BruxZir® Solid Zirconia Full-Arch Implant Prosthesis: Clinical and Scientific Compendium

GLIDEWELL LABORATORIES

BruxZir® Solid Zirconia Full-Arch Implant Prosthesis: Clinical and Scientific Compendium

Table of Contents

The BruxZir® Full-Arch Implant Prosthesis: Better than the Traditional Hybrid Denture

Introduction

The traditional implant-supported hybrid denture has played an important role in the rehabilitation of fully edentulous patients. However, the susceptibility of hybrid dentures to acrylic fracture and wear makes it necessary to look for alternative restorative options that offer long-term durability.

Background/Problem – Case Studies

The use of osseointegrated implants as a foundation for fixed full-arch prostheses has substantially enhanced the quality of life for edentulous patients.[1] For many years now, when a patient presents with an edentulous arch or with conditions warranting the removal of their existing natural dentition, clinicians have had the option of placing dental implants to retain an implant-supported prosthesis. The superiority of fixed full-arch restorations compared to conventional dentures cannot be overstated. By dramatically increasing prosthetic stability, implant-supported full-arch restorations significantly improve masticatory and speech function.[2] The positive impact of implant-supported prostheses on the oral health, comfort and esthetics of edentulous patients is accompanied by social and psychological benefits as well as improved personal confidence.[3] At the same time, dental implants mitigate gingival recession and bone loss, helping to preserve the shape of the patient's mouth and facial structures.[4]

While both removable and fixed implant-supported prostheses provide wide-ranging benefits for edentulous patients, fixed restorations have demonstrated superior impact on oral health, dental function, patient satisfaction, and quality of life.[5,6] For this reason, the acrylic hybrid denture has long been considered the optimal choice for full-arch restorations. There has been only one downside: The acrylic base and prosthetic teeth that form the body of the hybrid denture are prone to wear, chipping and fracture.[7] In many cases, a high degree of maintenance is required over the life of the restoration to reinforce the body of the prosthesis. This is because fixed full-arch implant restorations are subject to substantial forces associated with masticatory function, parafunctional habits, and bruxism. In the long term, this often causes hybrid dentures to break down, requiring ongoing maintenance and replacement of the prosthetic teeth or acrylic base. Clinicians encountering such issues now have the option of rehabilitating their fully edentulous patients with the BruxZir® Full-Arch Implant Prosthesis, as documented in many recent cases where patients presented with broken hybrid dentures (*Figs. 1–5*).

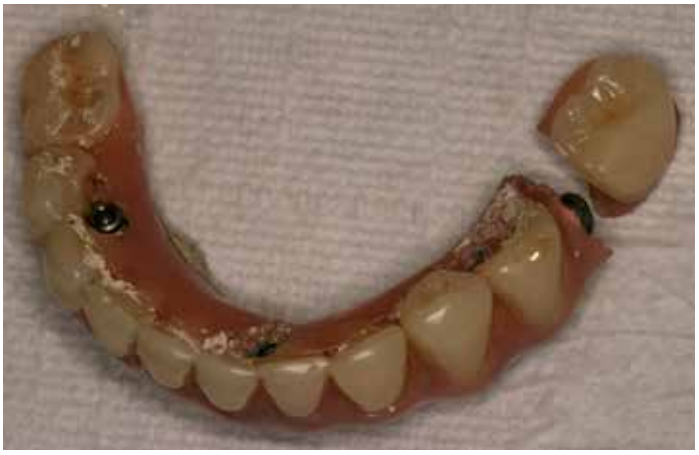


Figure 1: *Case 1 – Patient's acrylic hybrid denture fractured in different locations along the prosthesis over the first one and a half years of wear.*

Figure 2: *Case 2 – Patient with bruxism was treated with a traditional hybrid denture, which exhibited significant oclussal surface wear and exposure of the metal framework within one year of placement.*

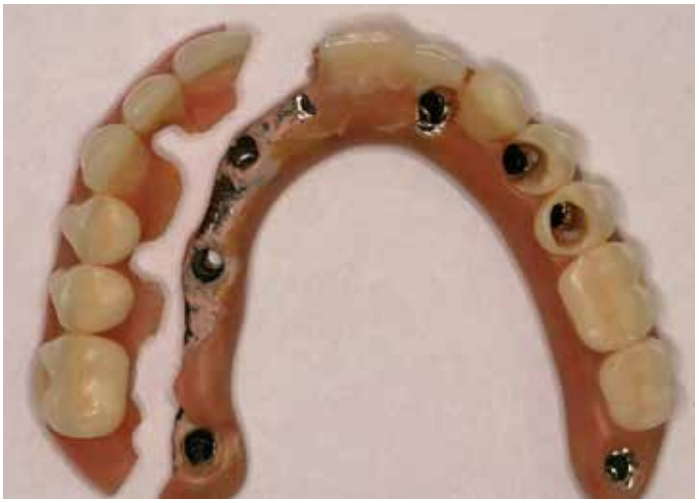


Figure 3: *Case 3 – Patient's fixed hybrid prosthesis broke on multiple occasions over the course of several years.*

Figure 4: *Case 4 – The patient presented with an acrylic hybrid showing signs of wear and de-bonding of anterior denture teeth after seven years of function.*

Figure 5: *Case 5 – After three years of wear and a few instances where prosthetic teeth needed to be replaced, the patient's original screw-retained hybrid denture fractured, with the patient's clenching habit a contributing factor.*

Solution – A New Standard in Durability

With improvements in material science and advancements in CAD/CAM technology, full-arch prostheses can now be precisely milled from monolithic zirconia, offering the esthetics and functionality of an acrylic hybrid denture with the added benefit of long-term durability. The BruxZir Full-Arch Implant Prosthesis is constructed from 100 percent solid zirconia, attaching to the implants through titanium copings. Exhibiting exceptional fracture toughness and flexural strength of up 1465 MPa, BruxZir Solid Zirconia has the ability to withstand the functional stresses that full-arch implant restorations are subject to over time.

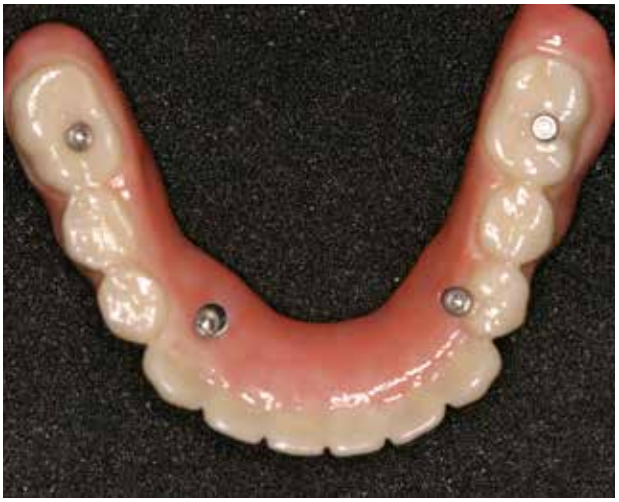
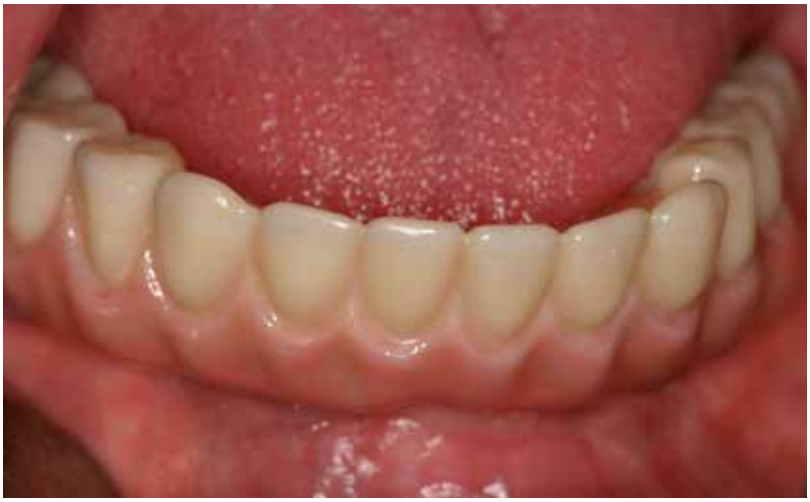
Unlike hybrid dentures, the entire body of the BruxZir Full-Arch Implant Prosthesis including the gingival and tooth areas is constructed from the same robust material. This singular construction avoids the dislodging of prosthetic teeth that can occur with hybrid dentures, minimizing the chances that edentulous patients will ever have to go without their prosthesis while the restoration is replaced or repaired.

The strength and durability offered by BruxZir Solid Zirconia is complemented by lifelike esthetics and excellent translucency. The teeth of the prosthesis exhibit color very similar to natural dentition, and advanced staining techniques are used to establish gingival areas that blend well with the patient's soft tissue. Additionally, BruxZir Solid Zirconia is biocompatible, hypoallergenic, and wear-compatible with the enamel of opposing teeth.[8]

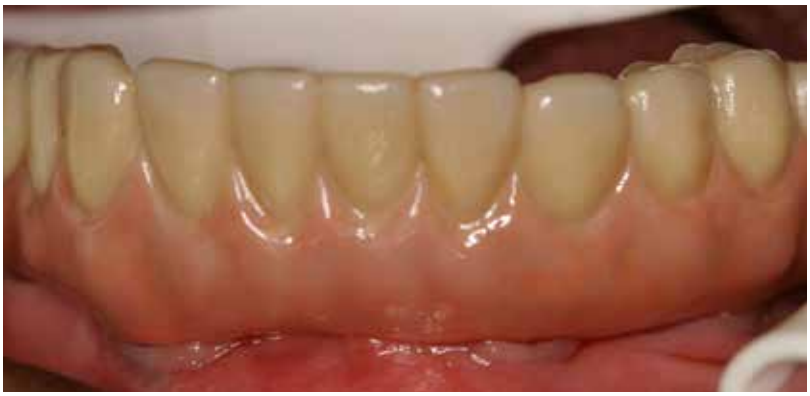
For the cases mentioned above, clinicians essentially followed the same procedure required for a traditional hybrid denture, with no added chair time. This includes preliminary impressions, jaw relationship records, and try-in and approval of the wax setup. As with the titanium framework of acrylic hybrids, it is crucial that full-arch prostheses fabricated from solid zirconia exhibit a passive fit. Thus, an implant verification jig is used when the final impression is taken, facilitating a passive fit for the definitive restoration by ensuring that the titanium connections are positioned in precise alignment with the implants.

Once the final impression has been taken, the definitive prosthesis is designed with advanced CAD/CAM technology, utilizing the final doctor-approved setup as a blueprint. The digital design process results in a prosthesis that embodies the exact morphology, teeth positioning, occlusion, incisal edges, and screw access holes of the final setup, while incorporating the tissue anatomy and implant positioning captured by the final impression.

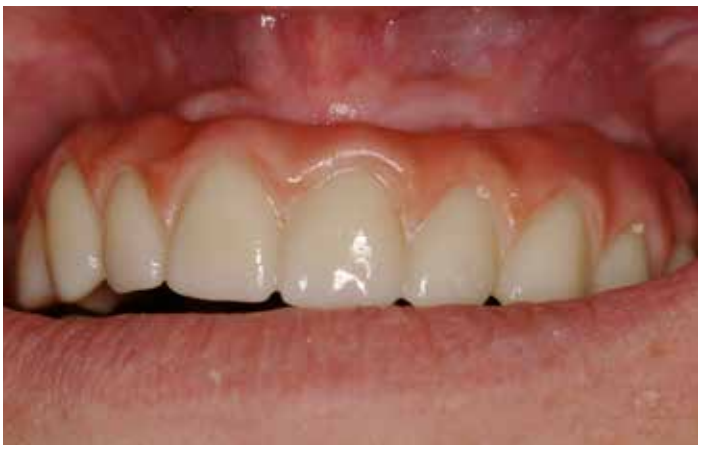
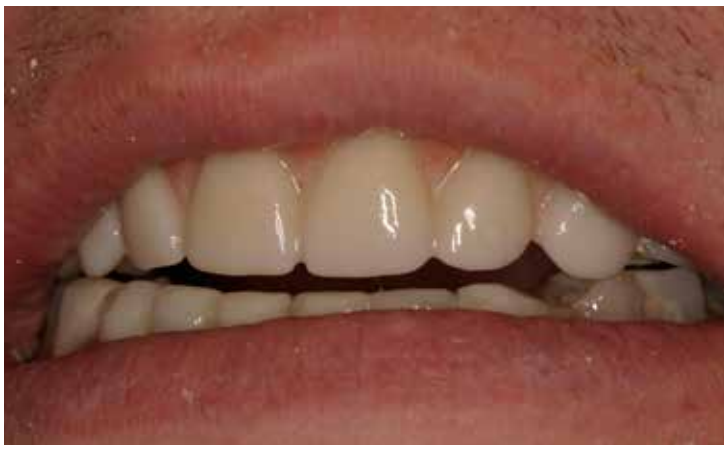
By the time the final monolithic zirconia restoration is milled, the synergy of attention to detail, advanced materials, and technology result in a prosthesis that fits perfectly, fully restores oral function to the patient, exhibits natural-looking esthetics, and, most importantly, promises long-term durability to the patients who count on their fixed implant restorations most (*Figs. 6–10*).

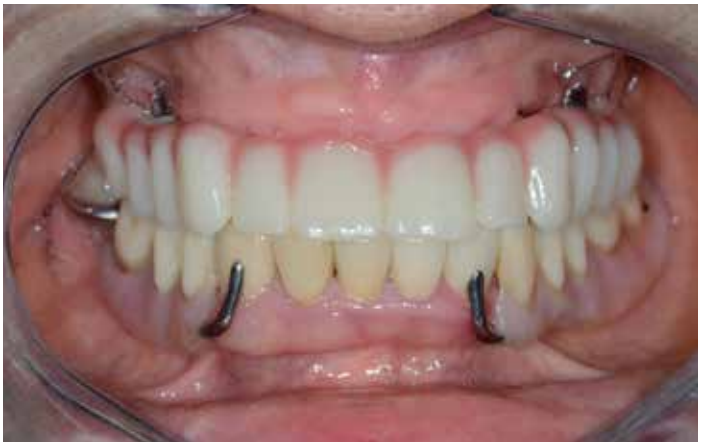
Figures 6a, 6b: *Case 1 – The fractured acrylic hybrid denture was replaced with the BruxZir Full-Arch Implant Prosthesis.*

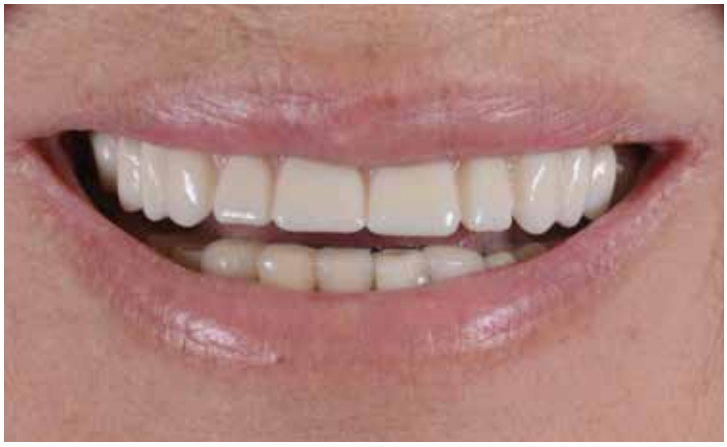



Figures 7a, 7b: *Case 2 – The traditional hybrid was replaced with a prosthesis fabricated from BruxZir Solid Zirconia in order to provide maximum resistance to occlusal forces.*

