ACP AMERICAN COLLEGE OF PROSTHODONTISTS Your smile. Our specialty.℠

The Use of Custom-Milled Zirconia Teeth to Address Tooth Abrasion in Complete Dentures: A Clinical Report

Joanne M. Livaditis[1] & Gus J. Livaditis, DDS[2]

[1]Student, University of Maryland, College Park, MD
[2]Private Practice, Baltimore, MD

The article is associated with the American College of Prosthodontists' journal-based continuing education program. It is accompanied by an online continuing education activity worth 1 credit. Please visit www.wileyonlinelearning.com/jopr to complete the activity and earn credit.

Keywords
Zirconia; dentures; removable prosthodontics.

Correspondence
Gus J. Livaditis, Ste. 100, 1206 York Rd., Baltimore, MD 21093. E-mail: LivaditisDDS@aol.com

The authors deny any conflicts of interest.

Accepted August 11, 2012

doi: 10.1111/j.1532-849X.2012.00943.x

Abstract

A patient exhibited severe abrasion of resin posterior denture teeth including perforation of the denture base. New dentures were provided to explore the application of zirconia teeth for complete dentures. [Correction added to online publication 07 November 2012: "Zirconium" corrected to "Zirconia".] Traditional denture procedures were combined with fixed prosthodontic CAD/CAM procedures to fabricate custom-designed four-tooth posterior segments in hollow crown form to reduce weight and with a retentive form for interlocking to the denture base. The new dentures were successful in reducing wear of the denture teeth over the short-term follow-up period.

Zirconia is currently used in numerous applications, including crowns, fixed dental prostheses (FDPs), dowels, cores, implants, implant abutments, and orthodontic brackets.[1-3] Of these applications, fixed prosthodontic restorations are the most relevant for complete dentures. Due to its compression resistance of approximately 2000 MPa,[1] zirconia has been shown to be effective for posterior teeth of fixed prostheses supported by and/or opposing natural teeth or implant-supported restorations. Given that soft-tissue-supported prostheses experience less masticatory force, the application of zirconia to dentures can be reasonably extrapolated from the use of zirconia in current practice.

Zirconia stabilized with 3% Y_2O_3 (3Y-TZP) is the form most commonly used for dental restorations.[1] In the following clinical report, the Y-TZP zirconia system included an alloy of 5% Y_2O_3 with 3% HfO_2 and less than 1% Al_2O_3 (crystal diamond high translucency YZ zirconia, DLMS-crystal zirconia). As reported by the manufacturer, this type of zirconia has a flexural strength of 950 MPa. The posterior tooth segments for this denture application were formed entirely in zirconia as there was no specific functional or esthetic advantage for layering porcelain.

Zirconia has numerous characteristics that make it attractive for use in dental restorations, including the proposed denture application. Zirconia is neither cytotoxic nor mutagenic, and it has been shown to induce a smaller inflammatory response in tissues and less bacterial colonization than other restorative materials.[3,4] Zirconia is tooth colored and opaque, providing a desirable alternative to fabricating less-esthetic porcelain-fused-to-metal frameworks. Unlike most brittle, moderately strong ceramic materials that are subject to failure, zirconia ceramic has been shown to inhibit crack growth.[5] It also has been shown to wear less than other ceramic materials when opposed by zirconia during testing[6] and to cause less wear on antagonists than other ceramics do.[7]

Clinical report

A 50-year-old patient with 13.5-month-old complete maxillary and mandibular dentures was referred for evaluation and treatment. The dentures exhibited normal contact of the anterior teeth but extreme wear in the posterior areas, with a higher degree of wear on the left side than on the right. The patient's occlusal vertical dimension (OVD) was maintained by the anterior teeth, which exhibited no abrasion. The degree of abrasion on the posterior teeth resulted in a 5 to 7 mm interocclusal space in the most severe areas. Abrasion occurred to the extent that the maxillary denture was perforated through the denture base with an opening of approximately 7 × 20 mm (Fig 1). The referring dentist reported that the patient's previous dentures also exhibited a similar degree of abrasion over a period of 27 months. Both sets of dentures consisted entirely of resin-based denture teeth.

