Fracture Resistance of Zirconia FPDs with Adhesive Bonding Versus Conventional Cementation

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This study investigated the fracture resistance of three different zirconia fixed partial dentures (FPDs) with different cementation methods. Forty-eight three-unit FPDs were adhesively bonded (AB) or conventionally cemented (CC). Sixteen glass-infiltrated zirconia FPDs were used as a control. Fracture resistance was determined after aging. The zirconia systems showed no significant different fracture forces with the different bonding methods (CC: Cercon [1,231.5 ± 410.1 N], Ceramill [1,311.3 ± 318.3 N], Vita YZ [1,269.0 ± 317.4 N]; AB: Cercon [1,072.3 ± 516.7 N], Ceramill [1,358.6 ± 176.4 N], Vita YZ [1,270.6 ± 267.6N]) or between the different materials. The control group provided significantly lower fracture strength. Regarding fracture resistance, adhesive bonding or conventional cementation of zirconia FPDs showed no restrictions for posterior application. *Int J Prosthodont 2011;24:168–171.*

High-strength, partially stabilized zirconium dioxide polycrystal ceramics (zirconia), in combination with computer-aided manufacturing (CAM), allow for increasing the indication for all-ceramics to replace posterior teeth and to fabricate longer-span restorations.

Zirconia has a high fracture strength (> 700 MPa) with a small range of strength variation.[1] Glass-infiltrated zirconia, which is based on lanthanum glass-infiltrated zirconia-alumina crystals, shows lower strength values (200 to 400 MPa). In contrast to glass-ceramics (approximately 100 MPa), which need to be bonded adhesively to increase the strength of the restoration, zirconia crowns may be cemented conventionally.[2] Nevertheless, conventional cementation may be limited because of the obtuse preparation angle needed, which may be applied in the data digitizing process.

Clinical trials are the first choice for evaluating the use of new materials. However, the results of significant clinical investigations are often restricted by high investments and expenditure, sometimes combined with low outcomes resulting from a small number of subjects or high deviations of the results. Al-Amleh et al[3] reviewed the clinical performance of zirconia restorations. The relevance of cementation was underlined by the fact that loss of cementation was reported in 7 of 16 studies. In vitro fracture tests allow for predicting the combination of different material layers, but failure type and pattern may vary for clinically relevant restorations, especially with regard to individual design, dimension of the restoration, or the type and thickness of the cement. Nevertheless, in vitro simulations become more important for time-lapsed testing of new materials in advance. These tests combine reproducible laboratory conditions with basic requirements (occlusal force, thermocycling) of the clinical situation.

The aim of this investigation was to analyze the fracture performance of different zirconia three-unit FPDs after simulation of oral service. The hypothesis was that the type of cementation, whether adhesive bonding or conventional cementation, had no influence on fracture resistance.

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Table 1 Materials Used

Core	FPD type	Veneer
Ceramill, Amann-Girrbach	Zirconia	Zi-Creation, Willi Geller
Vita YZ Cube, Vita Zahnfabrik	Zirconia	Vita VM 9, Vita Zahnfabrik
Cercon Base, DeguDent	Zirconia	Cercon Ceram S, DeguDent
Vita zirconia, Vita Zahnfabrik (control)	Glass-infiltrated zirconia	Vita VM 7, Vita Zahnfabrik

FPD = fixed partial denture.

Table 2 Basic Firing and Time Schedules

Shade	Start temperature (°C)	Temperature increase (°C/min)	Final temperature (°C)	Holding time (min)
Zi-Creation				
Dentin	450	55	900	1
Glaze	480	45	810	1
Glaze powder	480	45	790	1
Vita VM 9				
Stain	500	80	880	1
Dentin	500	55	930	1 (V: 7.49)
Glaze powder	500	80	780	1
Cercon Ceram S				
Dentin	450	60	840	1 (V)
Glaze	450	60	810	1 (V)
Vita VM 7				
Base dentin	500	60	950	1 (V: 7.27)
Dentin	500	55	910	1 (V: 7.27)
Glaze	500	80	900	1

V = vacuum.