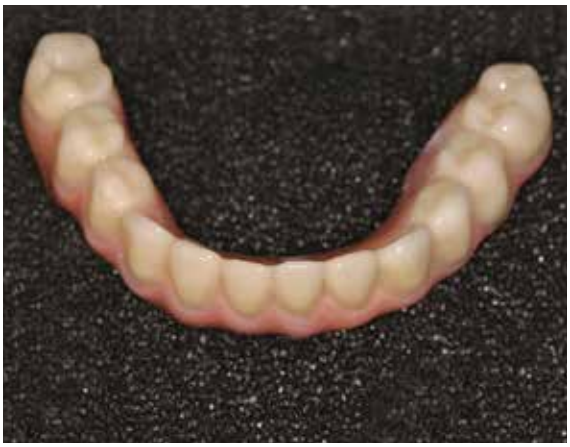



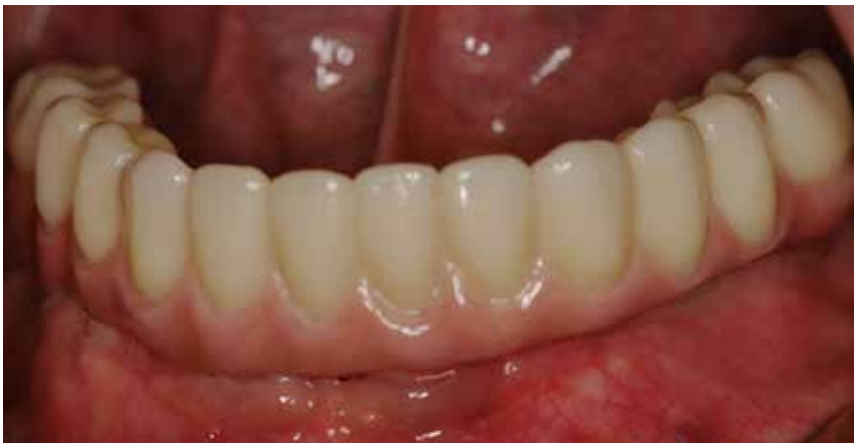
Figures 8a, 8b: *Case 3 – The patient was transitioned into a BruxZir Full-Arch Implant Prosthesis to avoid the need for future repairs or replacements.*





Figures 9a, 9b: *Case 4 – The BruxZir Full-Arch Implant Prosthesis provided the prosthetic durability the patient desired while replicating the form and function of the original hybrid denture.*



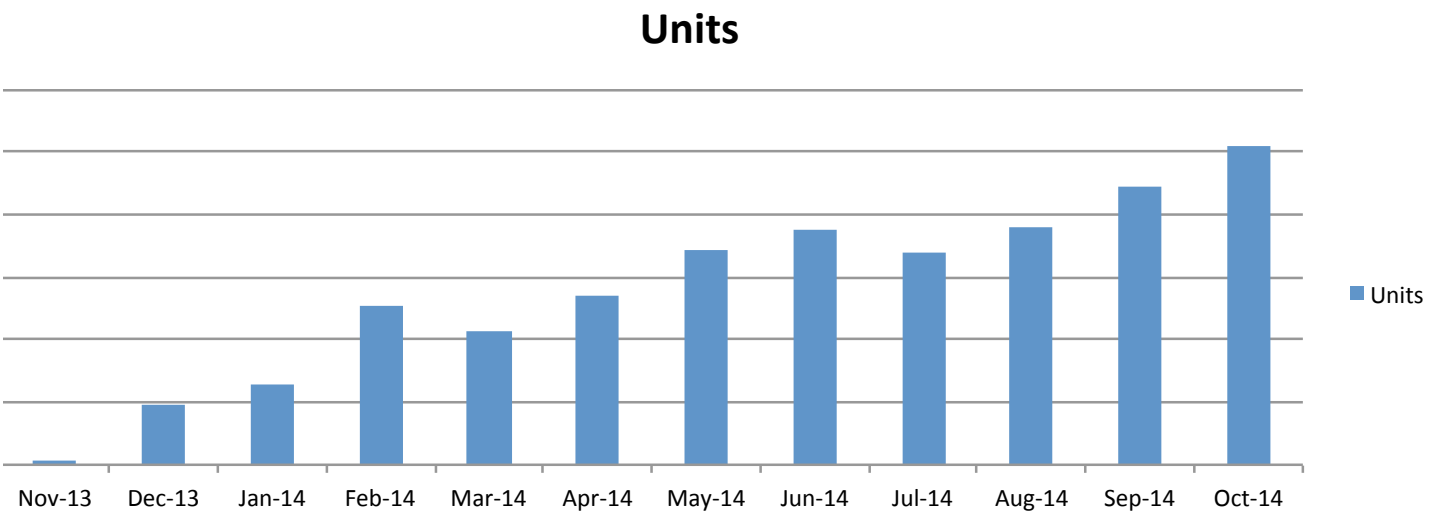


Figures 10a, 10b: *Case 5 – Rather than again repairing the acrylic hybrid denture, the patient's edentulous arch was restored with a BruxZir Full-Arch Implant Prosthesis.*

Conclusion

The long-term viability of dental implants has been proven time and again. While fixed hybrid dentures have made a life-changing impact on edentulous patients, their reliance on an acrylic base and denture teeth makes them vulnerable to breakage and wear. A comprehensive literature review has concluded that for cases at risk to the above-mentioned issues, although the traditional implant-supported hybrid denture is a proven treatment option, more durable restorations should be considered. The BruxZir Full-Arch Implant Prosthesis is an excellent alternative that maximizes the odds that the restoration will last as long as the implants holding it in place.

Whether a patient is receiving a full-arch implant restoration for the first time or is being transitioned out of a hybrid denture that has become undependable, growing numbers of clinicians are prescribing the BruxZir Full-Arch Implant Prosthesis and achieving excellent results (*Fig. 11*).



Figures 11: *Monthly prescriptions for the BruxZir Full-Arch Implant Prosthesis.*[9]

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9. Glidewell Laboratories internal data

Comprehensive Case Study

BruxZir® Full-Arch Implant Prosthesis


*by **Michael McCracken, DDS, Ph.D.** and **Jonathan P. Ouellette, DMD***

The fixed implant-supported prosthesis presents numerous advantages over traditional removable complete dentures. By stabilizing the prosthesis to the maximum degree possible, this implant solution effectively restores oral function, comfort and esthetics, while minimizing bone loss and the devastating soft-tissue changes associated with edentulism.[1] The protocol for delivering these full-arch restorations is relatively simple, and the positive impact this treatment can have on patients cannot be overstated. Patients who have suffered from edentulism for years are simply thrilled when they experience the improved quality of life offered by a fixed restoration.[2,3]

Fixed hybrid dentures, which attach to implants via screws inserted through a titanium substructure, have been used to successfully restore fully edentulous patients for decades. Their durability, however, leaves room for improvement. There are three issues that can complicate the long-term success of the traditional fixed hybrid denture: the acrylic teeth tend to wear; the teeth can fracture or dislodge from the acrylic base; and the acrylic base itself can fracture. The BruxZir® Full-Arch Implant Prosthesis (Glidewell Laboratories; Newport Beach, Calif.) eliminates these issues, providing a restoration that is more durable in the long term, while sacrificing nothing when it comes to esthetics.

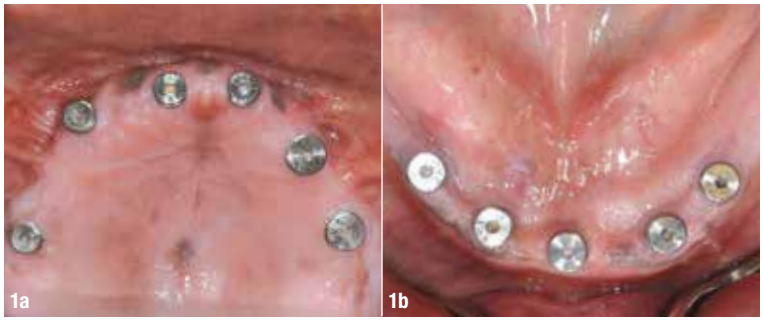
This fixed prosthesis is milled from a single block of solid zirconia and attaches to implants through titanium bases. Utilizing advanced staining and glazing techniques, the prosthetic teeth are colored to closely mimic natural dentition, and the gingival areas are colored to match the shade of the patient's soft tissue.

The prosthesis is incredibly strong because it is milled from BruxZir Solid Zirconia, an exceptionally fracture-resistant material that exhibits flexural strength up to 1465 MPa. This leads to several benefits for both doctor and patient. First, there is no need to replace worn denture teeth, which is a common occurrence with traditional hybrid dentures. Next, as a single construction, monolithic zirconia reduces or eliminates the possibility of fractured or dislodged teeth, which can occur with traditional hybrid prostheses due to the prosthetic teeth being bonded into the resin base. This durability minimizes the odds that the patient will ever have to go without their prosthesis due to damage or repair.

The following case report illustrates the step-by-step protocol involved in restoring an edentulous arch with the BruxZir Full-Arch Implant Prosthesis. Clinicians can follow a straightforward clinical protocol to success, substantially improving the lives of patients by providing a fixed, esthetic and long-lasting full-arch implant restoration.

Case Report

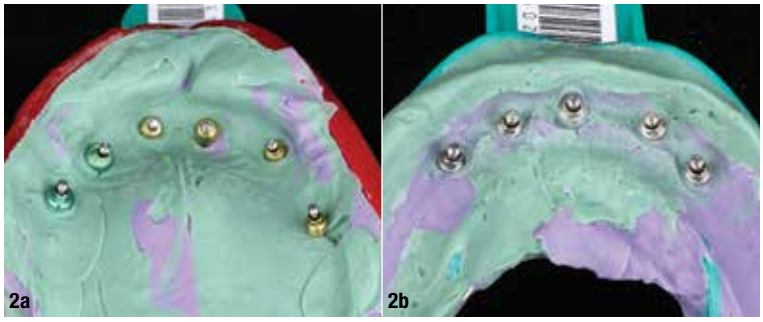
The patient is a 58-year-old male with no contraindications for implant treatment. Following bilateral sinus grafting, the patient had a total of 11 BioHorizons® Internal Hex implants (BioHorizons; Birmingham, Ala.) placed, including six in the maxilla and five in the mandible *(Figs. 1a, 1b)*. The mandibular implants were placed 5 mm anterior to the mental foramen. The maxillary implants were placed in available bone from first molar to first molar using a flapless, guided surgical approach. The implants integrated for over six months, and the patient presented for restoration of his edentulous arches.



***Figures 1a, 1b:** The patient presented with six maxillary and five mandibular implants that were fully integrated and ready for restoration.*

Step 1: Preliminary Impression

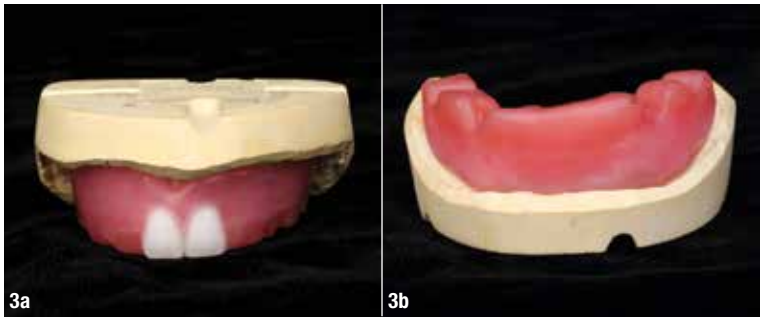
First, simple preliminary impressions of the implants were made. After removing the healing abutments, closed-tray impression copings were seated. The impressions were made using Capture® VPS material (Glidewell Direct; Irvine, Calif.) in stock plastic trays, and the impression copings were placed back into the impressions before the case was sent off to the laboratory *(Figs. 2a, 2b)*.



Figures 2a, 2b: *After removing the impression tray, the closed-tray transfer copings were placed back into the impression.*

Step 2: Wax Rim and Centric Jaw Relationship

The laboratory poured casts from the initial impressions and fabricated bite blocks and occlusal rims for the centric jaw relationship (CJR) records *(Figs. 3a, 3b)*. The bite blocks were seated, the occlusal rims were contoured, the vertical dimension was established, and jaw relation records were taken using conventional denture techniques. Each bite block contains two screw-retained temporary cylinders that allow the wax rims to be screwed down, producing a very accurate CJR. The contoured rims were returned to the laboratory with the initial casts.

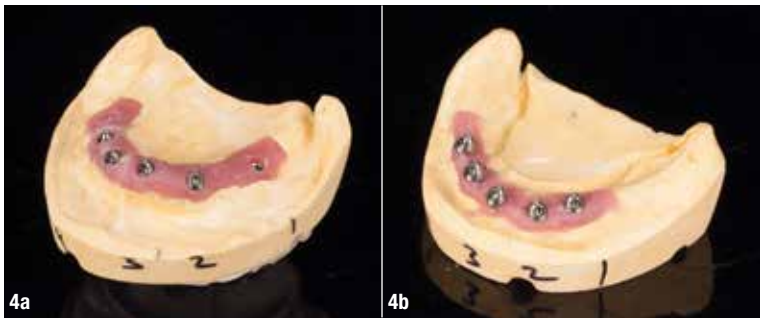


Figures 3a, 3b: *The lab fabricated both bite blocks onto the stone models so the CJR could be obtained.*

Step 3: Wax Setup, Implant Verification Jig and Final Impression

Delivery of Multi-Unit Abutments (as necessary)

Upon receiving the wax rims and jaw relation records, the laboratory and dentist consult to determine if multi-unit abutments are necessary. Many times, implants must be placed with a 15-degree angulation or higher, depending on patient anatomy. Often, angulated implant placement can result in screw access holes in the incisal edge or facial surface of the anterior teeth of the prosthesis. In these cases, multi-unit abutments are required to correct the angulation in order to avoid screw access openings that are visible on the facial surface of the anterior prosthetic teeth.



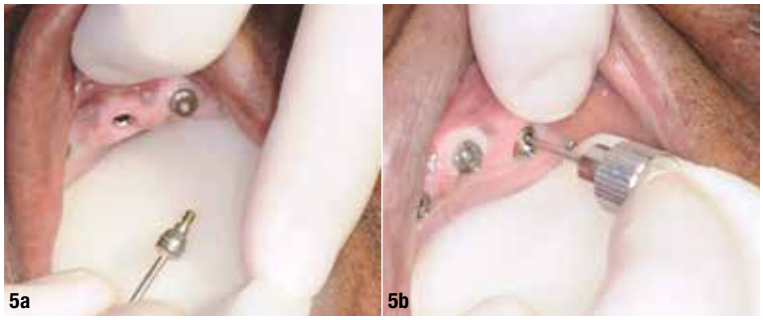
Figures 4a, 4b: *The lab selected the necessary multi-unit abutments for the maxillary and mandibular arches, placing them in proper position and sequence on the soft-tissue models.*

Based on the initial impression and the contoured occlusal rim, the patient required four multi-unit abutments in the anterior maxilla to ensure that the screw access openings were within the confines of the planned prosthesis. Multi-unit abutments also help simplify restorations in cases where the tissue is thicker than 2 mm by raising the prosthetic platform. In this case, all five of the mandibular implants benefitted from multi-unit abutments that were used due to tissue thickness. The laboratory selected straight and angled Inclusive® Multi-Unit Abutments (Glidewell Direct; Irvine, Calif.) and arranged them in their proper positions on the working casts before sending them out for placement *(Figs. 4a, 4b)*.

At the next clinical appointment, the patient's healing abutments were removed, and the multi-unit abutments were transferred to the patient's mouth and torqued into place *(Figs. 5a, 5b)*. The multi-unit abutments effectively corrected the angulation of the implants, keeping screw access aligned toward the palatal aspects of the planned anterior teeth and out of the esthetic zone *(Fig. 6)*.

Wax Setup Try-in

At the same appointment, trial denture setups in wax were evaluated *(Figs. 7a, 7b)*. Each setup was seated and screwed into place via the included temporary cylinders *(Fig. 8)*. The setups were evaluated for proper esthetics, phonetics, contours, occlusion and tooth arrangement, and the necessary adjustments were made per standard denture protocol.



