Enhancing Fracture and Wear Resistance of Dentures/Overdentures Utilizing Digital Technology: A Case Series Report

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Fracture; wear; denture; overdenture; CAD/CAM; zirconia; framework; SLM; milled.

Abstract
Since it was first introduced into the dental world, computer-aided design/computer-aided manufacturing (CAD/CAM) technology has improved dramatically in regards to both data acquisition and fabrication abilities. CAD/CAM is capable of providing well-fitting intra- and extraoral prostheses when sound guidelines are followed. As CAD/CAM technology encompasses both surgical and prosthetic dental applications as well as fixed and removable aspects, it could improve the average quality of dental prostheses compared with the results obtained by conventional manufacturing methods. The purpose of this article is to provide an introduction into the methods in which this technology may be used to enhance the wear and fracture resistance of dentures and overdentures. This article will also showcase two clinical reports in which CAD/CAM technology has been implemented.

Wear resistance
Wear of occluding denture tooth surfaces is an inevitable sequela of successful treatment with removable prostheses. Although the severity of this wear process relies on several factors, major determinants include the length of service, the physical nature of opposing dentition, and presence of parafunctional habits. When the extent of wear becomes more significant, the patient’s occlusal vertical dimension, chewing efficiency, and esthetics are increasingly compromised.2,3

Various solutions have been discussed in the literature to address the issue of wear, including highly cross-linked acrylic resin teeth,9 amalgam or metal inserts on occlusal surfaces, and the use of composites.10 Of the assorted solutions, however, gold occlusal surfaces have been the most frequently referenced option.

Since the concept was first introduced to dental literature in 1964,2 a number of methods to construct gold occlusal surfaces have been described. Some authors have advocated construction after the prosthesis has been processed, inserted, and adjusted,2-5 while others described techniques to incorporate gold occlusal surfaces prior to processing.6-8 Whether gold occlusal surfaces are created before or after the denture...
processing, extra steps such as waxing, investing, casting, and polishing are required, which are time consuming and expensive, and require considerable technical expertise. After creating gold occlusal surfaces, a variety of cementing and bonding agents have been recommended to attach the gold occlusal surfaces to the prepared prosthetic teeth, including composite resin, adhesive resin cement, and chemically activated acrylic resin.

As the cost of gold has risen, and as patient acceptance of metal display has declined, alternative materials for durable yet esthetic occlusal surfaces have come to the market. The
fabrication of a maxillary denture with posterior occlusal onlays in one of those alternative materials, zirconia, is now possible with CAD/CAM subtractive (milling) technology.

**Fracture resistance**

Similarly, CAD/CAM technology can be used to enhance the fracture resistance of conventional and implant-supported prostheses. Fracture of an acrylic resin denture base can be an inconvenient and vexing complication to treatment. The etiology of denture fractures has been extensively investigated and reported

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**Figure 8** Final tooth setup for mandibular implant-assisted overdenture.

**Figure 9** Split stone flask index for space analysis.

**Figure 10** Completed metal framework design.

**Figure 11** Designed SLM metal palate framework for maxillary denture.

**Figure 12** SLM metal framework tried on mandibular cast.

**Figure 13** SLM framework fitted to final cast.

**Figure 14** Space verification using SSF before processing.
Causes of these fractures include occlusal disharmony, excessive occlusal forces, flexure and fatigue of the denture base as a result of alveolar resorption, thin spots in the denture base, impact damage as a result of dropping the denture, as well as fractures by neuropsychiatric patients. Denture base fractures are more commonly seen with implant-supported removable complete dentures than tissue-supported prostheses. This is an inherent complication in the anterior portion of bar-retained mandibular overdentures when an inadequate thickness of acrylic resin exists to house the dimensions of the bar and clips. This tendency also holds true in cases of limited interarch space for Locator or ball attachment retained implant overdentures.

The use of a metal base or metal framework for a removable prosthesis is not a new concept. A “suspended” internal framework in a denture prosthesis was described by Morrow et al in 1968. A number of authors have since formulated additional techniques to incorporate reinforcing metal frameworks within a denture base before processing. Dental laboratory fabrication of a framework and the subsequent prosthesis remains a labor-intensive, technique-sensitive task typically performed by an experienced dental laboratory technician. With the introduction of the additive selective laser melting (SLM) technology to fabricate partial removable dental prosthesis (RDP) frameworks, a more cost-effective method to manufacture metal frameworks is now available.