During the initial consultation, the patient reported having numerous teeth extracted immediately before the first dentures.

Figure 1 (A) Anterior teeth displayed no wear and maintained the OVD. (B) Tooth abrasion resulted in lack of occlusion of posterior teeth. (C) Greater wear occurred on patient's preferred chewing side. (D) Wear pattern extended beyond tooth surfaces resulting in perforation of the denture base.

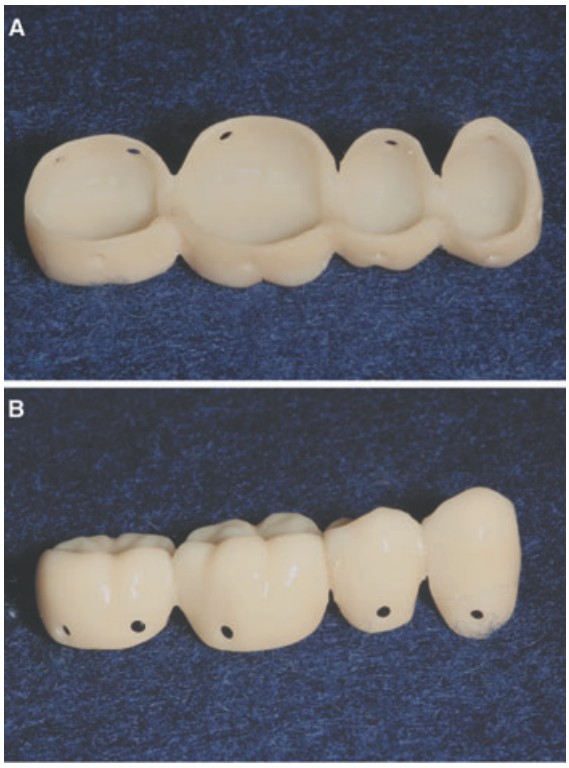

Figure 2 (A) Zirconia teeth were milled in four-tooth segments. The teeth were milled in a hollow form to reduce the weight of the zirconia teeth. (B) Holes were created in subgingival areas of the segments in the presintered stage to provide retention to the denture base.

He described wearing the dentures at night and using denture adhesive throughout the 40-month denture-wearing period. No unusual habits such as holding or biting objects with the teeth were identified. Upon reviewing his diet, the patient reported no unusual patterns except for frequent snacking on sourdough pretzels. He also reported being told that he had a bruxing habit.

Figure 3 The zirconia segments were filled with tooth-colored composite to prevent discoloration by the pink denture base resin. Additional retention was created in the composite filler.

Figure 4 Trial insertion with resin denture teeth set in a customized arrangement. Posterior teeth were scanned to generate the full-contour pattern for milling the zirconia teeth.

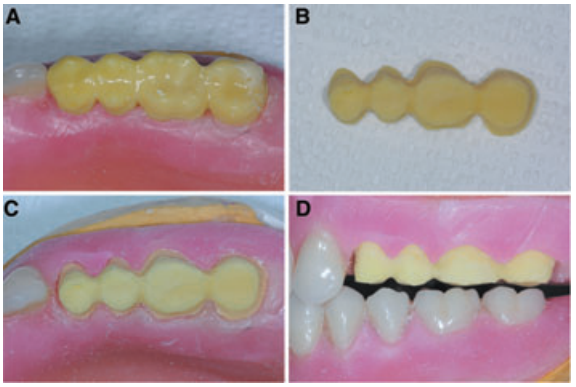

Figure 5 (A) Impressions were made of the posterior segments of the trial denture. The segments were replicated in a material for trimming. The segments were indexed to the denture base for accurate repositioning. (B) The segments were trimmed to fixed prosthodontic abutment form. (C) The prepared abutment segments were repositioned in the denture base for scanning. (D) The prepared abutment segments were scanned and the abutment scans were merged with the full-contour scans to generate the zirconia tooth segments.

Figure 6 The milled, sintered, and glazed segments were repositioned in the denture base with the anterior teeth. Occlusion and patient acceptance of the esthetic arrangement were verified during a trial insertion.