Figures 5a, 5b: *The healing abutments were removed, and the multi-unit abutments were tightened into the four maxillary implants requiring angulation correction. Note the use of a sponge to protect the patient's airway.*

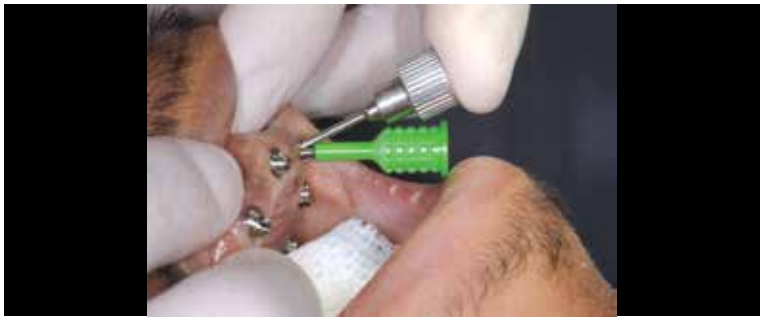


Figure 6: *The silver implant driver demonstrates the actual angle of the implant placed in the premaxilla. This angulation was indicated by patient anatomy. However, without correction the screw access hole would be visible on the facial surface of the restoration. The angled multi-unit abutment corrects the angulation, as reflected by the green plastic abutment carrier. Note the use of 4x4 gauze to protect the airway, as multi-unit abutment components are very small.*

Figures 7a, 7b: *Wax setups were provided by the lab, with each including two temporary cylinders that attach to the implants in order to stabilize the bases.*

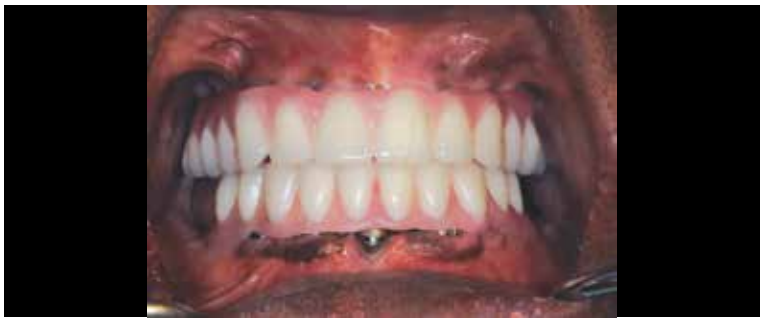
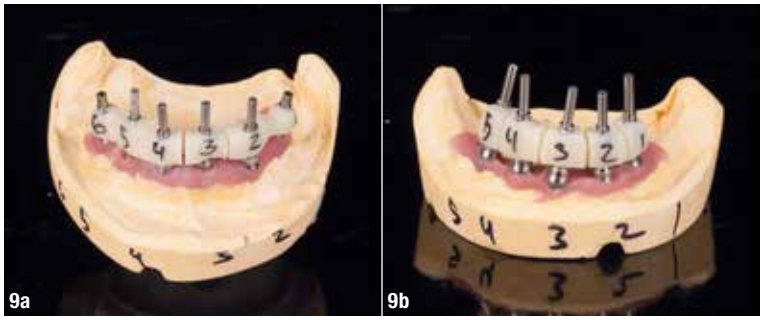


Figure 8: *The wax setups were seated, evaluated and adjusted to ensure proper contours, esthetics and tooth positioning.*

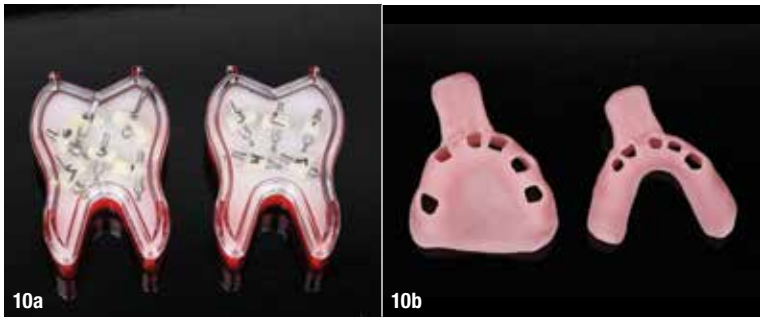
Implant Verification Jig and Final Impression

The lab fabricated, sectioned and numbered an acrylic implant verification jig for each arch on the working casts *(Figs. 9a, 9b)*. Because the implant verification jig helps to ensure an accurate final impression and a precise fit of the BruxZir Full-Arch Implant Prosthesis, it is the most crucial step in the restorative process. Custom trays for the final impressions were supplied along with the verification jigs *(Figs. 10a, 10b)*. Note that where multi-unit abutments were used, the implant verification jig was fabricated to connect to the abutments instead of the implants.

Each section of the verification jig contains a titanium cylinder, which is essentially a non-engaging impression coping. The titanium cylinders were inserted into each implant or multi-unit abutment according to their numbering sequence. After verifying that a small gap exists between each acrylic segment, the verification jig was fully seated by tightening the guide pins *(Fig. 11)*. The acrylic pieces were then connected using PATTERN RESIN™ (GC America; Alsip, Ill.). The material was flowed completely through and around the gaps, and into the joints of the verification jig *(Figs. 12a, 12b)*. The process was completed by placing a thicker mix of resin around the outside edges.

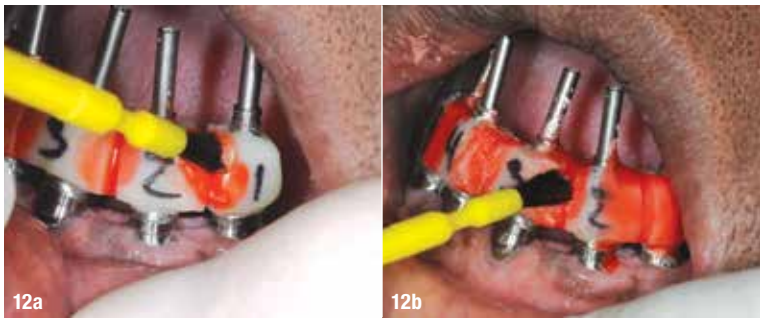


Figures 9a, 9b: *The lab fabricated the implant verification jigs on the working models. Each acrylic section of the jig contains a titanium cylinder that attaches to the implant or multi-unit abutment. By precisely capturing the depth and angulation of the implants in the final impression, the verification jig ensures an accurate fit of the final prosthesis.*



Figures 10a, 10b: *The verification jig components were sent to the office along with custom trays, which were fabricated to fit over and pick up the implant verification jig in the final impression.*

Figure 11: *Implant verification jig fully seated in the mandible after tightening the guide pins.*



Figures 12a, 12b: *The acrylic sections of the implant verification jig were luted together, with material flowed completely through and around the gaps.*

After the acrylic had set completely, a final impression was made using an open-tray impression technique. First, the custom tray was tried in to ensure a proper fit over the titanium cylinders. Then, vinyl polysiloxane (VPS) material was injected under and around the implant verification jig *(Fig. 13)*. The impression tray was filled and seated, ensuring that all of the titanium cylinders were accessible through the holes of the tray *(Figs. 14a, 14b)*. Once the material had set, the guide pins were loosened and the custom tray was removed, picking up the implant verification jig in the final impression *(Fig. 15)*. After performing this procedure for each arch, the case was returned to the lab for fabrication of the provisional prostheses.

Step 4: Delivery of Fixed Provisional

Fixed provisional appliances, which were produced using precise CAD/CAM technology that effectively preserves the doctor-approved setup, were provided by the laboratory *(Fig. 16)*. Fabricated from poly(methyl methacrylate) (PMMA), these provisionals provide an extra layer of quality assurance by allowing the patient to live with and confirm the proposed restoration during a trial period. It is labor-intensive to mill and finish the BruxZir Full-Arch Implant Prosthesis, so it is important to take care in this step as it helps to ensure an accurate final restoration.

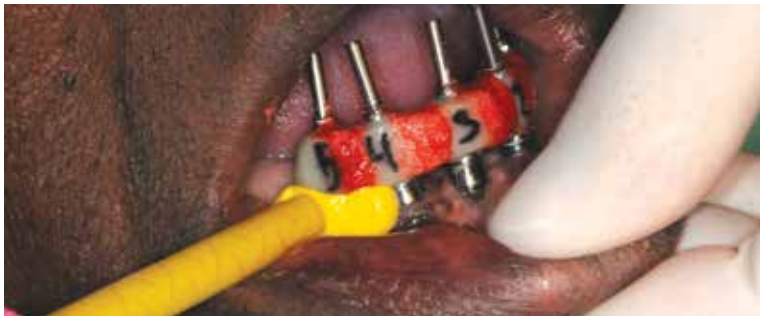
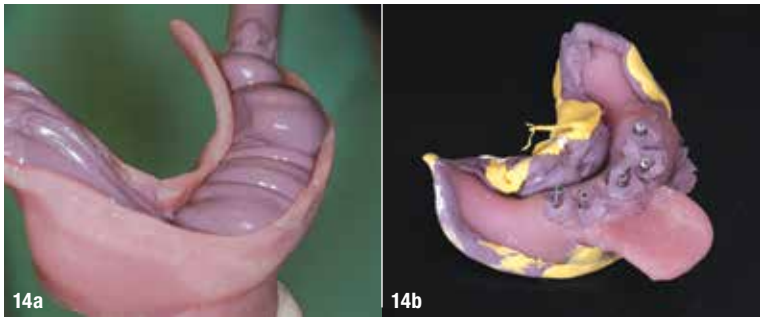


Figure 13: *VPS material was injected under and around the verification jig to capture the soft-tissue contours.*



Figures 14a, 14b: *After being filled with VPS material, the custom tray was seated, ensuring the titanium cylinders extended through the holes in the tray. This allows for removal of the guide pins so the verification jig can be picked up in the final impression.*

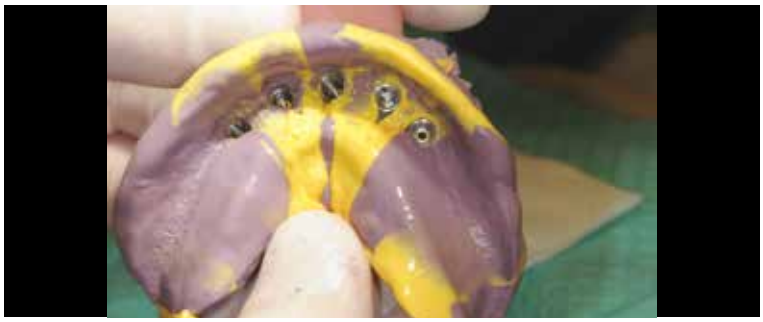


Figure 15: *The splinted implant verification jig was picked up in the final impression. Because it was splinted together and contained within the VPS material of the custom tray, the verification jig produced an extremely accurate impression.*

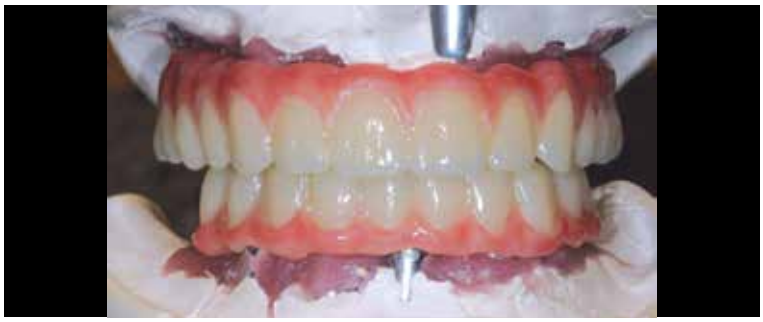


Figure 16: *The fixed provisional appliances fabricated by the laboratory helped confirm the accuracy of the definitive prosthetic design.*

The fixed provisional appliances were seated, and the prosthetic screws were tightened to 30 Ncm. The prostheses exhibited a nice fit that was comfortable for the patient *(Fig. 17)*. The patient functioned well with the temporary appliances for a few weeks. Once the patient approved the provisionals, the laboratory fabricated the final prostheses.

Step 5: Delivery of the BruxZir Full-Arch Implant Prosthesis

The final restoration was fabricated using the CAD design that was confirmed during the provisional trial period *(Figs. 18a, 18b)*. In this case, the AP spread and the opposing fixed all-zirconia prosthesis dictated a reduced arch for the lower prosthesis, with premolar occlusion. After removing the fixed provisional appliances, the final prostheses were seated. The prosthetic screws were tightened and the occlusion was verified. The screw access openings were first filled with a suitable material, and then covered with composite *(Fig. 19)*. The patient received an occlusal device to wear at night in case of undiagnosed parafunctional habits.

The fit, occlusion and esthetics of the final restoration were excellent *(Fig. 20)*. The patient was exceptionally pleased with the function offered by this fixed restoration. He even returned to the clinic the next day just to show his appreciation for his new smile, which he should be able to enjoy for a great number of years given the extraordinary durability of BruxZir Solid Zirconia.

Summary

The BruxZir Full-Arch Implant Prosthesis offers an important new treatment option for edentulous patients. It provides excellent esthetics, and has better strength and wear properties than a traditional acrylic-metal hybrid prosthesis. Along with durability, this fixed full-arch implant restoration minimizes bone loss and maximizes prosthetic stability, function and comfort. This option should be part of the treatment plan discussion for every edentulous patient. **IM**

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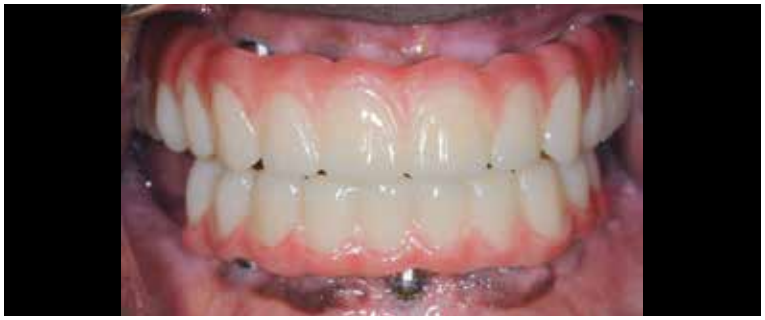


Figure 17: *The provisional prostheses fit well, and afforded the patient a trial period to evaluate the proposed restoration for esthetics and function over a period of weeks. Note that the gingival shade was adjusted for the fabrication of the final restoration.*

Figures 18a, 18b: *The lab fabricated each prosthesis from a single block of BruxZir Solid Zirconia and utilized advanced staining and glazing techniques to maximize the esthetics of the definitive restoration.*

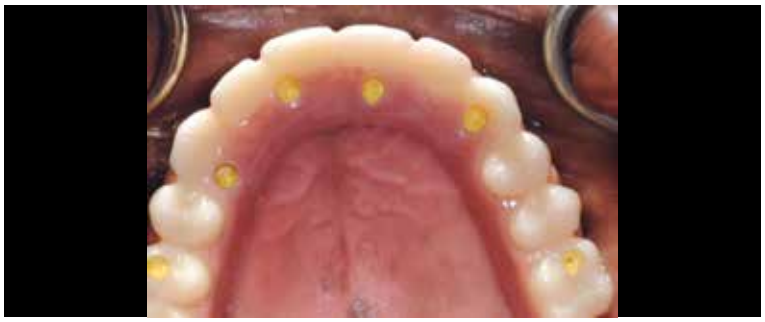
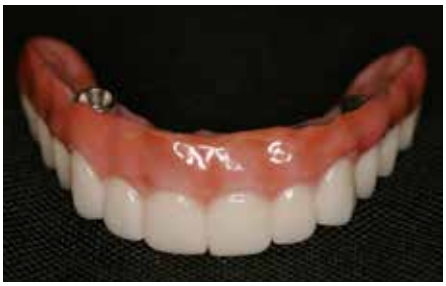
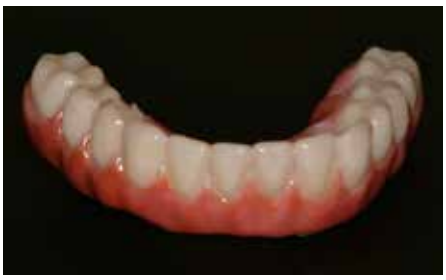


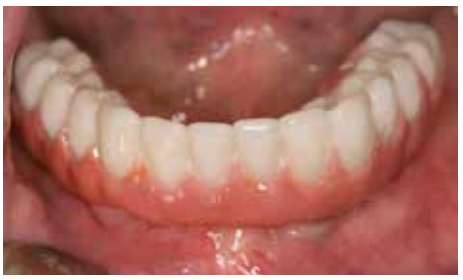
Figure 19: *After being filled with a suitable material, the screw access openings were covered with pink composite resin for the gingival areas and tooth-colored composite for the prosthetic teeth.*

Figure 20: *The patient was extremely satisfied with the function and esthetics of the final restoration, which fit perfectly thanks to the precision of the CAD/CAM design process and the confirmation provided during the provisional trial period.*

Additional Clinical Examples







BruxZir Solid Zirconia makes up the teeth, gingival areas and body of the full-arch restoration, eliminating the need to bond material to a metal framework and thus minimizing the possibility of breakage or dislodged prosthetic teeth.

The provisional full-arch implant prosthesis is a functional temporary restoration that allows the patient to verify the definitive design before the final restoration is fabricated from monolithic zirconia.

Final BruxZir Full-Arch Implant Prosthesis in place. Its unique combination of esthetics, function and long-term durability has elicited an extremely positive response from patients.

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Contrast Ratio of Six Zirconia-Based Dental Ceramics

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Keywords
Zirconium dioxide; translucency; thickness.