This article documents and examines the use of both additive and subtractive methods to create conventional dentures and implant-assisted overdentures with enhanced wear and fracture resistance.

Patient 1: Maxillary complete denture with milled posterior zirconia onlays

A 55-year-old male was referred to the graduate prosthodontics clinic for fabrication of a maxillary complete RDP. Four years ago, his mandibular dentition had been successfully restored in an outside practice with metal ceramic crowns and a fixed dental prosthesis (Fig 1). In the interval following his mandibular rehabilitation, he reported replacement of his maxillary denture five times due to the severe wear of the denture teeth opposing his porcelain restorations. His last maxillary complete denture also fractured, and he had no maxillary prosthesis for 1 year. A treatment option to remake the maxillary denture with milled gold occlusal onlays was presented to the patient, but was rejected due to esthetic concerns. An alternative milled zirconia onlay approach was selected.

Technique

1. A new maxillary complete denture was fabricated, optimizing patient esthetics and phonetics (Fig 2). Masticatory efficiency and comfort were maximized with clinical remount and occlusal refinement of the clinically fitted prosthesis. After a period of comfortable denture wear, the final denture occlusal anatomy was digitally scanned (3Shape; 3Shape A/S, Copenhagen, Denmark). An interocclusal record made in centric relation (CR) was scanned as well.

2. All posterior acrylic resin teeth were prepared for zirconia onlays with 1 mm of occlusal reduction and a 2-mm central isthmus. The preparations included the palatal cusps but ended on the lingual inclines of the buccal cusps (Figs 3 and 4). An additional scan was performed of the prepared teeth and merged with the original scan.

3. In the design phase, preparation finish lines were outlined and proximal margins connected to virtually create a single splinted framework covering all premolars and molars. The milling parameters for zirconia were entered according to the manufacturer’s recommendations.

4. Using the merging function of the 3Shape software, a zirconia framework design was selected to reproduce the original tooth shape and form. Occlusal contacts were refined and brought to idealized positions via the scanned interocclusal CR registration (Fig 5).

5. After approval, the virtual splinted zirconia onlay designs were transmitted to the milling center for fabrication (Whip Mix Corporation, Louisville, KY). Upon receipt from the milling center, the external onlay surfaces were polished and tried in. After fit and occlusal accuracy were verified, onlay intaglio surfaces were treated with Z-prime (Bisco, Schaumburg, IL) prior to final cementation to enhance the bond to the resin cement. Retentive undercuts were made in the onlay preparations to
create both chemical and mechanical retention of the resin cement to the acrylic teeth.
6. Bonding was completed using translucent dual cure resin cement (Rely X Unicem; 3M ESPE, St. Paul, MN). Excess cement flash was removed, and occlusal refinement was accomplished on the articulator via the previously fabricated remount cast (Fig 6). Minimal adjustments were required intraorally before definitive prosthesis delivery (Fig 7).

Patient 2: Maxillary complete denture with metal palate opposing a mandibular implant overdenture with internal metal framework

A 72-year-old female patient presented to the graduate prosthodontics clinic for complete denture care. She reported dissatisfaction with her previous prosthesis due to the thickness of the palatal area and the repeated fracture of her mandibular implant-assisted overdenture.

