was restored with a screw-retained implant-supported zirconia fixed prosthesis. A milled polymethyl methacrylate (PMMA) maxillary interim prosthesis was fabricated to intraorally confirm the diagnostic wax pattern. The interim PMMA prosthesis was then scanned, and three screw-retained titanium milled bars were designed that provided the substructure of the definitive restoration. A cement-retained milled zirconia prosthesis was then designed and fabricated. The zirconia prosthesis provided the superstructure of the definitive complete-arch restoration. After confirming esthetics, phonetics, occlusion, and accessibility for oral hygiene, the superstructure was cemented with temporary cement to enable retrievability.


The complete-arch fixed implant-supported prosthesis has been associated with a high biologic success rate after long-term function, along with a variety of technical and prosthodontic complications. Special consideration has been given to implant-supported fixed complete prostheses (ISFCP) in the maxillary arch because they have been associated with esthetic and phonetic difficulties. Therefore, adequate planning is needed when fabricating a maxillary ISFCP. The extension of the maxillary alveolar ridge resorption, the necessity for adequate lip support, the ability to fabricate a retrievable prosthesis, the accessibility for oral hygiene, and phonetics determine the potential for fabricating a fixed maxillary prosthesis.

In some clinical situations where advanced maxillary alveolar ridge resorption is observed and implants cannot be placed at a prosthetically ideal position, an implant-supported overdenture may offer superior esthetics and/or phonetics. Overdentures may offer more latitude in implant placement and can be fabricated in clinical situations involving implants placed at prosthetically unfavorable positions. However, overdentures have been associated with increased maintenance as compared to fixed implant-supported prostheses. The use of milled bars in conjunction with a removable...
prosthesis may offer reduced maintenance issues. In addition to the reduced incidences of technical complications, ISFCPs offer enhanced masticatory function and retention security. In clinical situations where severe bone resorption precludes implant placement at an ideal prosthetic position, some authors have suggested the fabrication of individual crowns cemented on an implant-supported substructure. The limitation of this treatment modality is the high cost associated with it.

In recent years and in an attempt to overcome technical complications involving chipping and wear of the prosthetic teeth, several authors have suggested the use of layered or monolithic zirconia for completely edentulous arches with high short-term success.

The purpose of the current clinical report is to introduce a treatment modality for the completely edentulous arch where implants have been placed in a prosthetically unfavorable position. Computer-assisted design/computer-assisted manufactured (CAD/CAM) titanium milled bars are fabricated as a substructure, and a CAD/CAM-milled zirconia superstructure is fabricated and cementsed on the milled substructure.

Clinical Report

A 61-year-old man presented at the Center for Prosthodontics and Implant Dentistry at Loma Linda University seeking treatment for his maxillary and mandibular complete...
edentulism. He had received eight threaded root-form implants in the maxillary arch (NobelReplace Conical Connection [Nobel Biocare] for implants at the area of teeth no. 11, 21, and 23; NobelActive [Nobel Biocare] for an implant at the area of tooth no. 13; and Roxolid SLA bone level implants [Straumann] for implants at the area of teeth no. 16, 14, 24, and 26) and five threaded root-form implants in the mandibular arch. After discussing various treatment options, a decision was made to restore both arches with ISFCP.

A preliminary impression was made from both arches by using a custom tray and polyvinyl siloxane impression material (Aquasil, Dentsply Sirona). The preliminary cast was utilized to fabricate an acrylic-resin bar (Pattern Resin, GC America) by splinting the impression copings in the laboratory. The acrylic resin bar was sectioned with a diamond disk (Kontour Stone, Brasseler USA) and then splinted with autopolymerized acrylic resin (Pattern Resin, GC America) intraorally to make the definitive impression and the definitive stone cast according to the direct splinting technique (Fig 1).22

After obtaining interocclusal records, maxillary wax patterns and mandibular denture teeth set-ups were made (Fig 2) and intraorally verified. In the laboratory, impression copings were placed on the implant analogs of the definitive maxillary stone cast, verifying the unfavorable implant position (Fig 3). A completely contoured screw-retained wax pattern was then made for the maxillary arch with the use of temporary abutments, according to

![Fig 2 Diagnostic wax patterns. (a) Frontal view. (b) Lateral view.](image)

![Fig 3 Unfavorable maxillary implant angulation. (a) Frontal view. (b) Lateral view.](image)
a technique that has been previously described (Fig 4a). The screw-retained wax pattern was then evaluated intraorally (Figs 4b and 4c). Intraoral evaluation of the diagnostic wax pattern allowed evaluation of esthetics, contours, lip support, and accessibility for oral hygiene.