Materials and Methods

The roots of human molars were coated with a 1-mm-thick layer of polyether (Impregum, 3M ESPE) to simulate human periodontium. Loaded with 50 N, this layer allows a maximum tooth mobility of 0.1 mm in the axial and vertical directions. Two teeth were inserted into polymethyl methacrylate (Palapress Vario, Heraeus Kulzer), forming a molar gap (10 mm, mandibular left second molar) for restoration with an FPD. Human molars were used as abutments to ensure a relevant FPD-tooth bond during the simulation process. Human antagonists, which were adjusted to the FPD, simulated a clinical near contact and wear situation; thus, varying dimensions of teeth were accepted.

All abutment teeth (n = 128) were prepared according to the method for a ceramic restoration (1 mm circular shoulder, 4-degree taper, 4 to 5 mm high). Sixteen FPDs of each material (three zirconia FDPs, one glass-infiltrated zirconia FDP; n = 64) were fabricated according to the manufacturers' instructions (Table 1). Because of the individual teeth, the frameworks were not uniform. All anatomically formed frameworks were veneered with an approximately 1.0- to 1.5-mm-thick layer of corresponding ceramic, as recommended by the manufacturers (Table 2). The demand for a constant veneering thickness required the size of the substructure to be adapted (connector: 4-mm high, 3.5-mm thick). Finally, all FPDs were glazed superficially. Frameworks were veneered for testing the strength of the clinically relevant restoration, consisting of the framework and veneer.

For comparing the influence of cementation, eight FPDs of each group were adhesively bonded (dual curing composite; Variolink II primer/bonding system and Syntac classic, Ivoclar Vivadent) and eight FPDs were cemented conventionally (zinc oxide–phosphate cement; Harvard, Hoffman & Richter). Thermocycling and mechanical loading (TCML; EGO; parameters:

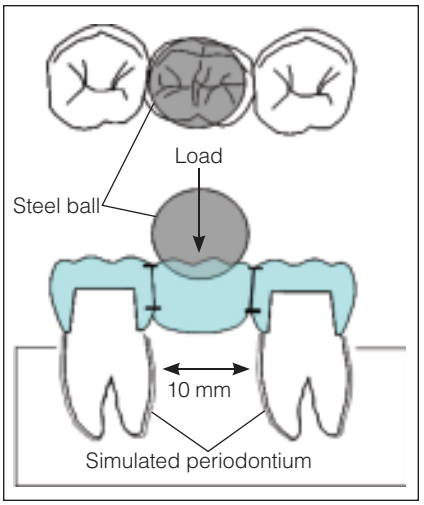

Fig 1 Design of the testing apparatus.

Table 3 Fracture Force (N)* and Number and Type of Failures After TCML

	Conventional cementation			Adhesive bonding		
Material	Median (25%/75%)	Mean (SD)	Failure (n)	Median (25%/75%)	Mean (SD)	Failure (n)
Ceramill	1,228.0[a] (1,028.8/1,639.8)	1,311.3 (318.3)	7v/1c	1,293.0[a] (1,237.8/1,556.5)	1,358.6 (176.4)	2v/6c
Vita zirconia	600.0[b] (500.0/686.0)	592.0 (133.7)	2v/6c	320.0[c] (268.0/355.0)	341.4 (111.8)	8c
Vita YZ	1,256.0[a] (908.0/1,599.0)	1,269.0 (317.4)	8c	1,194.5[a] (1,023.5/1,585.8)	1,270.6 (267.6)	8c
Cercon Base	1,140.5[a] (923.0/1,622.8)	1,231.5 (410.1)	3v/5c	1,227.0[a] (1,111.8/1,571.0)	1,072.3 (516.7)	3v/5c

SD = standard deviation; v = veneer; c = core.
*Different letters indicate significant differences (P = .05).

1,200,000 mechanical loads of 50 N and 6,000 thermocycles for 2 minutes with distilled water between 5°C and 55°C) were used for simulating 5 years of oral service.[4] During TCML, all FPDs were monitored.