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Abstract

Purpose: The objective of this study was to determine the effect of thickness and brands on the contrast ratio of six zirconia dental ceramics.
Materials and Methods: Six brands of yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) ceramics (ZENO® Translucent, Lava™ Plus High Translucency, inCoris TZI, Cercon® Base, Zeno®Zr, Lava™) were used in this study. Disc-shaped specimens with 15 mm diameter were prepared in five thickness levels (0.3, 0.6, 0.9, 1.2, 1.5 mm, n = 10) for each brand. The contrast ratio ($CR = Y^b/Y^w$) was determined from the luminous reflectance over black (Y^b) and white (Y^w) backgrounds using a spectrophotometer. Two-way ANOVA was performed to determine the significant differences among thicknesses and brands at $\alpha = 0.05$.
Results: The mean contrast ratio values of six zirconia ceramics were significantly different and influenced by both the thickness and brand. The mean contrast ratio values of all groups increased as their thickness increased from 0.3 to 1.5 mm. inCoris TZI was the most translucent, with the lowest contrast ratio at a thickness of 0.6 to 1.5 mm. The mean contrast ratio values of Lava™ and Lava™ Plus were significantly lower than those of Zeno®Zr, ZENO® Translucent, and Cercon® Base.
Conclusions: The thickness and brands had significant effects on the contrast ratio of six zirconia dental ceramics. The mean contrast ratio values of inCoris TZI, Lava™, and Lava™ Plus High Translucency were significantly lower than those of Cercon® Base, Zeno®, and ZENO® Translucent at all thicknesses.

Enamel and dentin are translucent materials. When they are restored, the optical properties of the materials used must match those of the tooth structure in order to restore their function and esthetics. Material translucency can be characterized by either the contrast ratio or the color difference over black and white backgrounds.[1] The contrast ratio (CR) can be obtained from the measured reflectance of a material over black and white backgrounds (as shown in Equation (1). The CR reaches 1.00 for an opaque material.

$$CR = Y^b/Y^w \quad (1)$$

where Y^b is the measured reflectance of a material over a black background, and Y^w is the measured reflectance of a material over a white background.

Translucency affects the overall appearance of the tooth, and it has been investigated in few studies for both tooth enamel and dentin.[2,3] Enamel is more translucent than dentin, while the color of dentin controls the whole tooth color. Light scatters through enamel and dentin, and it creates unique light interaction patterns that restorative materials have to imitate.[4] In dental practice, low translucency or opaque restorative materials are used to conceal the discolored tooth structure. For a maximum covering capacity, a contrast ratio of ≥ 0.98 is required.[1] On the contrary, high translucency dental materials are used to substitute dentin or enamel lost from caries or other causes, and an excellent match between the restored area and the tooth structure is required. Glass-based or glass-ceramic dental materials are high translucent materials, and are highly recommended for use in the esthetic zone. Many factors, such as their compositions, amount and size of crystal content or second phase, and porosity, can affect the translucency of these materials.[5] Therefore, the variation in the degree of translucency of dental core ceramics has been documented, ranging between 0.6 and 1.0 at a 0.5 to 0.8 mm thickness.[6,7]

Zirconia-based dental ceramics have become well accepted for use in fixed dental restorations because of their superior mechanical and biological properties. Many zirconia ceramics are currently available. Selection of these materials is challenging because of variations, especially in their optical properties, among these materials. Zirconia-based dental ceramics are polycrystalline materials. Their translucency depends on the amount of light scattering at the interfaces and within the

Table 1 Compositions of six zirconia materials obtained from the manufacturers and derived from this study and their sintering temperatures

Group	Material	Composition (provided by manufacturers)	Composition (determined in this study)	Sintering temperature (°C)
1	Zeno®Zr (Wieland, Pforzheim Germany)	$ZrO_2 + HfO_2$ 94.00% Y_2O_3 5.00% Al_2O_3 < 1.00%	$ZrO_2 + HfO_2$ 97.61% Y_2O_3 2.06% Al_2O_3 0.15% Other oxides 0.18%	1450
2	Cercon® base (DentsplyCeramco, York, PA)	ZrO_2 ~ 92.00% Y_2O_3 5.00% Hf_2O_3 < 2.00% Al_2O_3 < 1.00%	$ZrO_2 + HfO_2$ 97.58% Y_2O_3 2.05% Al_2O_3 0.16% Other oxides 0.21%	1350
3	Lava™ Frame (3M ESPE, St. Paul, MN)	ZrO_2 < 95.00% Y_2O_3 < 5.00% Al_2O_3 < 0.25%	$ZrO_2 + HfO_2$ 97.53% Y_2O_3 2.11% Al_2O_3 0.18% Other oxides 0.19%	1500
4	ZENO®Zr bridge translucent (Wieland, Pforzheim, Germany)	ZrO_2+HfO_2 94% Y_2O_3 5% Al_2O_3 1%	$ZrO_2 + HfO_2$ 97.7% Y_2O_3 2.174% MgO 0.126%	1450
5	Lava™ Plus High Translucency Zirconia Mill Blank (3M ESPE, St. Paul, MN)	ZrO_2 ≥99%	$ZrO_2 + HfO_2$ 97.766% Y_2O_3 2.073% Other oxides 0.16%	1450
6	inCoris TZI (Sirona Dental System Bensheim, Germany)	ZrO_2+HfO_2+Y_2O_3 ≥99.9% Y_2O_3 5.4% HfO_2 ≤5% Al_2O_3 ≤0.005% Fe_2O_3 ≤0.02% Other oxides ≤0.2%	$ZrO_2 + HfO_2$ 97.75% Y_2O_3 2.169% Other oxides 0.081%	1450

bulk materials. The main sources for light scattering are pores, second phases, inclusions and grains with different crystallographic orientation.[8] Unlike glass-based dental ceramics, although a slight variation in zirconia compositions has been reported by the manufacturers, the minute differences in their microstructures could cause a considerable difference in their optical properties; however, zirconia-based dental ceramics are considered opaque.[6,7] Zirconias claimed to be translucent have recently been introduced for use as monolithic restorations, but information about their translucency is limited. The objective of this study was to compare the contrast ratio of three translucent zirconia dental ceramics with those of three conventional zirconia ceramics.

Materials and methods

The zirconia materials used in this study are summarized in Table 1. Fifty disc-shaped specimens were prepared from pre-sintered blanks for each material. With a milling machine, the pre-sintered blanks were cut into 18-mm diameter cylinders. The zirconia cylinders were cut to obtain specimens with five thicknesses using a low-speed saw (Isomet Low-Speed Saw; Buehler, Lake Bluff, IL). The compensation for firing shrinkage was predetermined, so that the final thicknesses of these specimens were approximately 0.3, 0.6, 0.9, 1.2, and 1.5 mm with a 15 mm diameter after firing. After cutting, all specimens were colored using a coloring liquid for shade A2, except for Cercon®, in which the pre-sintered blocks were already shaded. The sintering was performed in the furnace according to the manufacturers' recommendations. After firing, the thicknesses of all specimens were measured three times using a micrometer (Mitutoyo Manufacturing Company Ltd, Kawasaki, Japan).

The contrast ratio of all specimens was measured using a spectrocolorimeter (ColorFlex, Model 45/0; Hunter associates Laboratory, Inc., Reston, VA). All specimens were measured using the 45°/0° geometry with CIE illuminant D65 and 2° observer function. The machine was calibrated using a black glass and a white tile as recommended by the manufacturer. Each specimen was placed at the specimen port with a 13 mm measuring window. Concerning the edge-loss effect, the measuring port was large compared with the size of the disc-shaped specimens, and it could permit the light to escape through the surrounding edges; however, there was a limitation for specimen preparation in this study. Even the large measuring window would decrease the effect of edge-loss,[9] but it was difficult to prepare thin, oversized specimens to compensate for firing shrinkage, especially for a low-strength pre-sintered block. Therefore, all specimens were made at least 1 mm larger than the surrounding edges of the measuring window, and the covering opaque backgrounds were used during the contrast ratio measurement to minimize the edge-loss effect. The spectral reflectance data were obtained in the range of 400 to 700 nm at 10 nm spectral resolution. Three measurements were made for each specimen using equation (1), and the

Table 2 Mean contrast ratio values of six zirconia ceramics

Thickness	Mean contrast ratio					
(mm)	Cercon®	Zeno®	Zeno® T	Lava™	Lava™ Plus	inCorisTZI
0.3	0.76 (0.02)[a]	0.75 (0.01)[a]	0.76 ± 0.03[a]	0.68 (0.01)[b]	0.69 ± 0.01[bc]	0.7 ± 0.01[c]
0.6	0.84 (0.02)[de]	0.86 (0.01)[d]	0.83 ± 0.01[e]	0.76 (0.01)[f]	0.79 ± 0.01[g]	0.75 ± 0.01[f]
0.9	0.91 (0.01)[h]	0.93 (0.01)[I]	0.9 ± 0.01[h]	0.83 (0.01)[j]	0.85 ± 0.01[k]	0.81 ± 0.01[l]
1.2	0.97 (0.01)[m]	0.97 (0.00)[m]	0.96 ± 0.01[m]	0.88 (0.00)[n]	0.91 ± 0.01[o]	0.85 ± 0.00[p]
1.5	0.99 (0.01)[q]	0.98 (0.00)[q]	0.98 ± 0.01[q]	0.92 (0.01)[r]	0.93 ± 0.01[s]	0.88 ± 0.00[t]

Same superscript letters mean no significant differences were found between groups both in rows and in columns.

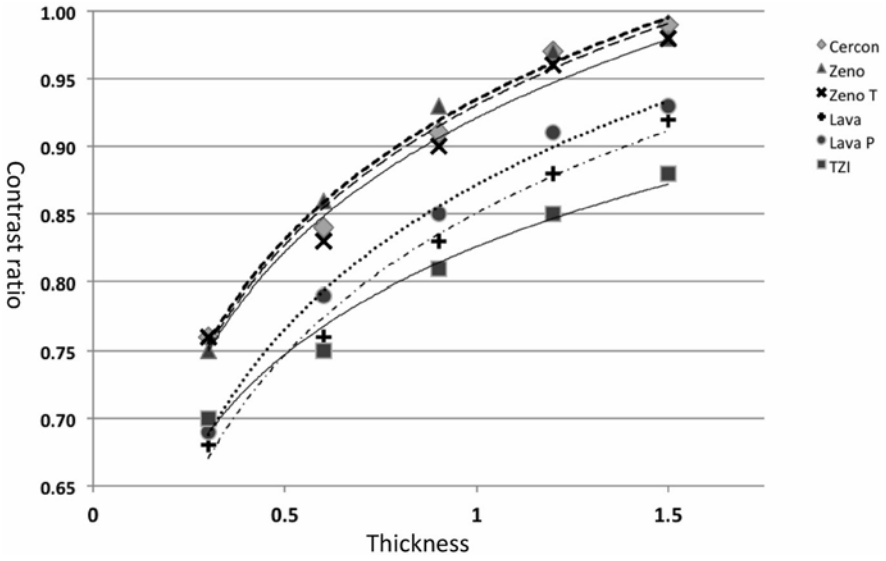

Figure 1 Logarithmic plots between the thickness and the contrast ratio of six zirconia ceramics.

mean contrast ratio was calculated. Statistical analysis of the mean contrast ratios was performed using two-way ANOVA at $\alpha = 0.05$.

The composition of the zirconia materials was determined using an X-ray fluorescence spectrometer (Oxford Model ED2000; Oxford Instruments, Oxfordshire, UK). Three disc-shaped specimens with 0.5 mm in thickness of each brand were prepared and fractured using a biaxial testing fixture attached to a universal testing machine (Model 4465; Instron, Canton, MA) with a 0.5 mm/min crosshead speed at room temperature in air. All fractured specimens were ultrasonically cleaned in ethanol for 10 minutes and then sputter-coated with gold. The microstructures were examined using a scanning electron microscope (JSM-5410LV; JEOL Ltd., Tokyo, Japan). The bulk density of all materials was determined using a density-measuring device (Model AG204; Mettler Toledo Inc., Columbus, OH). The amount of porosity can be calculated from the bulk density of a specimen with pores (ρ) and the theoretical density ($\rho_t = 6.1$ g/cc). Percent porosity is determined from $(1 - \rho/\rho_t) \times 100$.[5]

Results

The mean contrast ratio values of all groups are summarized in Table 2. The results from two-way ANOVA showed significant differences between groups with different thicknesses and brands ($p < 0.001$). An interaction between thickness and brand was also observed, and simple effect analysis was used to define the effect of thickness within each brand and the effect of brands within each thickness. Dunnett T3 multiple comparison test was used to define the rank within each brand and thickness level. The results from simple effect analysis indicated that the mean contrast ratio values of six zirconia ceramics were significantly different at each thickness level ($p < 0.0001$). It also showed that all zirconia tested in this study could be divided into two groups, the translucent group and the more opaque group. The first group consisted of Lava™, Lava™ Plus, and inCoris TZI. In this group, inCoris TZI was the most translucent, with the lowest contrast ratio values at thickness levels of 0.6 to 1.5 mm. The second group consisted of Zeno®, Zeno® Translucent, and Cercon® Base. The contrast ratio of specimens in this group

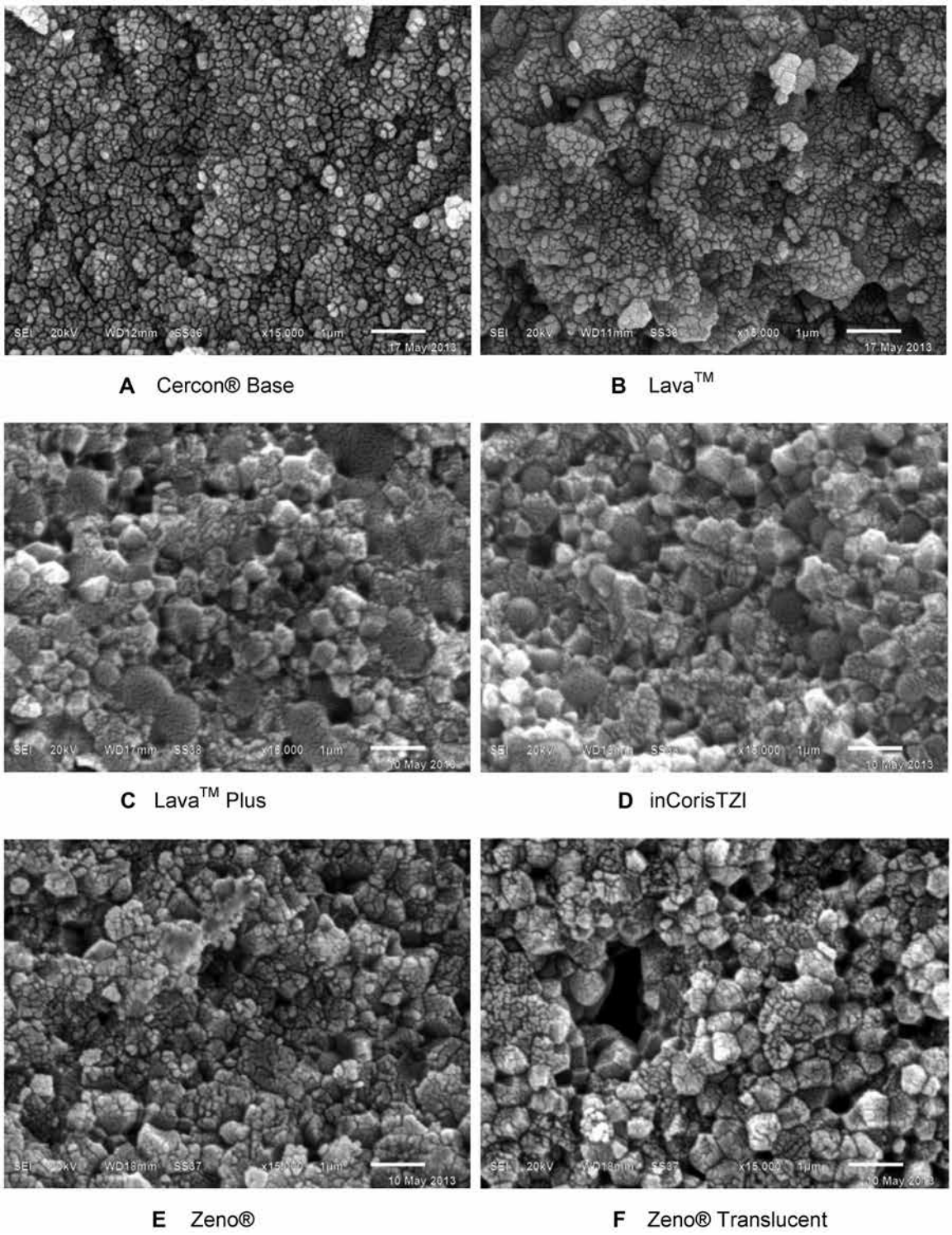

Figure 2 SEM micrographs of microstructures of six zirconia dental ceramics.

was not significantly different at all thickness levels, except at 0.6 to 0.9 mm thickness where Zeno® was more opaque than Zeno® Translucent and Cercon® Base. Significant differences were also observed at all different thicknesses for each brand ($p < 0.001$). The contrast ratio of thicker specimens was significantly higher than those of the thinner ones. The

Table 3 Density and%porosity of six zirconia ceramics

Materials	Cercon®	Zeno®	Zeno® T	Lava™	Lava™ Plus	inCorisTZI
Density (g/cc^3)	6.024 ± 0.013	6.036 ± 0.022	6.067 ± 0.023	6.037 ± 0.027	6.069 ± 0.031	6.068 ± 0.028
%Porosity	1.24	1.05	0.54	1.03	0.50	0.53

contrast ratio of the 0.3 mm group was the lowest and that of the 1.5 mm group was the highest for each brand. The significant differences between these groups are summarized in Table 2.