The oral examination revealed prominent ridge form on both arches. The patient's current dentures were evaluated and found to be well adapted and stable on the ridges. Retention could not be adequately assessed in light of the large perforation. The absence of posterior occlusion was considered to be a significant reason for the reliance on denture adhesive, as functioning only on anterior teeth would dislodge the dentures. The soft tissues appeared normal, and there were no indications of tissue irritation, tissue indentations, or pressure spots as might be seen with clenching or bruxing. Except for the extreme wear of the dentures, the patient was evaluated as a class I patient based on the Prosthodontic Diagnostic Index.[8]

Figure 7 (A) The dentures were processed, refined, and polished. (B) The dentures were provided to the patient after routine adjustments.

Figure 8 (A) At 8 months, dentures show loss of luster on the denture base areas. Teeth exhibit no wear. (B) The patient at 8 months depicting dentures with intact posterior occlusion.

The wear pattern on the dentures was consistent with localized abrasion, which could not be attributed to attrition, as there was no potential for frictional contact of the posterior teeth after the initial wear (Fig 1B, C). Since significant abrasion only occurred on the posterior teeth, the cause of abrasion was likely due to a material or object large enough to account for the 5 to 7 mm spaces in the posterior areas. The patient reported consuming three 16-oz bags of sourdough pretzels (Utz Quality Foods, Inc., Hanover, PA) per week during the 40-month period. Sourdough pretzels are characterized by thick loops of dough, a hard inner consistency, and a rigid crust with exposed large salt granules. The width of the pretzel loops (approximately 13 to 15 mm) was sufficient to have caused the posterior tooth wear. The projecting salt granules could have served as an abrasive material, and the large granule size (approximately 1 to 2 mm in diameter) may have increased abrasion due to a prolonged period needed to dissolve the salt.

Once the abrasion was attributed to the pretzels, the recommendation was made to the patient to reduce his consumption. When planning new dentures, the use of resin-based, including composite-based, posterior denture teeth was ruled out. Implant-supported prostheses were not acceptable to the patient. Other alternatives considered to prevent similar abrasion included the use of porcelain denture teeth or metal onlay denture teeth; however, potential chipping or fracturing of porcelain teeth was a concern, and metal onlay teeth were regarded as

esthetically unacceptable. The patient was informed that zirconia is used for restorations on natural teeth and on dental implants and may be an abrasion-resistant option for complete dentures. The patient was receptive to the possibility of obtaining more durable dentures and retained the option for conventional dentures in the event the effort was unsuccessful. This patient provided an opportunity to explore the application of zirconia teeth in complete denture procedures.

Various macromechanical forms are possible to provide retention of the teeth in the denture base. For this patient, retention was accomplished by drilling several holes in the subgingival areas of the zirconia teeth during the presintered stage (Fig 2). This method was used instead of bonding the denture base to the zirconia, because zirconia is typically not amenable to bonding without additional preparation of the zirconia surface. Bonding may be beneficial, however, to prevent potential leakage and staining at the interface of the denture base and teeth. Several procedures have been investigated to create a retentive and active surface on zirconia for bonding. These include (a) fusing a slurry of zirconia powder and "pore former" to the surface of the pre- or postsintered zirconia and later burning off the "pore former" to create a micromechanical surface for bonding,[9,10] and (b) using selective infiltration etching whereby a glass-containing compound is heated to molten stage for diffusion along grain boundaries. Upon cooling, the glass would be dissolved in an acid bath, exposing a retentive surface.[11,12] A third procedure involves fusing etchable porcelain to the zirconia, followed by etching the porcelain with hydrofluoric acid to create micromechanical retention to resin.[13-16] Additionally, two systems are commercially available for embedding silica on the surface of zirconia using air abrasion with aluminum trioxide particles modified with silica. A laboratory version uses 110 μm silica-coated alumina particles (Rocatec, 3M ESPE, St. Paul, MN), while a chairside system uses 30 μm particles (CoJet, 3M ESPE).[17-21] Both systems embed silica onto the zirconia surface, making the surfaces chemically reactive to resin with silane coupling agents. In this denture procedure there was no compelling need to incorporate micromechanical retention in the denture teeth unless staining at the interface had been observed to occur. The custom milling process and the hollow form of the teeth provided a reliable and efficient means for retention of the teeth to the denture base. Micromechanical retention and/or chemical adhesion features are more valuable for fixed prosthodontic restorations.

