Evaluation of Some Material Properties of Cercon Fixed Partial Dentures

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Abstract: Purpose: Metal-ceramic fixed partial dentures (FPDs) are limited in actual application due to the aesthetic appearance; in fact, they do not satisfy the current market demands for increased aesthetics. In contrast, new ceramics, such as Cercon®, meet these market needs for FPDs. The use of Cercon FPDs has increased substantially to avoid the aesthetics problem associated with metal-ceramic restorations. **Methods:** The present study was designed to evaluate a new generation of zircon-ceramic material (i.e., Cercon®) recommended for three- and four-unit FPDs. More specifically, marginal accuracy, fracture strength, and the nature of interaction between the resin cement and the zirconia core material were investigated. **Results:** The results revealed no significant difference in the marginal gap between the premolar and molar in the case of three- and four-unit FPD. However, a significant difference was observed in the interaction of the gap distance between the molars in three- and four-unit FPDs. Moreover, the fracture strength was increased by sandblasting the Cercon® material. **Conclusions:** In this in-vitro study, we concluded that Cercon FPDs can be easily milled with marginal accuracy and sandblasting the Cercon FPDs increase the fracture strength than treating the material with phosphoric acid.

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1. Introduction

Currently, the interest in computer-aided design (CAD)/computer-aided manufacturing (CAM) systems in dentistry is growing because these systems can decrease the costs associated with manpower and labor-intensive laboratory processes related to the traditional means of producing dental restorations. Also, these systems are used today in the processing of high-strength ceramics, such as zirconia or alumina. The intrinsic advantages of this technology for dental restorations include the ability to produce a precise fit and customized design, simple handling characteristics, and time saving production processes. In addition, the CAD/CAM components are extremely homogenous and biocompatible.[1]

Metal restorations can cause gingival discoloration, and the surrounding soft tissue may have an unnatural appearance; therefore, demands for dental restorations that offer a better aesthetic appearance and fear among the public concerning alleged adverse effects of dental metals and alloys have increased demand for aesthetically improved and biocompatible materials. As such, ceramic restorations are preferred due to their biocompatibility and aesthetics. Multiple clinical studies on the use of all-ceramic crowns and resin bonded FPDs have been documented. The use of a strong durable resin bonded to all-ceramic FPDs provides high retention.[2-6] Restoration provides good marginal adaptation, prevents microleakage, and increases the fracture resistance of the restored tooth. Giordano[7] concluded that the successful use of an all-ceramic material is dependent on clinical conditions, and low stress areas could successfully use restorations made of low strength castable materials such as In-Ceram Spinell or Empress 2. High stress areas require restorations made of In-Ceram alumina and In-Ceram zirconia.

Indeed, the advent of zirconia ceramics used in conjunction with computer technology has been a boon for dental science and the dental industry. This specific "zirconia dream" could be defined as "the general clinical application of a highly biocompatible zirconia ceramic material that is resistant on a long-term basis to all thermal, chemical, and mechanical impacts of the oral environment in a wide range of dental restorations." [8]

Currently, yttrium oxide partially stabilized zirconia (Y-PSZ) is of special interest due to its superior mechanical properties as compared to other dental ceramics. Zirconia (ZrO_2) is a ceramic material with adequate mechanical properties for manufactured medical devices. Zirconia is a crystalline dioxide of zirconium. Its mechanical properties are very similar to those of metals, but its color is similar to that of a healthy tooth. Yttrium oxide is added to zirconia as a phase stabilizer to maintain the high temperature tetragonal phase (t), thereby reducing spontaneous transformations into the monoclinic phase (m) at room temperature. The spontaneous transformation of t into m is known as "aging," and the t→m transformation is believed to cause the degradation of mechanical properties of the material. [9,10] Therefore, the addition of this material has improved the optical and mechanical properties of the ceramic and has created differences in the microstructure and mechanical properties of the resulting ceramic due to the reduction of the undesirable transformations (i.e., from the tetragonal to the monoclinic phase), thereby protecting against flaw propagation and fractures under a load.[9, 10]

Some physical properties of zirconia must be considered. Indeed, in addition to the inherent color that is similar to teeth, the material is also opaque.[11] This can be advantageous for the technician; i.e., when a dyschromic tooth or a metal post must be covered, a zirconia core can be used to conceal this undesirable aspect. Also, this material is very useful when monitoring the marginal adaptation through radiographic evaluation.[12]

An *in vitro* evaluation confirmed that zirconium oxide is not cytotoxic. [13, 14] No allergic reactions to ZrO_2 are expected, making it an ideal option for patients who suffer from a metal allergy. Moreover, there is no danger of corrosion, and this material is a very poor chemical and electrical conductor and withstands changes in temperature. Additionally, restorations made of all-ceramic material are suitable for restorations in the anterior and posterior regions.[13, 14] The use of ceramic restorations to restore missing posterior teeth is certainly desired by all practitioners. Zirconium oxide is the material of choice and will resist forces beyond that of typical mastication.[15]