The relationship between thickness and contrast ratio of zirconia dental ceramics was determined in this study using a logarithmic plot (Fig 1). The R^2 obtained from these plots for all materials was 0.94 to 0.99, indicating a strong relationship between the thickness and the contrast ratio parameters.

The compositions of zirconia materials obtained from the manufacturers and determined in this study are shown in Table 1. The microstructures of these zirconia materials are shown in Figure 2. The density and the calculated porosity are summarized in Table 3.

Discussion

Most zirconia-based core materials obtained from various manufacturers are yttria-stabilized tetragonal zirconia polycrystals (Y-TZP). Differences in grain size, amount of porosity, second-phase inclusions, or the discontinuity of refractive indices at the grain boundary are the primary factors affecting the transparency of polycrystalline ceramics.[5,8] The results from this study showed that the six zirconia materials used in this study had a different degree of translucency, an effect of both the brand and thickness of these materials. For the effect of different brands, slight differences in the amount of Al_2O_3 and other oxides within a range of 0.08 to 0.37% were observed according to the results from the X-ray fluorescence analysis and expected to be an important aspect for the translucency variation among brands of Y-TZP. For zirconia with lower contrast ratio values, the amount of other oxides was less than those of zirconia with higher contrast ratio values. The elimination of Al_2O_3 was noted.

The grain sizes of six zirconia materials used in this study were approximately in submicron ranges as reported by the manufacturers. The microstructures of these materials are shown in Figure 2. Previous studies emphasized that grain size is the key factor controlling the transparency of polycrystalline ceramics.[10-12] An opaque polycrystalline ceramic could be made translucent or transparent when the grain sizes are in submicron or nano-scale. It appears that grain sizes in the submicron scale are also the key to producing translucent zirconia dental ceramics.[13,14] To decrease the light scattering centers, the grain size of Y-TZP should be less than the visible wavelength (0.4 to 0.7 μm). In fact, the grain size of Y-TZP should be less than 40 nm if maximum transmission is required.[12] However, extremely small grain size (<0.2 μm) can affect the transformation toughening mechanism of Y-TZP and would affect its mechanical properties, which is undesirable.[15] Porosity within each material can also affect material translucency and should be kept low for transparent materials; however, porosity of less than 0.1% is preferred to minimize the scattering effect from pores and defects, because the translucency of single-phase oxide ceramics depends greatly on the pore concentration.[16,17] In this study, the amount of porosity ranged between 0.5 to 1.2% for six zirconia dental ceramics. Because of the greater amount of porosity and the limitation in grain size regarding the transformation toughening mechanism, the translucency of zirconia-based dental ceramics should be limited to an amount comparable to that of translucent core ceramics such as lithia-disilicate-based ceramic, with the intention that their optical and mechanical properties would be well balanced.

The effect of thickness on the translucency of some dental ceramics was reported in a previous study,[18] which showed that the relationship between contrast ratio and thickness was linear. The contrast ratio values obtained from this study confirmed the effect of thickness on the translucency of zirconia dental ceramics; however, the relationship between the thickness and the contrast ratio of zirconia dental ceramics was not linear. The logarithmic curves were precisely fitted to the points in the graphic plots between the thickness and contrast ratio values (Fig 1). The R^2 values for the logarithmic plots were 0.94 to 0.99 for all materials. Since the transmission of light declines nonlinearly with thickness,[17] it was reasonable that the relationship between the thickness and contrast ratio values of zirconia dental ceramics was not straight.

The results from the statistical analyses showed that the zirconia used in this study could be divided into two groups, translucent and opaque. In the opaque group, the contrast ratio ranged from 0.76 to 0.99 as the thicknesses increased from 0.3 to 1.5 mm. The contrast ratio values of specimens with thickness ≥1.2 mm were much closer to 1.00. In the translucent zirconia group, their contrast ratio values at thicknesses of 0.3 to 0.6 mm were comparable to lithia-disilicate-based core ceramic at 0.8 mm thickness.[6] The difference in translucency of zirconia materials signifies two applications. The first function for opaque zirconia is use as a masking material for discolored or metal abutment. The high opacity of these materials can make a perfect cover for the unesthetic core structure. The second application concerns the esthetic outcome. It is well accepted that an opaque restoration could not mimic the appearance of natural adjacent teeth because of the reduced amount of light transmission and much scattering through the restoration. With a more translucent core material, the amount of light transmission and scattering could be improved to match those of the natural teeth. Recently, dental zirconias with improved optical properties have been claimed to be the materials of choice for fabricating fixed partial prostheses without a veneering

material. For use as a monolithic restoration, the risk of porcelain chipping is eliminated, and an increase in fracture resistance is expected; however, there are still some questions about wear of opposing teeth, the difficulties for grinding and adjusting for proper contour and occlusion, and the possibility of minor correction for lost contact and occlusion.

Conclusions

From the results obtained in this study, the following conclusions could be drawn:

1. The thickness and brand had significant effects on the contrast ratio of the six zirconia dental ceramics tested in this study.
2. The mean contrast ratio values of inCoris TZI, Lava™, and Lava™ Plus High Translucency were significantly lower than those of Cercon® Base, Zeno®, and ZENO® translucent at all thickness levels.
3. inCorisTZI® was the most translucent material with the lowest contrast ratio values at 0.6 to 1.5 mm thicknesses.

Acknowledgments

Lava™ Plus High Translucency material was supplied by 3M ESPE.

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A study on the *in-vitro* wear of the natural tooth structure by opposing zirconia or dental porcelain

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PURPOSE. This study was conducted to evaluate clinical validity of a zirconia full-coverage crown by comparing zirconia's wear capacity over antagonistic teeth with that of feldspathic dental porcelain. **MATERIALS AND METHODS.** The subject groups were divided into three groups: the polished feldspathic dental porcelain group (Group 1), the polished zirconia group (Group 2), and the polished zirconia with glazing group (Group 3). Twenty specimens were prepared from each group. Each procedure such as plasticity, condensation, and glazing was conducted according to the manufacturer's manual. A wear test was conducted with 240,000 chewing cycles using a dual-axis chewing simulator. The degree of wear of the antagonistic teeth was calculated by measuring the volume loss using a three-dimensional profiling system and ANSUR 3D software. The statistical significance of the measured degree of wear was tested with a significant level of 5% using one-way ANOVA and the Tukey test. **RESULTS.** The degrees of wear of the antagonistic teeth were 0.119 $\pm$ 0.059 mm^3 in Group 1, 0.078 $\pm$ 0.063 mm^3 in Group 3, and 0.031 $\pm$ 0.033 mm^3 in Group 2. Statistical significance was found between Group 1 and Groups 2 and between Group 2 and 3, whereas no statistical significance was found between Group 1 and Group 3. **CONCLUSION.** Despite the limitations of this study on the evaluation of antagonistic teeth wear, the degree of antagonistic tooth wear was less in zirconia than feldspathic dental porcelain, representing that the zirconia may be more beneficial in terms of antagonistic tooth wear. **[J Adv Prosthodont 2010;2:111-5]**

KEY WORDS. Zirconia, Ceramic, Tooth, Wear

INTRODUCTION

The frequency of esthetic restoration in prosthodontics has been increasing due to increased interest in esthetics. Due to this trend, there has been increasing clinical application of the all-ceramic crown, which is more esthetic and bio-friendly, whereas there has been decreasing clinical application of the metal ceramic crown, which is less esthetic due to the metal coping. As the all-ceramic crown has relatively higher embrittlement and lower tensile strength, its application has been particularly limited to fixed partial dentures.[1-4]

To improve the embrittlement and lower tensile strength, reinforced dental porcelain was developed using aluminum oxide, leucite, lithium disilicate, and zirconia (zirconium oxide), and all-ceramic restoration has been applied not only to single tooth replacement, but also to fixed partial dentures.[5,6]

In particular, the latest developed zirconia has a polymorphic structure with chemical stability and volume stability, and suppresses crack progression via the volume extension caused by the transformation toughening mechanism that occurs during the phase transition. Due to these properties, zirconia has higher deflection and fracture strength than conventional dental porcelains, which is why its clinical use has been increasing.[7,8]

A zirconia full-coverage crown without veneering dental porcelain was recently released (Zirkonzahn prettau; Zirkonzahn GmbH, Bruneck, Italy). The zirconia full-coverage crown without veneering dental porcelain has advantages in that no dental porcelain is fractured due to the absence of an upper structure in it, and more strength can be obtained even in the case of less abutment removal using zirconia with strong hardness to manufacture the crown, compared to previous all-ceramic crowns. On the other hand, the zirconia full-coverage crown has the disadvantage of the abrasion of the

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opposing natural tooth upon the formation of the occlusal surface with zirconia. No study on the abrasion of the antagonistic natural tooth by zirconia has been conducted so far, though.

Accordingly, this study was conducted to evaluate the clinical validity of the zirconia full-coverage crown by comparing zirconia's wear capacity over an antagonistic tooth with that of feldspathic dental porcelain.

MATERIALS AND METHODS

A. Materials

Zirkonzahn prettau® (Zirkonzahn GmbH, Bruneck, Italy) and feldspathic dental porcelain [Vita Omega 900® (Vita Zahnfabrik, Bad Säckingen, Germany)] were used for the present study testing antagonistic tooth wear. Maxillary premolars extracted for orthodontic purpose were used as antagonistic teeth.

B. Methods

1. Preparation of the specimens

The dental specimens were produced by embedding the premolars that were recently extracted for orthodontic demands. The teeth were embedded in acrylic resin mould with only the buccal cusp exposed. The teeth with worn-out cusps or too sharp or fractured teeth were excluded from the subjects.[9]

2. Preparation of the dental porcelain specimens

The dental porcelain specimens, the control group, were produced into a cuboid with a width of 20 mm, a breadth of 10 mm, and a height of 5 mm, according to the manufacturer's manual; then the specimen surface was ground finished with 1200-grit silicone carbide abrasive under water cooling. These specimens were designated as Group 1.

3. Preparation of the zirconia specimens

The zirconia specimens underwent plasticity and were then produced into cuboids with a width of 20 mm, a breadth of 10 mm, and a height of 5 mm, according to the manufacturer's manual. After the specimen's surface was ground with a sheet of 1,200-grit abrasive paper, it was designated as Group 2. The polished specimens that underwent glazing were additionally designated as Group 3.

4. Wear testing machine

A wear test was conducted using the chewing simulator CS-4.8 (SD Mechatronik, Feldkirchen-Westerham, Germany) which has eight chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. Each of the chambers consists of an upper sample holder that can fasten the specimen with a screw and a lower plastic sample holder in which the specimen can be embedded (Fig. 1).

The dental specimens were embedded in acrylic resin in the lower sample holder (Fig. 2), for use as antagonistic wear materials. The dental porcelain and the zirconia were embedded in acrylic resin in the upper sample holder, and were then fixed with a fastening screw (Fig. 3).

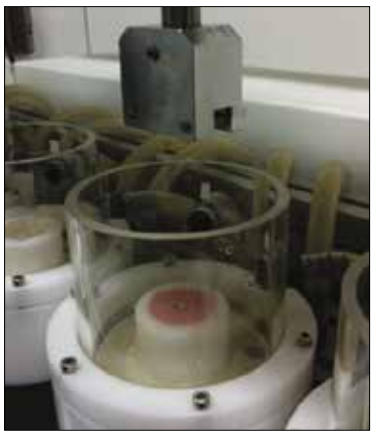

Fig. 1. Specimen chamber.

Fig. 2. Human premolar cusps embedded in acrylic resin (self-cure) in the lower sample holder.

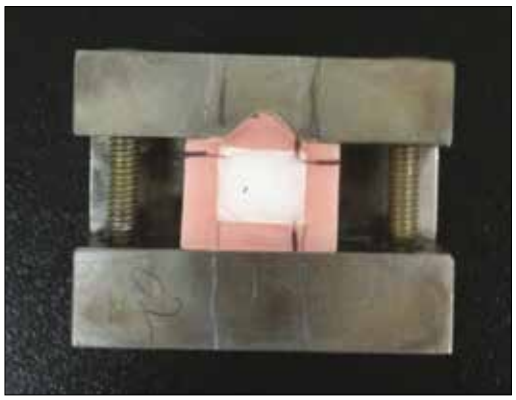

Fig. 3. Antagonistic samples embedded in acrylic resin, which was fixed into the upper sample holders.

Table 1. Materials and surface conditions of the test specimens

	Group 1	Group 2	Group 3
Antagonist	Omega 900® polished with a 1,200-grit abrasive	Zikonzahn prettau® polished with a 1,200-grit abrasive	Zikonzahn prettau® with glazing
Numbers	20	20	20

Table 2. Test parameters

Cold/hot bath temperature:	5℃/55℃	Dwell time:	60 s
Vertical movement:	6 mm	Horizontal movement:	0.3 mm
Rising speed:	55 mm/s	Forward speed:	30 mm/s
Descending speed:	30 mm/s	Backward speed:	55 mm/s
Weight per sample:	5 kg	Cycle frequency	0.8 Hz
Kinetic energy	$2,250 \times 10^{-6}$ J		

Table 3. Statistical comparison of the groups using the Tukey test

Groups	Omega 900® (1,200-grit abrasive paper)	Zirkonzahn prettau® (1,200-grit abrasive paper)	Zirkonzahn prettau® (glazing)
Omega 900®(1,200-grit abrasive paper)	-----	0.000*	0.099
Zirkonzahn prettau®(1,200-grit abrasive paper)	0.000*	-----	0.008*
Zirkonzahn prettau®(glazing)	0.099	0.008*	-----

*Statistically significant.

5. Wear test

A weight of 5 kg, which is comparable to 49 N of chewing force,[10,11] was exerted. According to previous studies, as 240,000 - 250,000 loading cycles in a chewing simulator are comparable to approximately one-year chewing from a clinical perspective,[12-14] the wear test was repeated 240,000 times to clinically simulate the one-year chewing condition, accompanying thermocycling (Table 2). The three-dimensional (3D) surfaces before and after the wear test were scanned using a 3D profiling system (MTS System Corporation, Eden Prairie, MN, USA), and the actual volume loss of the specimens was calculated with a computer by overlapping the 3D surfaces before and after the wear test using a 3D software (ANSUR 3D, University of Minnesota, Minneapolis, MN, USA).

6. Statistics

The mean and standard deviation of the test parameters were calculated using SPSS (Ver. 12.0, SPSS, Chicago, IL, USA). The statistical significance of the mean difference of each parameter was tested with a significant level of 5% using one-way ANOVA and the Tukey test.

RESULTS

The degrees of wear of the antagonistic teeth based on the restorative materials were 0.119 ± 0.059 mm³ (the greatest degree in the group where Vita Omega 900® dental porcelain was polished with a sheet of 1,200-grit abrasive paper), 0.078 ± 0.063 mm³ (the second greatest degree in the group that underwent glazing of Zirkonzahn prettau® according to the manufacturer's manual), and 0.031 ± 0.033 mm³ (the lowest degree in the group where Zirkonzahn prettau® was polished with a sheet of 1,200-grit abrasive paper (Fig. 4).

The one-way ANOVA showed a statistically significant difference among the groups, and the results of the Tukey test are presented in Table 3.