Hollow denture teeth, similar in form to conventional crowns or FDPs (Fig 2), were considered to be preferable to solid teeth to reduce the weight of the denture teeth without sacrificing strength. Zirconia is substantially heavier than traditional porcelain or resin; even in a hollow form, the zirconia teeth were approximately three times the weight of porcelain teeth and five times the weight of resin-based teeth. A potential complication of the hollow design could have been discoloration, if the moderately translucent zirconia teeth were filled and processed with a pink denture base resin; however, this problem was avoided by filling the zirconia teeth with tooth-colored resin immediately prior to processing the denture bases (Fig 3).

Denture teeth were not available in zirconia molds or shades, and no computer software program designed to fabricate denture teeth in zirconia was known to the authors at the time of this procedure. Such a computer program likely would have provided not only the mechanism for designing and milling the zirconia teeth, but also a method for accurately positioning the zirconia teeth on the denture base throughout the process. A software program and milling equipment designed for fixed prosthodontic procedures were used to the extent possible, and laboratory procedures were adapted as needed.

Clinical and laboratory procedures

The clinical phase for the zirconia dentures followed traditional complete denture procedures for the preliminary and master impressions, as well as for refinement of the occlusal rims and for interocclusal records. The new zirconia dentures were designed to include resin-based anterior teeth since no wear occurred in the anterior areas of the previous dentures. Denture teeth were set to create a customized arrangement, which was checked intraorally for optimal esthetics and occlusion (Fig 4). Laboratory procedures also paralleled traditional complete denture procedures, except for the fabrication and processing of the zirconia teeth.

The zirconia teeth were processed in four-tooth posterior segments. A customized arrangement of the teeth for trial dentures was completed prior to scanning; therefore, no benefit would have been derived by milling 16 individual teeth. A CAD/CAM system for fixed prosthodontic zirconia restorations was used to design and fabricate the zirconia denture tooth segments (DLMS-Crystal Zirconia, Scottsdale, AZ). First, a scan was made of the posterior segments of the trial tooth arrangement to generate the full contours and occlusal anatomy of the zirconia teeth. Next, an impression was made of the posterior segments of the trial tooth arrangement, the impression was poured in stone, and a vacuum-formed shell was created for each segment. The posterior teeth were removed from the trial denture bases, and indexing areas were formed in the trial bases for eventual repositioning of the segments. Using the vacuum-formed shells, the posterior segments were replicated in a semirigid polyether impression material (Ramitec, 3M ESPE) on the denture bases while registering the indexing areas. The posterior segments, formed with a material (Ramitec) with properties that facilitated carving (Fig 5), were removed and carved to simulate tooth preparation form for crowns. The carved segments were repositioned on the denture bases using the indexing areas. Then, the carved segments were scanned to serve as prepared dies for the design of crown segments by the computer program. The computer program integrated the initial scan of fully contoured teeth onto the tooth preparation scan to enable the designing, processing, and milling of each four-tooth fixed-prosthodontic-type restoration.

All segments were milled to provide zirconia thickness of approximately 1.5 mm except for the margin areas (Fig 2). The segments were formed using zirconia (DLMS) and milled (CBMS, Cercon, Dentsply Intl, York, PA). After milling and prior to sintering the segments, perforations were made in the subgingival areas of the teeth for retention of the segments within the denture base. The segments were then stained, sintered, further stained, and glazed.