The diagnostic wax pattern was then transferred to the laboratory and placed on the definitive stone cast and was subsequently scanned with a laboratory scanner unit (S600 ARTI Scanner, Zirkonzahn). Scanning abutments were also placed, and implant positions were scanned by utilizing the same laboratory scanner. The software incorporated in that
specific scanner had the potential to superimpose data from the scanned diagnostic wax pattern and the scanned stone model with the scanning abutments in place. After digitally duplicating the design of the diagnostic wax pattern, an interim prosthesis was fabricated by milling a polymethyl methacrylate (PMMA) blank (Multi-layer PMMA disks, Talladium) through a five-axis milling machine (Milling unit M5, Zirkonzahn). The software of the above-referenced scanner had the ability to uniformly cut back the gingival area of the prosthesis to a desired thickness so space would be provided to apply tissue-colored composite resin to simulate soft tissue esthetics. After milling the PMMA blank, tissue-colored composite resin (GRADIA gum shades, GC America) was applied and subsequently light polymerized to simulate gingival esthetics (Figs 5a and 5b). The esthetics, lip support, occlusion, and accessibility for oral hygiene were then confirmed intraorally (Fig 5c). The interim PMMA prosthesis was placed intraorally for 2 weeks to allow the patient to confirm esthetics and function. A cotton pellet and temporary filling material (Cavit G Temporary Filling Material, 3M) were placed in the occlusal access holes of the interim PMMA prosthesis.

After confirming esthetics and function, the interim prosthesis was removed and scanned with the same scanner utilized for the diagnostic wax pattern (Fig 5d). The interim prosthesis was digitally duplicated using that specific laboratory scanner’s incorporated software. Scanning the clinically verified interim prosthesis allows replication of the contours and occlusion when designing the definitive prosthesis.24

The data obtained from scanning the interim prosthesis were utilized to design and fabricate the definitive restoration. The definitive maxillary prosthesis was designed with a substructure that consisted of three separate titanium milled bars (Fig 6). The bars were milled from a titanium blank (TITAN 5 95H10, Zirkonzahn) with the use of a milling machine (M4 wet heavy metal milling unit, Zirkonzahn).25 The superstructure was milled from...
a zirconia blank (Prettau zirconia, Zirkonzahn). After milling, the zirco-
nia was stained with a water-based stain that was provided by the
manufacturer (Colour Liquid Prettau Aquarell, Zirkonzahn). After the
staining was applied, the prosthesis was sintered (Zirkonofen 600/V2,
Zirkonzahn) according to the manu-
facturer’s recommendations.

For the mandibular arch, the
prosthesis was designed as a milled
zirconia prosthesis. The design pro-
vided space to have titanium metal
sleeves inserted in the prosthesis.
The titanium sleeves were secured
with resin cement (Panavia SA,
Kuraray Dental) so the zirconia had
no contact with the titanium implant
surface.26,27

The maxillary milled bars were
confirmed to have passive fit28 and
the abutment screws were torqued
according to the manufacturer’s rec-
ommendations. The fit, esthetics,
and occlusion of the definitive pro-
thesis were then verified intraorally
(Fig 7). A fast-setting, light-body
dental composite (Exafast NDS Fast
Set, GC America) and composite
were placed at the occlusal access
channels of the mandibular pros-
thesis. The maxillary zirconia superstructure was
cemented with temporary cement
(Temp-Bond, Kerr Dental).29

The patient was given a resil-
ient splint. Prior research has sup-
ported that using an occlusal splint
is another method typically used to
protect restorations.20 The three-
year follow-up revealed no clinical
sign of pathosis, and there were no
technical or biologic complications.
Intraoral radiographic examination
revealed a stable peri-implant bone
level (Fig 8).