The degree of wear of the antagonistic teeth based on the restorative materials was four times higher in the group wherein Vita Omega 900® dental porcelain was polished with a sheet of 1,200-grit abrasive paper than in the group wherein Zirkonzahn prettau® was polished with a sheet of 1,200-grit abrasive paper, and they showed a statistically significant difference. The degree of wear of the antagonistic teeth based on the restorative materials was two times higher in the

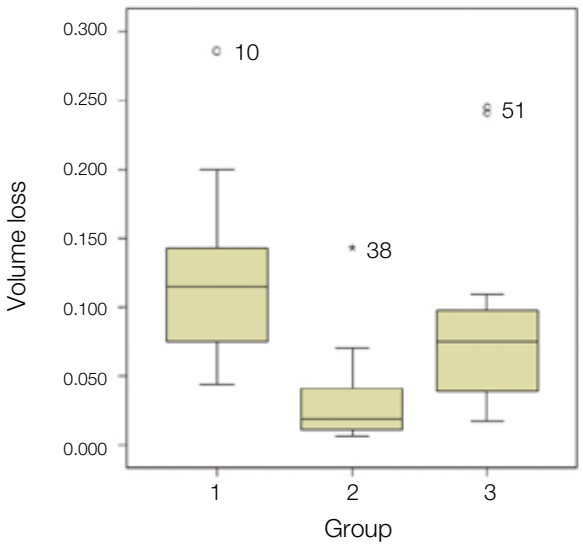

Fig. 4. Box plots of the volume loss (mm³) after 240,000 loading cycles.

group that underwent glazing of Zirkonzahn prettau® according to the manufacturer's manual than in the group wherein Zirkonzahn prettau® was polished with a sheet of 1,200-grit abrasive paper, and they showed no statistically significant difference. The degree of wear of the antagonistic teeth based on the restorative materials was two times higher in the group wherein Vita Omega 900® dental porcelain was polished with a sheet of 1,200-grit abrasive paper than in the group that underwent glazing of Zirkonzahn prettau® according to the manufacturer's manual, and they showed no statistically significant difference.

DISCUSSION

Dental wear is defined as tooth loss or surface damage caused by direct contact between teeth or between teeth and other materials. Dental wear, one of the physiological phenomena that are experienced in a lifetime, occurs as a complex form of chemical and mechanical wear.[15]

Dental wear of natural teeth is considered normal. If restorative dental materials have different wear properties compared to the natural teeth, however, they can change the wear rate of antagonistic natural teeth.[16] In particular, excessive wear on the occlusal surface can cause an abnormal load and result in periodontal diseases, and can also cause temporomandibular disorders due to the vertical dimension, loss of centric occlusion, diagonal teeth, functional route change during chewing, or masticatory muscle fatigue.[17,19,20] Therefore, wear that occurs between the enamel of teeth and restorations is a very important factor that should be considered in the selection of restorative materials in clinical practice. Seghi suggested that a restorative dental material should have a wear degree similar to that of the enamel.[21]

Dental porcelain was introduced approximately 100 years ago, and has been used for more natural and esthetic restorations. It has a few disadvantages, such as dental porcelain fracture and excessive wear of antagonistic teeth.[22]

Zirconia has a polymorphic structure with chemical stability and volume stability, and suppresses crack progression via the volume extension caused by the transformation toughening mechanism that occurs during the phase transition. Due to these properties, zirconia has higher deflection and fracture strength than conventional dental porcelains, which is why its clinical use is increasing.[7,8] The zirconia full-coverage crown (Zirkonzahn prettau®) was recently released. This product has a few improved characteristics such as greater transparency than that of the previous zirconia, a color liquid that can express the dentin's color tone, and a stain that can be directly applied to the zirconia. In addition, the zirconia full-coverage crown has advantages in that no dental porcelain is fractured due to the absence of an upper structure, and more strength can be obtained even in the case of less abutment removal using zirconia with strong hardness to manufacture the crown compared to previous all-ceramic crowns.

The surface hardness and friction coefficient are commonly used to estimate the degree of wear of restorative dental materials. Conventionally, greater hardness has been believed to cause more wear. Therefore, more wear was expected from zirconia, as zirconia has strong surface hardness. According to scientific studies, however, there is no significant correlation between the restoration hardness and the degree of wear of antagonistic teeth. On the other hand, the degree of wear is more affected by the surface structure and the roughness of the restorations or environmental factors.[24]

A wear test was conducted to investigate the degree of wear of antagonistic teeth with zirconia using a dual-axis chewing simulator. Compared to previous wear tests, the vertical and horizontal movements were more accurately simulated with a computer, the degrees of wear were more accurately compared using volume rather than height, and the condition of the oral cavity was more realistically simulated with the accompanying thermocycling.[25]

According to a previous study led by DeLong *et al.*[17] on dental wear caused by dental porcelain, 300,000 chewing cycles showed a volume decrease of 0.162 ± 0.057 mm^3. That result is significantly correlated to this study's resulting in volume decrease of 0.119 ± 0.059 mm^3 in 240,000 chewing cycles with feldspathic dental porcelain. In this study, the degree of wear of the antagonistic teeth was much lower in zirconia than in dental porcelain. This is likely to be attributable to the fact that zirconia is harder but softer than dental porcelain. More wear was shown in the polished zirconia group with glazing than in the polished zirconia group. This result is likely to be attributable to the fact that porcelain composite was added in the glazing process. Therefore, the polished zirconia full-coverage crown without glazing is more effective in reducing antagonistic teeth wear.

Wear in the oral cavity can be classified into two-bodied wear and three-bodied wear.[18] Two-bodied wear is wear in the condition of the saliva alone, whereas three-bodied wear is wear in the condition of other mediators such as food and paste, besides saliva.[18] This study measured two-bodied wear, with the limitation that the complex wear phenomena were not fully simulated. Therefore, long-term clinical follow-up will be required for the zirconia full-coverage crown. In addition, a study on the effect of zirconia weakness caused by tetragonal change due to chewing force or water based on direct zirconia exposure upon clinical application of zirconia will also be required.

CONCLUSION

Despite the limitations of this study on the evaluation of antagonistic teeth wear, less wear of antagonistic teeth was shown with zirconia than with the previous feldspathic dental porcelain. As for the zirconia surface process, the degree of wear of

the antagonistic teeth was less in the polished zirconia group than in the polished zirconia group with glazing, but no statistically significant difference was found. It is likely that the polished zirconia full-coverage crown without glazing is more effective in reducing antagonistic teeth wear.

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USA

Expertise

Wear behavior of BruxZir®

General Specifics

Designation:	Wear Test (Chewing Simulator)
Test Specimen:	• BruxZir • Ceramco®3
Sponsor:	Glidewell Laboratories 4141 MacArthur Blvd. Newport Beach, CA 92660 USA
Contact Person:	Wolfgang Friebauer, MDT, CDT
Date of Order:	Proposal 03/22/2010
Contractor/Investigator:	Prof. Dr.rer.nat Dipl.-Ing. Jürgen Geis-Gerstorfer
Realization:	Ch. Schille (PhyTA)
Date of Report:	9/15/2010

Material/Product

The following materials were investigated:

1.) BruxZir
ZrO_2 (Tosoh Material)
Lot # S 309853 P

2.) Ceramco®3
Feldspatic Ceramic, A3 (Dentsply Material)
Lot # 09 001 402

Sample Preparation

The samples were delivered by the sponsor in a test-ready condition. Ten specimens of each material and each surface condition respectively were tested. The specimen size was ca. 10x10x2 mm.

Both groups of materials were hand prepared by the sponsor as follows:

1. Course: Diamond disk 9 µm w/300 rpm
2. Medium: Diamond disk 3 µm w/150 rpm
3. Fine: Diamond disk 1 µm w/150 rpm + Diamond polish

All samples were tested in the as delivered state.

Test Procedure

The wear tests were performed using a pin-on-disk apparatus (chewing simulator, Version 3.1.29, Willytech; Munich, Germany). The chewing procedure (simulation of bruxism) consisted of 1.2 x 10^6 cycles under a load of 50 N and a horizontal movement of 0.2 mm (in water). As antagonists, 6 mm Steatite balls were used. This protocol simulates the clinical performance of the materials over period of approx. five years.
The amount of wear was determined topographically with the use of a 3-D profilometer (Concept 3D; Mahr, Germany) by measuring the depth of wear track of the restorative material and the height loss of the antagonist.

Fig. 1: Sample in test cell with antagonist/Steatite ball holder (top).

Fig. 2: Assembled test devices in the chewing simulator.

Fig. 3: Embedded Steatite balls in the antagonist holder (top), and samples after finishing the wear test (left: Ceramco®3, right: BruxZir; sample No. 10 each).

Overall three test series were performed with the chewing simulator using half of the materials at any one time (first and second run: 2x3 specimens of each material; third run: 2x4 specimens) in order to eliminate potential systematic errors during the wear tests.

To simulate moist conditions of the oral cavity, the test chambers were filled with distilled water.

As antagonists, 6 mm Steatite balls were used. The Steatite balls were polymerized in the aluminum-antagonist holders using Palavit G. A new steatite ball was applied for each test. The contact point of the antagonists was adjusted at the middle of the samples.

The cyclic two body wear tests were carried out in such a way that the antagonist hit the sample vertically with a load of 5 kg followed by a horizontal movement under a load of 0.2 mm. At the end of this track, the antagonist was lifted 5 mm and then the wear cycle was repeated at its original position 1,200,000 times. The feed-motion speed was 40 mm/min.

Determination of wear

From each sample the 3-D Topography was measured before and after the wear test with 121 measuring profiles within an area of 3x3 mm using a 3-D measuring device with a 2 µm tactile probe (Apparatus: Perthometer S6P, Mahr; Goettingen, Germany; tactile probe: MFW-250; software: Perthometer Concept 3D, Vers. 7.1). This procedure was used to calculate the maximum depth of wear Pt quantitatively.

The substance loss of the antagonist situation (Steatite balls) was determined with a calibrated stereo microscope (Wild) measuring the diameter of the flattended balls and calculating the height of wear.

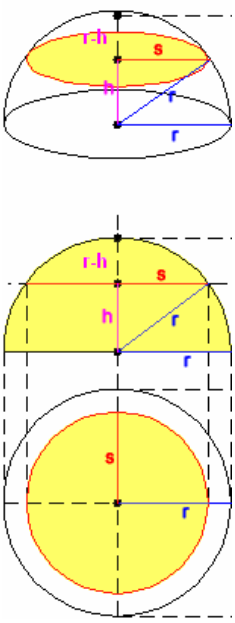

Fig. 4: Principle of the determination of wear r-h of the balls based on the abrasion radius s measured.

Results

The following tables represent the wear data of the materials investigated.

BruxZir		
Sample No.	Wear of Antagonist [µm]	Wear of Material [µm]
1	82.7	2.6
2	48.9	0.4
3	113.7	2.5
4	52.9	1.9
5	45.1	0.4
6	64.2	0.7
7	63.2	0.7
8	79.1	0.6
9	92.4	1.4
10	73.0	0.9
Mean	72	1
S.D.	21	1

Table 1: Single values of BruxZir.

Ceramco®3		
Sample No.	Wear of Antagonist [µm]	Wear of Material [µm]
1	77.5	46.9
2	81.5	91.6
3	146.2	35.0
4	110.2	50.5
5	44.1	31.7
6	194.0	82.3
7	111.2	64.1
8	158.4	Sample broken
9	122.5	31.2
10	50.6	49.2
Mittelwert	110	54
S.D.	48	22

Table 2: Single values of Ceramco®3.

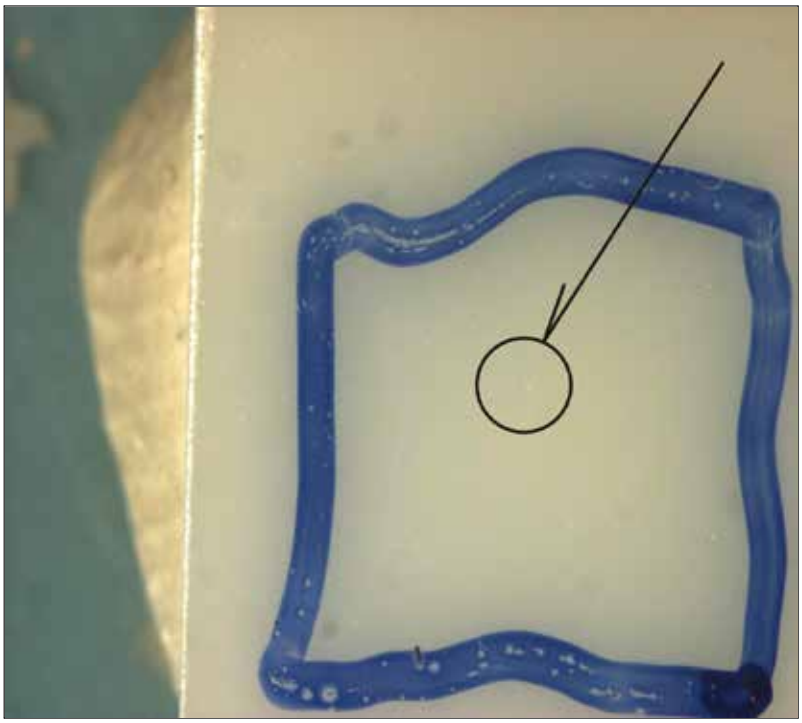

Fig. 5: **BruxZir** after wear test (sample No. 4). The contact area is indicated by the circle.

Fig. 6: **Ceramco®3** after wear test (sample No. 4). The contact area is indicated by the bright spot.

Fig. 7: Situation of the antagonist after the wear test in contact with **BruxZir** (sample No. 4).

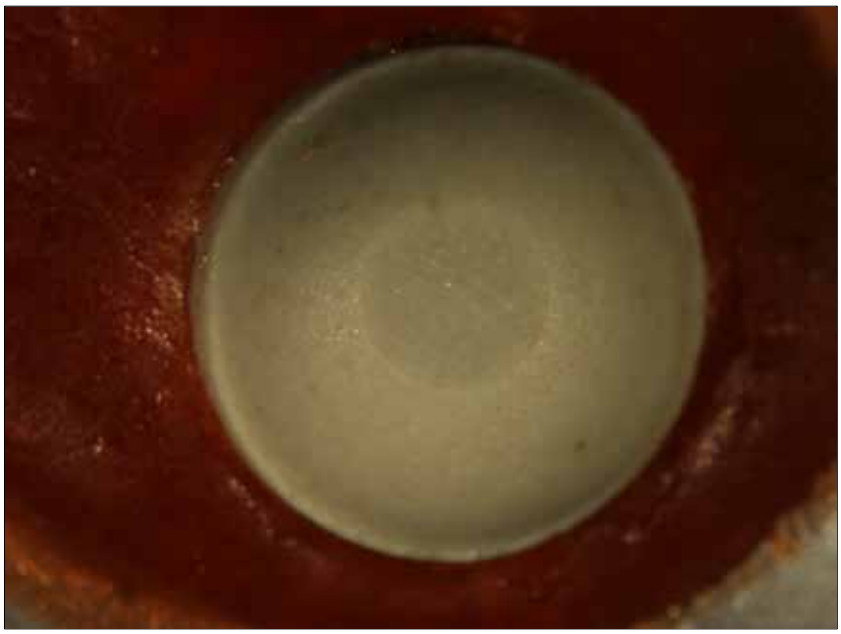

Fig. 8: Situation of the antagonist after the wear test in contact with **Ceramco®3** (sample No. 6).

Topography

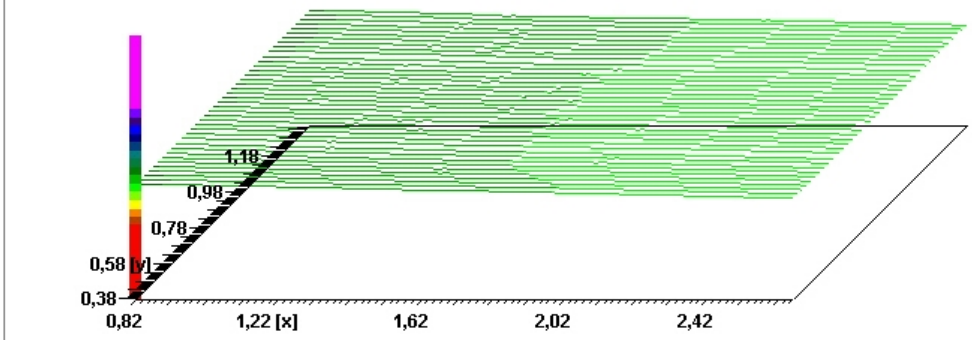

Fig. 9: Example of the topography of **BruxZir** after wear test (sample No. 4).