Koutayas *et al.*[16] and McLaren[17] evaluated the influence of the design and the mode of loading on the fracture strength of all-ceramic FPDs bonded with resin cement and concluded that a dynamic load significantly affected the fracture strength due to microleakage at the interface between the restoration and the cement. Rosentritt *et al.*[18] evaluated the fracture strength of different all-ceramic FPDs and concluded that zirconium oxide ceramic showed the highest fracture strength value as compared to that of In-Ceram and Empress 2 fixed restorations.

The geometrical design of long span FPDs and the difficulties associated with the milling process of brittle ceramic materials contribute to significant differences in the marginal discrepancies of these restorations. Yet, the level of marginal fit in alumina and zirconia FPDs created with the direct ceramic system meet clinical requirements. Tinschert *et al.*[19] and Hauptmann and Reusch[20] revealed that the glass ceramic for posterior three-unit FPDs should have a connector cross section of 16 mm^2 at minimum. Interestingly, zirconia overcomes these limiting factors, they also concluded that posterior FPDs made of zirconium oxide with a cross section of 9/12/9 mm^2 at the connector areas can be used for FPDs while still providing sufficient mechanical properties. Luthy *et al.*[21] concluded that zirconia stabilized with yttria in 3 mol% frameworks demonstrated high load leaving capacities. In four-unit posterior FPDs, the framework required a connector size that was greater than 7.3 mm^2.

White *et al.*[22] found that zirconia offers many advantages when compared to existing core materials. The performance of layered zirconia had not been previously evaluated. A significant difference in leakage was found between all-ceramic groups cemented with different luting agents. The least amount of leakage was found in groups cemented with adhesive resin composites, followed by compomer cement. The highest amount of leakage was found in groups cemented with zinc phosphate cement. Ultimately, adhesive composite luting cement demonstrated acceptable clinically marginal discrepancies.[23]

The margins in the Cercon system were also satisfactory for clinical use. The dimensional stability of Cercon was maintained during the firing and glazing of the porcelain.[24] Scanning Electron Microscopy (SEM) and infrared spectrophotometry of the ceramic surface treated with silicate, aluminum oxide, and zirconium oxide ceramics revealed a good bond to the luting composite.[25] Chepman *et al.*[26] evaluated the flexural strength of high temperature ceramics after restoration and concluded that the flexural strength is not affected by sandblasting.

The heat treatment of the zirconia core reduced the flexural strength of the core after the first firing, but the untreated specimens showed a statistically significant higher flexural strength and no significant surface roughness.[27] The cyclic fatigue behavior of zirconia in water makes it an appropriate material for the fabrication of all-ceramic, multi-unit posterior FPDs.[28] Moreover, zirconia based ceramics possessed significantly higher flexural strength than lithium disilicate ceramics.

The failure loads of different zirconia based, all-ceramic FPDs were evaluated before and after artificial aging.[29] Forty-eight zirconia frameworks for three-unit FPDs were fabricated using three different manufacturing all-ceramic systems. No significant differences were found in comparisons between the groups before artificial aging; indeed, all tested restorations have the potential to withstand occlusal forces that are applied in the posterior region and could be an alternative to metal-ceramic restorations.[29] Oh and Gotzen.[30] stated that the fracture of ceramic FPDs tend to occur in the connector areas because these stress concentration fractures of all-ceramic restorations are initiated at the center of the gingival embrasure toward the occlusal loading on the pontic. Since this issue is very important, the aim of our study was to evaluate some properties of CAD/CAM Cercon FPDs (i.e., the marginal discrepancy, fracture strength, and the interaction between the resin cement and the zirconia core material).

2. Materials and Methods:

A copper metallic master model was designed for three- and four-unit posterior FPDs. The diameter of the abutment was 7.0 mm or 11.0 mm corresponding to the premolar or the molar, respectively. The preparation of the abutment included designing an axial surface that had a taper of 7 degrees, and the abutment periphery was designed as a round shoulder finishing line that was 1mm in thickness. An edentulous area of 8mm simulated three-unit FPDs, while an edentulous area of 17mm simulated four-unit FPDs. The occlusal surface was designed as a flat surface. All connectors were fabricated with a gingival curvature of 0.45 mm to standardize the influence of the connector design on the fracture strength of the Cercon FPDs.