Discussion
The significance of the alternative
restorative protocol presented is
that it can be applied in clinical situ-
ations involving the restoration of
implants with unfavorable angula-
tion. The CAD/CAM compound
prosthesis can also be fabricated
for partially edentulous patients by

![Fig 7](a) Intraoral view, milled titanium bars. (b) Intraoral view, milled zirconia maxillary prosthesis. (c) Facial view, maxillary and mandibular prosthesis at maximum intercuspation position. (d) Facial extraoral view, definitive maxillary and mandibular prostheses. (e) Definitive prostheses, panoramic radiograph.)
following similar clinical and labora-
tory steps.

The selected superstructure consisted of a zirconia monolithic milled prosthesis. Ceramic veneered zirconia frameworks have been associated with a high incidence of technical complications mainly due to ceramic chipping. Use of monolithic prostheses has been associated with high short-term success and limited technical complications. In addition, Cardelli et al indicated that monolithic zirconia complete-arch rehabilitations induced a clinically acceptable wear pattern of the opposing arch. Long-term studies are needed to establish the biologic and technical complications when using a complete-arch zirconia restoration.

The substructure in the presented clinical situation consisted of three separate milled titanium bars. The rationale for having three separate milled bars was to provide a tapping area for ease of superstructure retrievability. This is made possible by providing inter-bar superstructure pontic areas so the clinician can retrieve the superstructure. In addition, fabricating a single complete-arch milled bar when multiple implants are present has been associated with difficulties in obtaining sufficient passive fit. However, clinicians may elect to fabricate a single milled bar connecting the supporting implants by relying on the superior accuracy of milled frameworks. In such cases, the clinician may need to modify the superstructure design to allow for retrievability.

The presented combined prosthesis involved milled titanium frames to provide support and retention to the superstructure. Some clinicians may elect to fabricate individual cast or milled abutments that would provide retention and support to the superstructure; the advantage of this treatment modality is the lack of concern regarding the accuracy of fit of the substructure, since individual abutments are not connected and presence or absence of passive fit of the substructure is not an issue. On the other hand, milled bars might provide superior retention and support due to the increased surface area.

An alternative design would entail providing palatal screws that would secure the zirconia superstructure on the titanium substructure. However, this modality might increase the cost of fabricating the prosthesis. In addition, it is unknown if adding retentive screws on the palatal aspect of the superstructure would result in microfractures of the zirconia material.

It should be mentioned that the presented combined prosthesis is mostly indicated to restore excessively misaligned implants due to either extensive osseous resorption or operator error. Use of multiunit abutments at either 17 or 30 degrees typically enables the restorative dentist to fabricate a screw-retained prosthesis. In the presented case, even with the use of multiunit abutments, the occlusal access channels would have been at the facial aspect

Fig 8 Three-year postloading intraoral radiographs.
of the teeth. The presented design concept mostly applies for clinical situations where the use of multiunit abutments would not have been effective.

A limitation of the presented restorative protocol is the increased cost associated with the fabrication of the milled bars and zirconia superstructure when compared to a screw-retained complete-arch fixed prosthesis. On the other hand, the laboratory cost associated with the presented CAD/CAM compound prosthesis is significantly reduced when compared to a prosthesis that has been designed with a substructure and individual cementable crowns on top of the substructure.15–17

Another limitation of the presented CAD/CAM compound prosthesis is the unknown amount of retention associated when cementing a complete-arch zirconia superstructure to a titanium milled bar by using a temporary cement. Garg et al29 indicated that the amount of retention obtained when a temporary cement is used over a milled abutment ranges between 333.86 and 394.62 N. However, their study was conducted on single abutment-supported crowns. The amount of retention that is obtained when a complete-arch superstructure is cemented over a milled bar is unknown. In addition, the effect of using temporary cement on the peri-implant soft tissue remains in question.

Conclusions

The CAD/CAM compound prosthesis can offer an alternative restorative protocol when restoring implants with unfavorable angulation. A long-term clinical study is needed to validate the application of the presented protocol on a routine basis.

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References