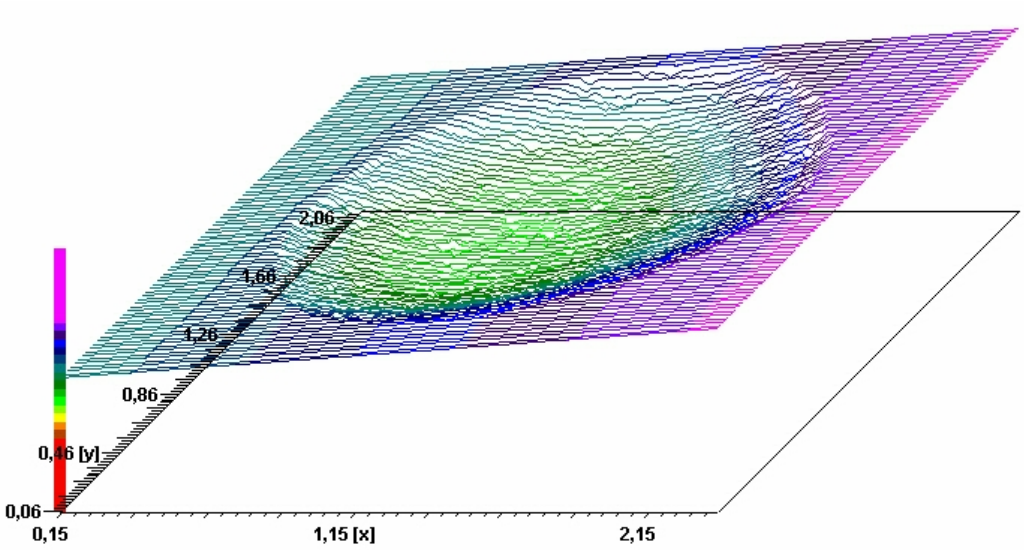

Fig. 10: Example of the topography of **Ceramco®3** after wear test (sample No. 2).

D-Profile

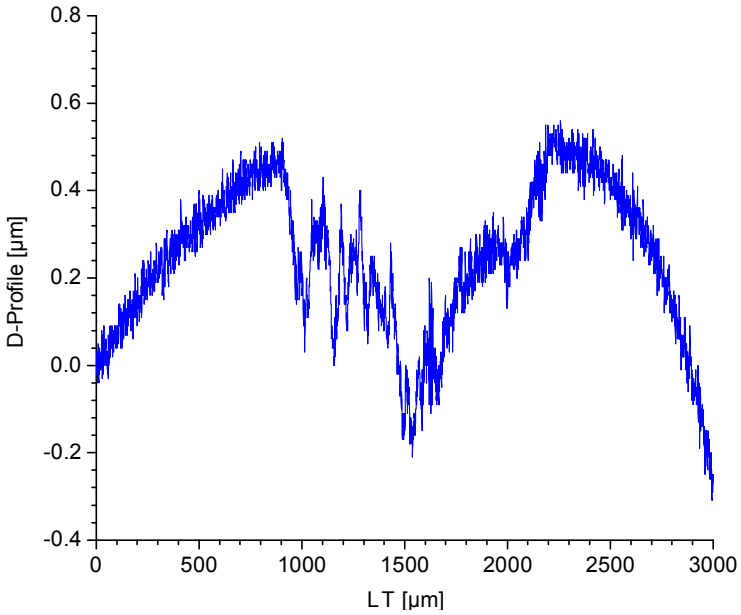

Fig. 11: Example of a single wear profile of **BruxZir** (sample No. 10, line 45).

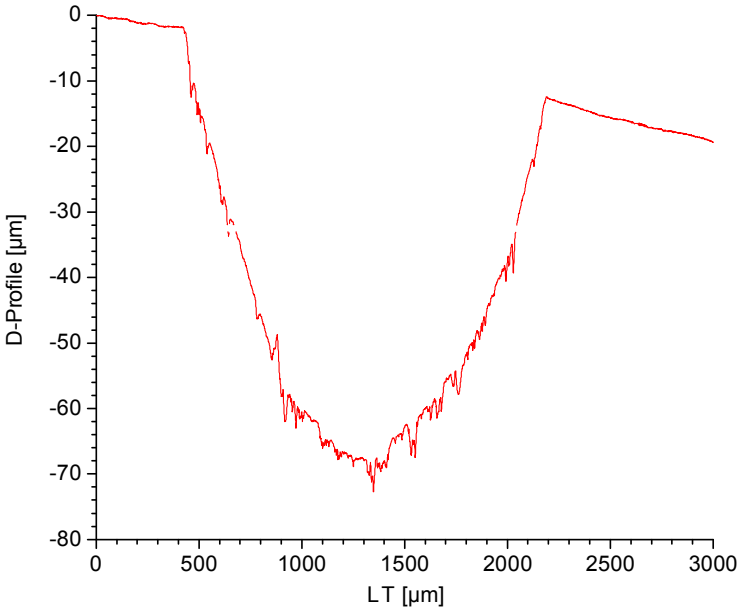

Fig. 12: Example of a single wear profile of **Ceramco®3** (sample No. 2, line 45).

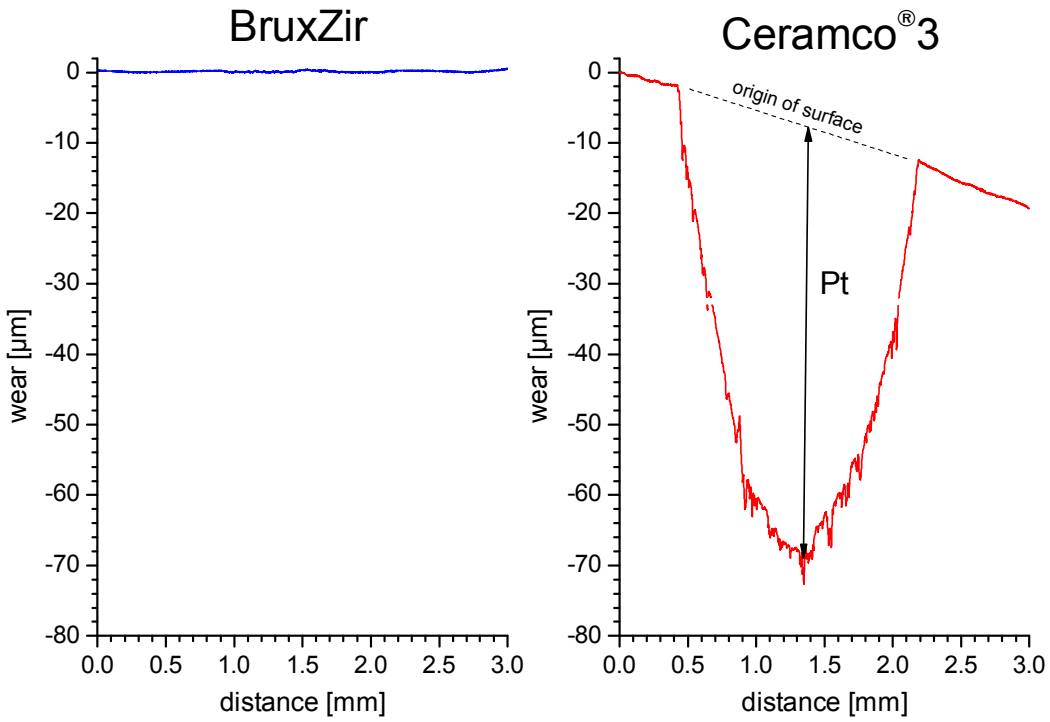

Fig. 13: Comparision of wear of BruxZir and Ceramco®3.

Statistics

The significance Pt values of BruxZir and Ceramco 3 and the values of antagonist height loss was evaluated using t-test ($p<0.05$). The wear differences between the materials as well as between the antagonists (Steatite balls) was significantly different.

Summary

- After 1.2 million wear cycles under a load of 5 kg, BruxZir revealed barely detectable wear with a measured mean value of 1 ± 1 µm.
- Compared to BruxZir, wear of Ceramco®3 with a mean value of 54 ± 22 µm was clearly higher.
- The wear of the antagonist situation (Steatite ball) was found to be significantly lower with BruxZir (72 ± 21 µm) than with Ceramco®3 (110 ± 48 µm).

Tübingen, 15 September 2010

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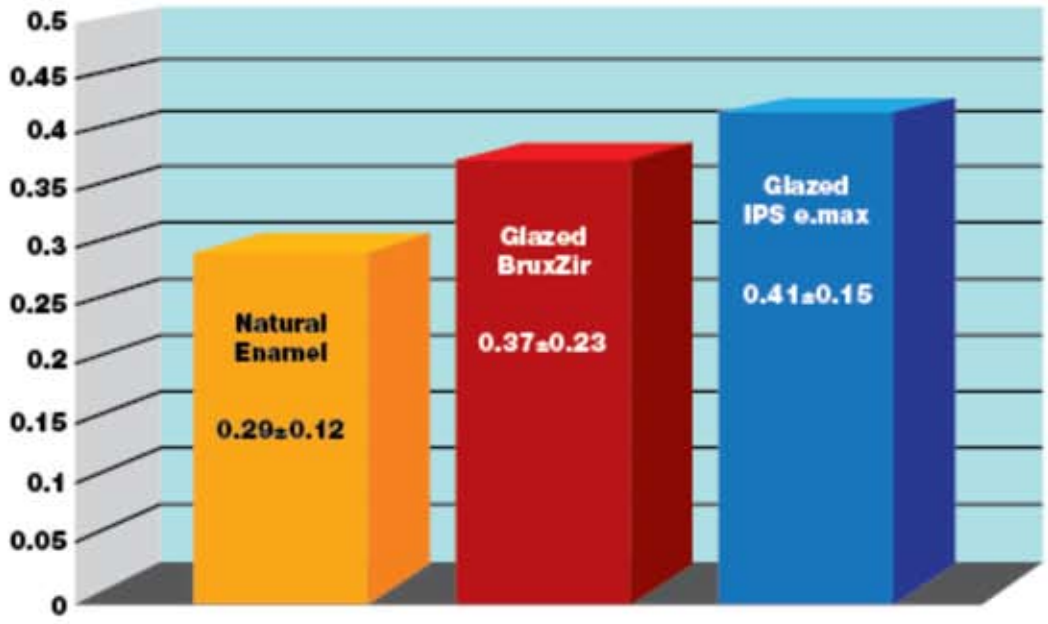
Prof. Dr. J. Geis-Gerstorfer
Contractor/Investigator

Wear of Enamel on Polished and Glazed Zirconia

(AADR Abstract ID#129615 2010 S. SHAH, C. MICHELSON, P. BECK, L.C. RAMP, D. CAKIR, and J. BURGESS)

The results after 100,000 cycles show that the volume loss in mm is virtually identical between glazed IPS e.max® and glazed BruxZir® Solid Zirconia.

While studies typically provide both depth and volume measurements, depth measurements are not considered as accurate as they do not distinguish between a small and deep hole versus a wide and shallow hole. Therefore, the volume loss measurement is considered more accurate.



Other studies are ongoing, and as more details emerge we will share them.

Material against Enamel	Results: Volume (mm^3)
Enamel	0.29 ± 0.12
BruxZir Glazed	0.37 ± 0.23
IPS e.max Glazed	0.41 ± 0.15

IPS e.max is a registered trademark of Ivoclar Vivadent.

Gordon J. Christensen
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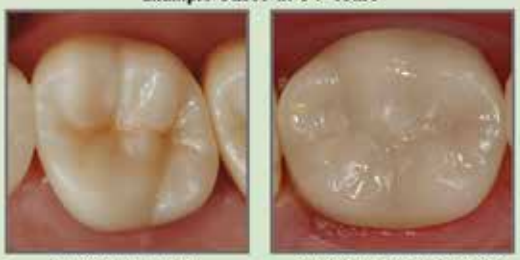
BruxZir and e.maxCAD: Superior Clinical Performance at 3+ Years

Gordon's Clinical Bottom Line: The TRAC research section of CR has been conducting a controlled clinical study of monolithic restorations for 3-1/2 years. These restorations are serving far better than anticipated. *This report contains an update on the well-documented positive TRAC Research results.*

TRAC RESEARCH® Scanning electron microscope *(SEM)*, clinical, and laboratory examinations are showing ***equally excellent service for*** **BruxZir *and* e.maxCAD** milled full-contour crowns on molars at 41 months of service in a practice-based controlled clinical study. ***This service record exceeds that of over 100 other tooth-colored materials studied by TRAC over the past 39 years using the same methods.*** The superior performance of these two products has commanded our close attention. Literally millions of these two products have now been placed by U.S. dentists over the past five years—tipping dominance away from the time-honored PFM. Yet clinical research has lagged far behind clinical use, leaving important questions unanswered.

This report provides follow-up on the one-year data published in the June 2012 *Clinicians Report* to update clinicians as answers begin to develop to the following critical clinical questions.

Example Cases at 3+ Years



BruxZir full-zirconia | e.maxCAD lithium disilicate

Critical Clinical Questions and Answers Beginning to Develop after 3+ Years of Service

1. Does BruxZir zirconia severely wear opposing dentition?

NO, see chart below. Concern that zirconia would severely wear opposing dentition dictated our locating and measuring all facets on test crowns and all types of opposing dentition. Three-year data below show **BruxZir zirconia crowns caused 23% *less* wear of opposing dentition than the pressed ceramic-over-zirconia Control *(PressCeram by Swiss NF over zirconia by Metoxit)* and about the *same* wear as e.maxCAD lithium disilicate processed with an *experimental* 12.5-minute post-mill procedure. BruxZir *received more wear than it caused.***

Table 1: Percent area worn by the Test Crowns and the Opposing Dentition

Brands names of materials studied	% area worn by Test Crowns on Opposing Dentition			% area worn by Opposing Dentition on Test Crowns		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
BruxZir	5.5 ✱	10.3 ✱	12.8 ✱	8.2 ✱	14.5 ✱	29.6 ✱
e.maxCAD *(27 min. post-mill processing)*	6.7	10.8	17.9	4.6	7.3	11.1
e.maxCAD *(12.5 min. post-mill processing)*	4.7	7.9	11.3	6.1	9.4	13.4
Pressed ceramic-over-zirconia *(Control)*	10.9	14.2	16.6	8.2	11.1	16.4

✱ *Data apply only to BruxZir zirconia. Other zirconia formulations may perform differently.*

2. Does BruxZir zirconia lack of flexibility adversely affect the occlusal system?

Some people predicted tooth mobility, mastication muscle strain, and joint disfunction. None of the predicted problems have been noted to date in this study. If you have experienced any of these problems with BruxZir, please contact by email rella@tracresearch.org.

3. Do full-zirconia dental restorations undergo phase change in the 100% humidity of the oral cavity?

To date, phase change problems such as surface cratering and microcracks have not been noted by SEM, nor have particles released into soft tissues with resulting inflammatory changes been seen in this study. However, more time is needed to eliminate this question. In 2001, some zirconia hip joint implants showed these changes occurring within months to beyond five years of clinical use. BruxZir was released commercially in summer 2009, so these are critical years regarding this question. Other more recently released dental zirconias will require similar long-term monitoring.

4. If e.max lithium disilicate is performing so well, why consider use of BruxZir full-zirconia?

There are no data to indicate BruxZir and e.maxCAD could not serve equally well in all *single-unit* situations. Empirically, both dentists and lab technicians have preferred to take advantage of e.max lithium disilicate's beauty for anterior teeth and BruxZir's high strength for the following:

- When minimal tooth preparation can be used.
  This study shows BruxZir meeting its claims by serving well with less than 1.0 mm occlusal reduction and near-feather edge margins on molars, even in patients with bruxing/clenching habits. e.maxCAD was not tested with minimal reduction preparations because these claims were not made for this product.
- In areas that force shallow preps due to limited space.
- For labs, anytime the preps are too shallow to allow predictable positive clinical results with other materials.

BruxZir and e.maxCAD: Superior Clinical Performance at 3+ Years (continued from page 1)

4. If e.max lithium disilicate is performing so well, why consider use of BruxZir full-zirconia? (continued)

Table 2: BruxZir and e.maxCAD are the *antithesis of one another* in many characteristics.

Differences			Similarities
BruxZir		e.maxCAD	BOTH BruxZir and e.maxCAD
• Very high flexural strength *(1000+ MPa)*	V	• Lower flexural strength *(about 350 MPa)*	• Time consuming to remove, and removal risks prep gouging
• Adequate and improving esthetics	E	• Excellent esthetics	
• Minimal prep permissible	R	• Deeper prep preferable	• Glaze degrades at occlusal contacts, but the unglazed materials function well in occlusion
• Moderately worn by opposing dentition	S	• Moderately wears opposing dentition	
• Very long post-mill processing *(8.5 hours)*	U	• Shorter post-mill processing *(12.5 to 27 min)*	• Currently, more time consuming for labs to polish than to glaze
• Mills smoothly at margins	S	• Milling causes many small chips at margins	
• Cannot acid etch, can sandblast gently		• Acid etches well, must not sandblast	

5. Should BruxZir and e.maxCAD be final polished or glazed?

After only six months, it was evident the glazes would not last long. By three years, 54% of the glaze applied on occlusal surfaces in this study was no longer present *(31% removed by dentists for occlusal adjustment and 23% removed by use)*. Glaze is used because it is faster than polishing, leaves surfaces very smooth, and preserves characterization stains. However, the clinical degradation and resulting gross surface roughness negates all these points. Options are to improve the glazes or develop easy polishing techniques and internal characterization of blocks.