Technique
1. After a wax try-in appointment, the dentures were flasked using the split stone flasking technique (SSFT), and all wax boiled out. This innovative technique was devised by Dr. Russell Johnson and presented in the poster competition at the 2013 Annual Session of the American College of Prosthodontists. The SSFT permits rigid indexing of denture tooth positions for space analysis (Fig 8).
2. The space between the teeth and the edentulous ridge was filled with lab condensation silicone putty (Sil-Tech; Ivoclar Vivadent, Amherst, NY; Fig 9) and digitally scanned (3Shape). The scanned silicone mold provided a 3D representation of the space available for the metal framework.
3. Using the removable partial denture design software for the 3Shape, a metal framework with tripodal cast stops and metal struts over the Locator housings was created virtually within the restorative space and transmitted to the manufacturer for sintering (Argen Dental Laboratory, San Diego, CA; Fig 10). The maxillary metal palate framework was designed in a similar fashion (Fig 11).
4. Upon receipt from the manufacturer, fit and reproduction fidelity were verified (Figs 12 and 13). Both frameworks were opaqued in areas of planned acrylic resin retention with a light-cured pink opaquer (Ropak UV; XPDent, Miami, FL) and allowed to cure for 15 minutes in a curing oven. The SSF was used to verify sufficient space between the opaqued frame and overlying denture resin teeth before processing (Fig 14).
5. Framework tissue stops were luted to the casts with chemically cured acrylic resin (Lang Dental Manufacturing Co., Wheeling, IL). The SSF for both prostheses were incorporated in the conventional brass flasks, as described by Johnson, and heat processed per the manufacturer’s recommendations. Locator attachments were picked up intraorally in the mandibular prosthesis.
6. The definitive prosthesis was inserted and the patient reevaluated in 1 week to verify phonetic competency, occlusal accuracy, and patient satisfaction with the comfort and esthetics (Figs 15 and 16).

Discussion

This report has examined two examples of care that highlight the potential of CAD/CAM technology to enhance wear and fracture resistance for both conventional and implant overdentures. The use of milled zirconia restorations for complete dentures has been reported in the literature: examples used full occlusal coverage with zirconia mechanically connected to the underlying acrylic resin teeth by diatorics.22 However, none of the presented patients, only the palatal cusps were onlaid with preparations ending on lingual inclines of the buccal cusps for esthetic purposes. The shade matching between resin acrylic teeth and polished zirconia is a challenge and represents a point of concern for some patients, especially those with high esthetic expectations or with a high smile line. The fear of weakening the buccal cusp by not incorporating it in the onlay design was addressed by employing a lingualized occlusal scheme for the tooth setup.

The use of porcelain denture teeth has also been suggested as a remedy for excessive wear when opposing porcelain restorations; however, porcelain teeth require considerable restorative space to be considered as a viable option. The main form of connection between porcelain teeth and the acrylic resin denture base is purely mechanical. In circumstances of limited restorative space, grinding the intaglio of porcelain teeth may compromise the retentive diatorics and result in the eventual separation of the porcelain tooth from the acrylic resin denture base. The use of zirconia over prepared acrylic teeth takes advantage of the chemical bond strength of acrylic teeth in relation to the denture base, while simultaneously providing a good bonding substrate for the milled zirconia. Other materials have been described in the literature for onlays, including milled lithium disilicate.23 The reported design requires individually milled crowns at a cost considerably more significant than that of zirconia milled in quadrants. The use of splinted zirconia may also enhance the retentive properties compared to individual crowns. Additionally, lithium disilicate requires greater thickness than zirconia for adequate fracture resistance and is less appropriate in circumstances of limited restorative spaces. Finally, polished zirconia has been shown to have superior wear characteristics when opposing unrestored natural teeth.24–26

For SLM framework fabrication, the physical properties of base metal alloys make them the material of choice for this purpose. Allergies to such materials have been reported in the literature, with an estimated frequency of 10% in females and 1% in males.27 Careful medical history and allergy testing should be considered to make an appropriate material choice for each patient. Metal palate designs create limitations for relining and rebasing such dentures. Garfield has described an acid etch technique that can be used to mitigate this concern somewhat.28 The rough surface texture created by SLM framework production is ideal for mechanical retention between the framework and the denture resin. Conversely, polishing such highly irregular
exposed portions of these SLM frames is time consuming and requires considerable technical expertise.

**Conclusion**

These clinical reports demonstrated the following:

1. The total estimated time from initial scanning through design, milling, shipping, and receipt of CAD/CAM frames is 3 to 4 days.
2. The cost of CAD/CAM products represents a considerable savings from that of conventionally fabricated frames.
3. SLM products are particularly suited for fabrication of frames that will be totally incorporated within a prosthesis, negating the finish and polish issues with raw SLM surfaces.
4. After 2 years of service, a stable occlusion was confirmed for both patients presented, with no clinical signs of occlusal wear or prosthesis fracture.
5. Digital technology is being used to efficiently create clinically successful and reliable dental restorations. In the near future, CAD/CAM may well become the preferred fabrication method for most dental prostheses.

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