The zirconia segments were repositioned in the trial denture bases and were evaluated intraorally to confirm proper occlusal relationship (Fig 6). The soft tissue areas of the dentures were refined in the trial dentures and prepared for processing. After flasking the dentures and eliminating the denture base wax, the zirconia segments were filled with tooth-colored resin (Vita Zeta, Vita Zahnfabrik, Bad Säckingen, Germany). Additional retention was created in the resin that filled the segments (Fig 3). The dentures were processed, removed from the flasks, cleaned, and polished. They were provided to the patient with routine checks and adjustments. Occlusal adjustments were made using conventional diamond burs and polished with rubber wheels (Dedeco Classic #4950 and #4960, Dedeco Intl., Long Eddy, NY) (Fig 7).

The patient was followed for 8 months prior to this publication. At the 8-month visit, the patient reported having ended consumption of the sourdough pretzels. Within the 8-month period, the zirconia dentures had been exposed to the sourdough pretzels for 4.5 months. The dentures exhibited loss of luster and slight wear of the denture base in the areas adjacent to the teeth; however, the zirconia teeth exhibited no abrasion or loss of the glazed surface (Fig 8). The patient reported being very satisfied with the dentures. When informed about possible "clicking" of the teeth, as is sometimes encountered with porcelain teeth, the patient indicated no such awareness. The patient has continued to use denture adhesive as he has from the time of extractions, and to wear the dentures at night. The patient continues to be monitored for changes in the zirconia teeth and abrasion of the adjacent denture base.

Discussion

During this treatment period, two methods for using zirconia teeth in future complete denture procedures were envisioned: (1) premanufactured denture teeth, and (2) CAD/CAM fabricated teeth custom-designed for each patient. With the first option, zirconia teeth could be manufactured and made accessible in a variety of molds similar to currently available denture teeth. Through a manufacturing process that would produce high volume in a factory setting, the mass production of zirconia teeth could integrate features, such as hollow form, optimal thickness to balance strength and weight considerations, tooth-colored resin internally, and retention for interlocking with denture base resin.

With the second option, laboratory computer programs for designing and milling could provide a wide range of tooth molds or patterns, avoiding an extensive inventory of manufactured teeth. Ideally, a CAD/CAM program would automate the process of creating denture tooth segments while simultaneously including retentive features in the zirconia teeth; however, a combination of new clinical procedures and modifications to existing computer technology would be needed. A combined clinical and laboratory program would enable several features: (1) virtual customized tooth arrangements milled in resin material for trial insertion, and (2) evaluation of tooth arrangement by the clinician and patient with an option for virtual alteration before or after trial insertion. Since the fabrication of zirconia teeth consumed a substantial portion of the laboratory effort for the patient described in this report, the development of a software program designed specifically for complete denture applications would significantly reduce the effort required to fabricate customized denture tooth arrangements.

Shortly after treatment of this patient, two computer-generated denture systems (Dentca CAD/CAM Denture, Dentca, Inc, Los Angeles, CA; and Avadent Digital Dentures, Global Dental Science LLC, Scottsdale, AZ) were introduced commercially. Both systems incorporate commercially available premanufactured resin-based teeth, and both systems mill denture bases by scanning traditional impressions provided by the dentist. Teeth are selected from a library of tooth molds; then, computer programs arrange the teeth in occlusion and relation to each denture base from clinical data provided by the dentist. Additional anatomical data are obtained from the scanned impressions and from the occlusal devices, which relate the arches in centric relation at the selected OVD. Denture teeth may be trimmed to accommodate limited interocclusal space, to refine the occlusion, and to provide esthetic modifications. Neither system currently offers the capability for custom-milled denture teeth regardless of the tooth material; however, these systems incorporate advances in denture fabrication that have been available in fixed conventional and implant prosthodontics for several years. The application of custom-milled denture teeth in removable complete dentures is only a matter of time and demand.

Summary

The patient described in this report presented with a severe degree of denture tooth abrasion. Tooth abrasion in complete dentures remains a significant concern, particularly with commonly used resin-based denture teeth. Porcelain denture teeth are resistant to abrasion but susceptible to fracture. Zirconia is anticipated to improve resistance to abrasion, result in fewer tooth fractures, and provide a longer useful life than other materials used for teeth in complete dentures. In conclusion, zirconia denture teeth may serve as a valuable alternative to existing denture teeth, provided that procedures for designing, fabricating, orienting, and processing the teeth are comparable to or improvements on traditional procedures.