Figure 1: SEM documentation of glaze degradation over time for either BruxZir or e.maxCAD

A. Very smooth surface finish on glaze initially.
B. Glaze loss and roughening after only 6 months of service.
C. Severe glaze roughening and loss exposing underlying material at 3 years.
D. Magnification shows glaze roughness compared to underlying smooth material.

Critical Clinical Questions and Answers Beginning to Develop after 3+ Years of Service (continued)

6. What are the best instruments for occlusal adjustment?

February 2013 *Clinicians Report* gave detailed analyses of 16 products, naming **Luster** *(Meisinger)* and **OptraFine** *(Ivoclar Vivadent)* **as CR Choices.**

7. Is TRAC's experimental 12.5-min. post-mill processing procedure for e.max the same, better, or worse than the original 27-min. procedure?

The two procedures were statistically the same in 18 variables monitored, but crowns treated using the experimental 12.5 minute method showed numerically less wear of opposing dentition.

8. Does endo entry access compromise BruxZir and e.maxCAD restorations?

YES. October 2012 *Clinicians Report* gave detailed information on best instruments and techniques, and concluded with the necessity to ***use new diamonds, light pressure, and copious water coolant with 1mm or more of occlusal material thickness.***

Figure 2: Full-mouth restoration with BruxZir in a heavy bruxing male

9. What are the best products and techniques for removal of BruxZir and e.maxCAD crowns?

New fine-grit, round-ended taper diamonds used with water coolant, light touch, and frequent examination to avoid gouging underlying dentin works best. Additionally, Polaris Crown Cutting Wheel *(Pollard Dental Products)* is preferred by some clinicians, but requires attention during use to avoid unintended cutting.

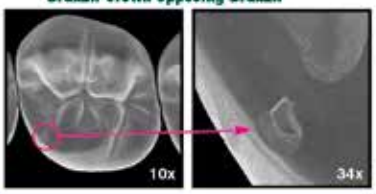
10. What is the best cementation technique for BruxZir and e.maxCAD?

See below and page 4. Steps and best products are different for zirconia vs. lithium disilicate.

11. Can zirconia have the translucency and colors available now with lithium disilicate?

Translucency and colors of zirconia are improving, but currently lithium disilicate is superior in these characteristics. However, BruxZir esthetics can be adequate *(see Figure 2, 30 full-crown BruxZir case at right)*.

Figure 3: Small, non-progressing chip in a BruxZir crown opposing BruxZir



12. What is the expected service life and failure mode of BruxZir and e.maxCAD?

No one knows. The first and only chip in this study occurred on BruxZir at one year and has not progressed *(see Figure 3 at right)*. More time is needed to answer this question. **Current exceptional service justifies hope for exceptional longevity.**

TRAC Conclusions:

BruxZir and **e.maxCAD** full-contour crowns on molars have demonstrated clinical service superior to all other tooth-colored materials studied clinically by TRAC over 39 years. To date, their service record resembles that of cast metal. Clinical service over three plus years has begun to answer many critical clinical questions, but important questions remain on possibility of phase change of zirconia in 100% humidity of the oral cavity, glaze use, service life, and failure mode. Status reports will be forthcoming as answers to these and other pertinent questions emerge through this study.

THE DENTAL ADVISOR
Improving Patient Care Through Research & Education

Research Report

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Number 59 – May 2014

Translucency of CAD/CAM Ceramics

Purpose: To measure the translucency parameter (TP) of CAD/CAM ceramics.

Methods:

Four unshaded zirconia ceramics [***BruxZir*** *(Glidewell Laboratories),* ***Lava Plus*** *(3M ESPE),* ***NexxZr T*** *(Sagemax)* and ***Zenostar Zr*** *(Ivoclar Vivadent, Inc.)*] were tested. The specimens (n=5) were square (12 mm x 12 mm ± 0.5 mm) with thicknesses of 0.5 and 1.0 mm ± 0.05 mm (parallel faces). The specimens were cut to approximate length and width dimensions using 1.5-inch diamond-cutting wheel. They were then sliced to a thickness 0.2 mm greater than required using a diamond saw. Based on previously determined shrinkage factors, the specimens were ground with 600-grit SiC paper to the thickness needed to attain final sintered dimensions. Each material was sintered using the heating and cooling profile recommended by the manufacturer.

Color measurements were performed using a *Color-Eye* spectrophotometer *(X-Rite)*. The translucency parameter (TP) was calculated as the difference in L*a*b* readings of specimens recorded against white and black backgrounds in reflectance mode. The differences between the reflection values against the two backgrounds were calculated at every 10 nm within the 360-750 nm range.

Means and standard deviations were determined. The data were analyzed by analysis of variance. Fisher's PLSD multiple comparison test was calculated at the 0.05 level of significance.

Results:

The translucency parameters for four zirconia ceramics at thicknesses of 0.5 and 1.0 mm are listed in the Table. Curves of the differences between the reflection values against the two backgrounds versus wavelength at thicknesses of 0.5 and 1.0 mm are shown in Figures 1 and 2, respectively.

Table. Translucency Parameter (TP) of four zirconia products at two thicknesses

Material	Thickness, mm	TP*
Lava Plus (3M ESPE)	0.5	10.3 (0.2)[a]
	1.0	7.1 (0.4)
NexxZr T (Sagemax)	0.5	10.3 (0.2)[a]
	1.0	7.6 (0.2)[bc]
BruxZir (Glidewell Laboratories)	0.5	10.7 (0.1)
	1.0	7.8 (0.1)[c]
Zenostar Zr (Ivoclar Vivadent)	0.5	10.3 (0.1)[a]
	1.0	7.4 (0.1)[b]

**Means with standard deviations in parentheses. Fisher's PLSD intervals at the 0.05 level of significance for comparisons of means among products and between thicknesses were 0.2 and 0.1, respectively.*

Figure 1: Differences (RD) between reflection values against white and black backgrounds at 0.5 mm thickness.

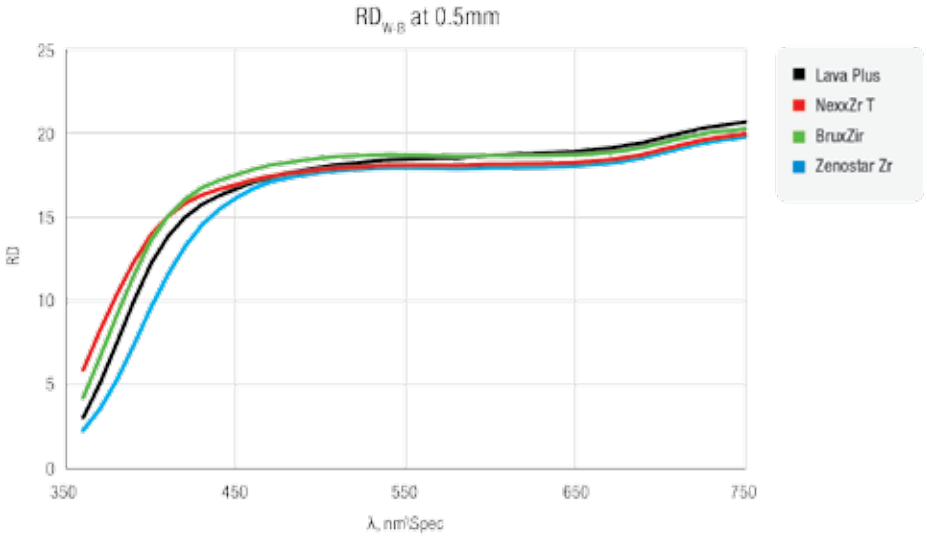
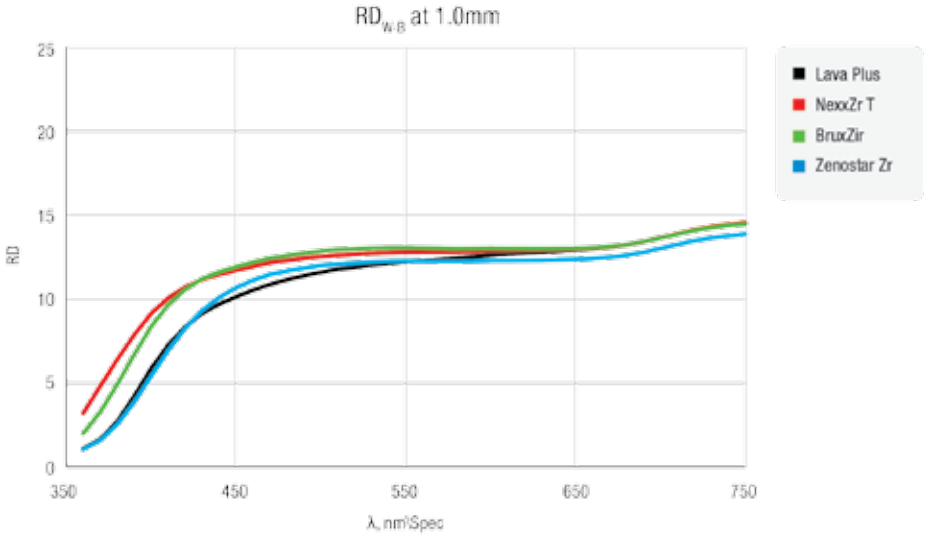


Figure 2: Differences (RD) between reflection values against white and black background at 1.0 mm thickness.

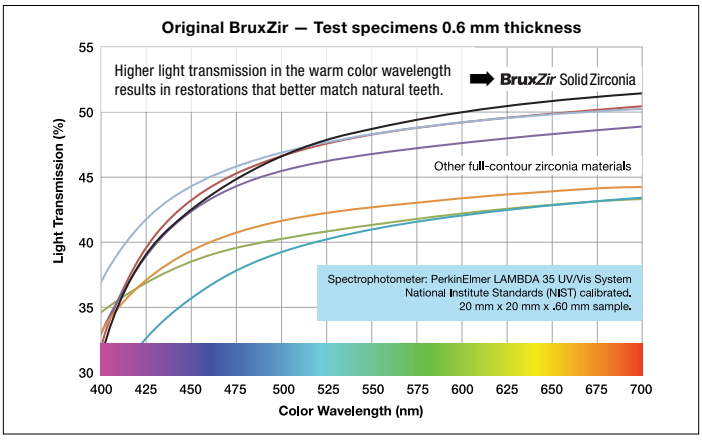


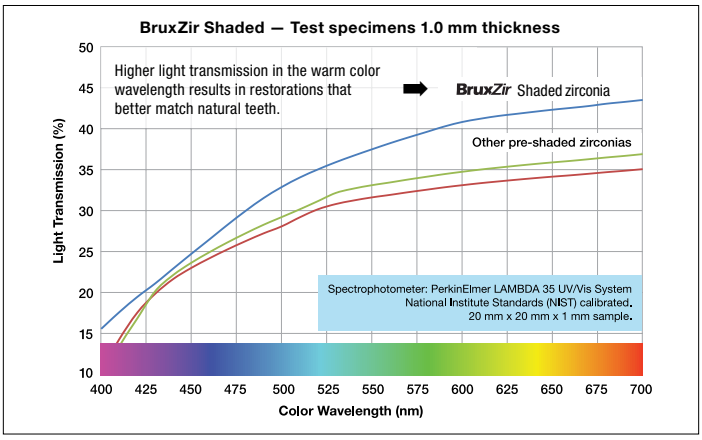
Conclusions:

Specimens of the zirconia products were more translucent at 0.5 mm thickness than at 1.0 mm thickness. At the 0.5 mm thickness, the translucency parameter ranged from 10.3 to 10.7, and ***BruxZir*** was significantly more translucent than the other three products. At the 1.0 mm thickness, the translucency parameter ranged from 7.1 to 7.8, and ***BruxZir*** was significantly more translucent than ***Zenostar Zr*** and ***Lava Plus***. Translucency parameter was a function of wavelength when measured between 360-750 nm in reflection.

Transmission vs. Wavelength Graph

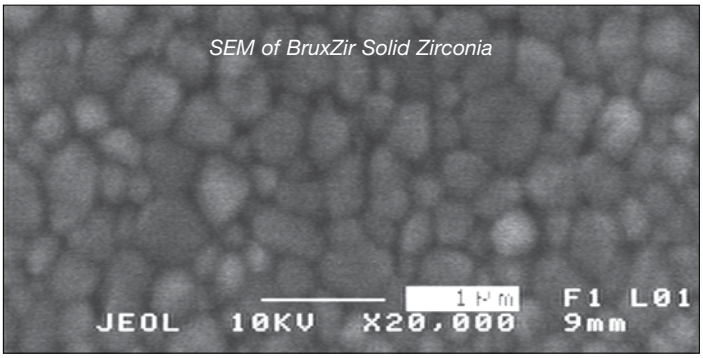
BruxZir exhibits higher light transmission resulting in a more natural shade value.

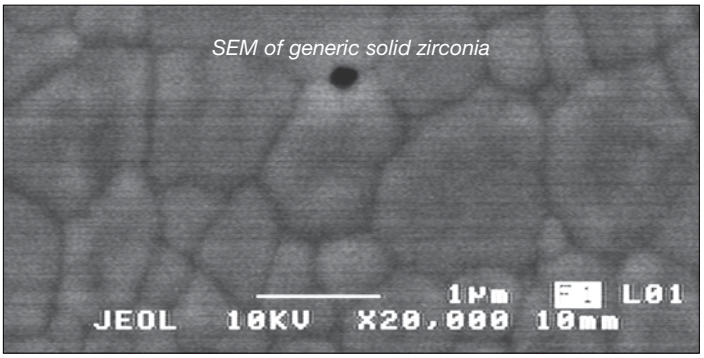




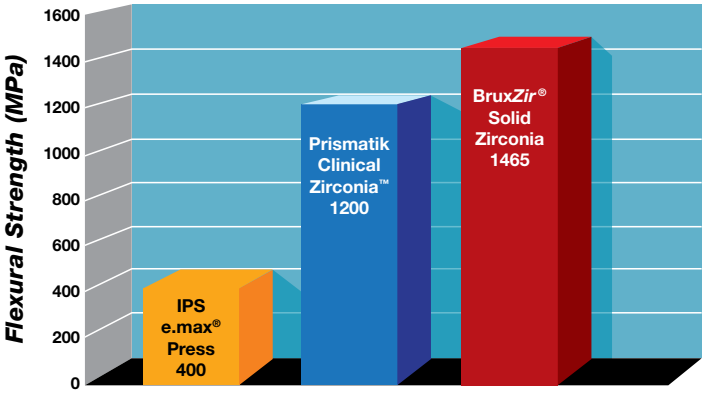
Scanning Electron Microscope Images

SEM of sintered, colloidally processed BruxZir Solid Zirconia vs. sintered, isostatically pressed zirconia



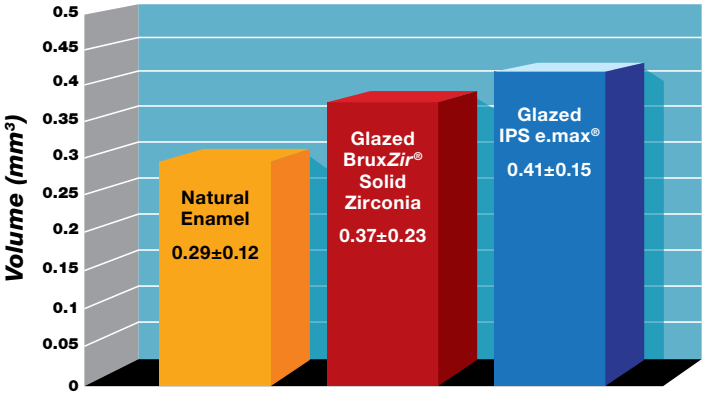


High Flexural Strength



Lithium disilicate ceramics have 400 MPa and typical zirconia materials have a flexural strength of more than 1200 MPa. However because of post-powder processing, BruxZir Solid Zirconia dental restorations are able to exceed that strength threshold, with flexural strengths up to 1465 MPa.

Antagonist Wear Study



The antagonistic (Steatite balls) wear shows BruxZir only with 72±21 micron, which is significantly lower than Ceramco 3, with 110±48 micron. The university of Tübingen study was run using an eight chamber Willytec Chewing Simulator at 1.2 million cycles.

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