After aging, all FPDs were loaded until fracture (testing machine, Zwick; velocity = 1 mm/min). The force was applied using a steel ball (12-mm diameter), which was positioned in the center of the pontic to ensure a three-point contact (Fig 1). This test setup guaranteed that the load was divided according to a parallelogram of forces: forces in the direction of the cusp (chipping) and the direction of the substructure (strength). A tin foil (1 mm) between the pontic and antagonist tooth was used to prevent force peaks. FPDs were examined optically before and after fracture testing. Failure mode was rated as fracture of the veneer or core. Medians and means were calculated for fracture resistance. The Mann-Whitney U test (α = .05) was used for statistical analysis of the data.

Results

No significant differences were found for fracture resistance between adhesively bonded and conventionally cemented zirconia FPDs (P > .674). Fracture resistance was not significantly different between the zirconia systems (.916 > P > .248). The glass-infiltrated zirconia control provided significantly lower fracture values compared to zirconia (P < .003). The glass-infiltrated zirconia also showed significantly different values between adhesive and conventional cementation methods (P = .005). In most FDPs, fracture occurred as a fracture of the core rather than chipping of the veneering ceramic (Table 3). The location of failure was dependent on the type of cementation only for Ceramill FPDs.

Discussion

Fracture force revealed no significant differences between adhesive bonding and conventional cementation. Conventional cementation provided no disadvantages with respect to fracture behavior, even under clinical conditions.[3,5,6] Although the results of this study are limited to the cements investigated, the tested systems represent typical and frequently applied materials. TCML (with clinically relevant occlusal forces and bath temperatures) was applied to age the specimens and is supposed to result in a performance approximated to the clinical situation. If no failure occurs during simulation, subsequent static fracture benchmark tests, which provide worst-case scenarios, can locate initiated weak points or at least compare the tested materials to clinically well-known systems. During TCML, occlusal loading caused local wear and disruption in the contact points. This local weakening of the veneering ceramic seemed to be the origin of fractures that occured during loading. Glazing after occlusal adjustment or regular polishing during clinical application[7] may reduce the chipping phenomena.

Investigating the effect of different bonding techniques (adhesive or conventional) requires human abutment teeth, therefore accepting the influence of the individual FPD design (connector, veneer) and dimension of preparation (taper, height) on fracture force and pattern. Because of the fracture location, different fracture patterns between adhesive and conventional cementation methods might be attributed to differences in the quality of the veneer, the veneering process, or at least the different compressibility and stability of the cements. However, these in vitro tests only demonstrate a very simplified, time-lapsed simulation of the clinical situation. Therefore, the results may vary in comparison to the clinical situation (eg, the use of extracted teeth or optimized conditions for reparation, fabrication, and bonding).

Conclusions

Adhesive bonding, as required for low-strength ceramic systems, is not necessary for high-strength zirconia. Zirconia, therefore, may allow easier application, even under subgingival or wet conditions. All systems tested showed good to sufficient fracture resistance and no influence from the type of cementation on fracture resistance.

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Literature Abstract

A prospective randomized clinical study of changes in soft tissue position following immediate and delayed implant placement

This study compared the soft tissue position outcome in immediate and delayed implant placement protocols. Twenty-four patients with 26 implant sites were involved in this study. The apicocoronal changes at the midbuccal and proximal mucosal positions at implant sites from the time of tooth extraction to 3 and 6 months following extraction were studied. The implant sites were either treated immediately with endosseous implants after extraction or allowed 3 months of postextraction and post–socket preservation healing prior to implant placement. Soft tissue was measured vertically and buccolingually. The results were compared between immediate versus delayed implant placement and thin versus thick gingival biotype. The results indicated that there were no significant differences in tissue measurement between tissue biotypes (thick vs thin) and time of implant placement (immediate vs delayed). However, there are some issues with this study that limited the usefulness of its clinical implications. The loading protocol was not mentioned. Readers may therefore assume that there was no prosthetic rehabilitation throughout the entire study period. Also, the overall study period of 6 months is short with respect to tissue healing and functional longevity expectations of osseointegrated implants.

van Kesteren CJ, Schoolfield J, West J, Oates T. *Int J Oral Maxillofac Implants* 2010;25:562–570. **References:** 34. **Reprints:** Dr Thomas Oates, Department of Periodontics, UTHSCSA, 7703 Floyd Curl Drive, San Antonio, TX 78229-3900. Email: oates@uthscsa.edu—*Ansgar C. Cheng, Singapore*