Acknowledgment

The authors would like to acknowledge the assistance of George Diacoloukas, CDT of Friendship Dental Laboratory, Baltimore, MD, for the design and fabrication of the zirconia teeth.

References

1. Zarone F, Russo S, Sorrentino R: From porcelain-fused-to-metal to zirconia: clinical and experimental considerations. Dent Mater 2011;27:83-96
2. Koutayas SO, Vagkopoulou T, Pelekanos S, et al: Zirconia in dentistry: part 2. Evidence-based clinical breakthrough. Eur J Esthet Dent 2009;4:348-380
3. Vagkopoulou T, Koutayas SO, Koidis P, et al: Zirconia in dentistry: part 1. Discovering the nature of an upcoming bioceramic. Eur J Esthet Dent 2009;4:130-151

4. Manicone PF, Iommetti PR, Raffaelli L: An overview of zirconia ceramics: basic properties and clinical applications. J Dent 2007; 35:819-826
5. Giordano R, Sabrosa CE: Zirconia: material background and clinical application. Compend Contin Educ Dent 2010;31:710-715
6. Albashaireh ZS, Ghazal M, Kern M: Two-body wear of different ceramic materials opposed to zirconia ceramic. J Prosthet Dent 2010;104:105-113
7. Ghazal M, Yang B, Ludwig K, et al: Two-body wear of resin and ceramic denture teeth in comparison to human enamel. Dent Mater 2008;24:502-507
8. McGarry TJ, Nimmo A, Skiba JF, et al: Classification system for complete dentures. J Prosthodont 1999;8:27-39
9. Phark JH, Duarte S Jr, Blatz M, et al: An in vitro evaluation of the long-term resin bond to a new densely sintered high-purity zirconium-oxide ceramic surface. J Prosthet Dent 2009;101: 29-38
10. Duarte S Jr, Phark JH, Tada T, et al: Resin-bonded fixed partial dentures with a new modified zirconia surface: a clinical report. J Prosthet Dent 2009;102:68-73
11. Aboushelib MN, Kleverlaan CJ, Feilzer AJ: Selective infiltration-etching technique for a strong and durable bond of resin cements to zirconia-based materials. J Prosthet Dent 2007; 98:379-388
12. Aboushelib MN, Feilzer AJ, Kleverlaan CJ: Bonding to zirconia using a new surface treatment. J Prosthodont 2010; 19:340-346
13. Everson P, Addison O, Palin WM, et al: Improved bonding of zirconia substructures to resin using a “glaze-on” technique. J Dent 2012;40:347-351
14. Ntala P, Chen X, Niggli J, et al: Development and testing of multi-phase glazes for adhesive bonding to zirconia substrates. J Dent 2010;38:773-781
15. Valentino T, Borges G, Borges L, et al: Influence of glazed zirconia on dual-cure luting agent bond strength. Oper Dent 2012;37:181-187
16. Fushiki R, Komine F, Blatz MB, et al: Shear bond strength between an indirect composite layering material and feldspathic porcelain-coated zirconia ceramics. Clin Oral Investig 2011;16:1401-1411
17. Atsu SS, Kilicarslan MA, Kucukesmen HC, et al: Effect of zirconium-oxide ceramic surface treatments on the bond strength to adhesive resin. J Prosthet Dent 2006;95: 430-436
18. Attia A, Lehmann F, Kern M: Influence of surface conditioning and cleaning methods on resin bonding to zirconia ceramic. Dent Mater 2011;27:207-213
19. Blatz MB, Chiche G, Holst S, et al: Influence of surface treatment and simulated aging on bond strengths of luting agents to zirconia. Quintessence Int 2007;38:745-753
20. Smith RL, Villanueva C, Rothrock JK, et al: Long-term microtensile bond strength of surface modified zirconia. Dent Mater 2011;27:779-785
21. Tsukakoshi M, Shinya A, Gomi H, et al: Effects of dental adhesive cement and surface treatment on bond strength and leakage of zirconium oxide ceramics. Dent Mater J 2008;27: 159-171