The metallic master model for the posterior FPD abutment was duplicated with additional silicone rubber material (Rapid, Coltene AG, Altstatten, Switzerland) to make a working cast made of hard stone (Dentstone KD plaster All Packing company, UAS) for the CAD/CAM system to follow for the computerized design of the framework. A Cercon machine (Degudent GmbH, Hanau-Wolfgang Dentsply International Co., Germany) was used to fabricate Cercon FPDs. It consisted of Cercon art software and a scanner in the Cercon brain unit used for milling Cercon FPDs (Figures 1a, b, c).

The Cercon heat unit is a sintering furnace. Cercon recommends a sinter temperature of 1350^{0}C for 6 hours. A pre-sintered Cercon base with of length of 30 mm and 38 mm length were used for three-unit and four-unit FPDs, respectively. The scanning and milling Cercon procedure takes about 50 or 65 minutes for three- and four- unit FPDs, respectively. The Cercon base is secured in the milling frames, and the milled framework of the FPDs is about 30% larger than the final restoration to compensate for sintering. Sintering is required to achieve maximum strength for the presented blocks.

Figure (1 a, b, c): Cercon machine

Measuring of marginal accuracy

Twelve frameworks were prepared for each FPD design (i.e., three- and four-unit FPDs). The sintered frameworks were checked on each die to see that it fit at the margin (Fit checker, GC, Tokyo, Japan) in order to achieve the best possible fit. A stereomicroscope (Olympus Zoom Stereo Microscope, Japan, Model NO. 521145 TRPT) was used to measure the marginal gap at the premolar and molar for three- and four-unit FPDs.

Measuring of fracture resistance

A total of twenty Cercon frameworks were divided into two groups. Group I was three-unit FPDs, and group II was four-unit FPDs. Then groups I and II were subdivided into subgroups (i.e., group I subgroups a and b and group II subgroups c and d). Group I subgroup a and group II subgroup c were treated with 37% phosphoric acid for 2 minutes, while group I subgroup b and group II subgroup d were sandblasted with 50-micron aluminum oxide. After the surface treatment step, all groups were then covered with Cercon ceram. To the test model, the frameworks were cemented with resin cement Panavia F (Kurary Co, U made, Kita Ku Osaka 530, TaPan). Then, the castings were embedded in epoxy resin blocks (Kemapoxy 165, Egypt).

The fracture strength was measured using a universal testing machine (Comenten Industries, Inc., St. Petersburg, Florida, USA). The load was applied in the middle of the pontic or connector area of the three- and four-unit FPDs at a cross head speed of 5 mm/sec for all groups until fracture. The results were collected for all groups, and readings were taken at the peak value.

Analysis of Interfaces

The interaction between the Cercon core and the resin cement was studied using infrared spectroscopy (Bruker Vector spectrophotometer, Biodirect, Taunton, MA). Samples of the Cercon core, the resin cement, and the Cercon core with resin cement were ground into fine particle powders. Each powder was mixed with 2% potassium bromide using a hydraulic press to from a disk from each sample. The samples were analyzed using infrared spectroscopy to obtain absorbance bands between 4000 cm^{-1} and 400 cm^{-1}. The results were recorded photographically to study the nature of the interface.

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS/ version 17) software. More specifically, the means, standard deviations, and standard errors of means were determined. Comparisons between groups were done using the Student t-test value of significance at 5 percent.

3.Results

The mean marginal gap for milled ceramic three-unit FPDs with the master die at the premolar and the molar region was 58.50 ± 2.0 and 58.76 ± 3.41 microns, respectively. In contrast, the mean value for the four-unit FPD at the premolar and molar region was 65.24 ± 5.40 and 68.34 ± 4.52 microns, respectively, which was not significantly different as shown in Table 1.

Table 1: Mean marginal gap (microns) for the three-unit and four-unit milled ceramic FPDs

FPD units	Mean ± SD	SEM	*p*
Three-Unit			
Premolar	58.50 ± 2.0	0.89	0.887
Molar	58.76 ± 3.41	1.53	
Four-Unit			
Premolar	65.24 ± 5.40	2.41	0.354
Molar	68.34 ± 4.52	2.02	

p = *p* value for Student t-test

A comparison of the premolars in the milled ceramic three- and four-unit FPDs showed no significant changes between the two, while a comparison of the molar region in three- and four-unit FPDs showed a statistically significant difference at the 5% level (i.e., $p = 0.002$) as shown in Table 2.

Table 2: Mean marginal gap (microns) of the premolar and molar in milled ceramic FPDs

FPD units	Mean ± SD	SEM	*p*
Premolar			
Three-Unit	58.76 ± 3.41	1.53	0.053
Four-Unit	65.24 ± 5.40	2.41	
Molar			
Three-Unit	58.50 ± 2.0	0.89	0.002*
Four-Unit	68.34 ± 4.52	2.02	

p = *p* value for Student t-test
*: Statistically significant at $p \leq 0.05$

The mean fracture strength for the three-unit FPDs in group I (a) and the four-unit FPDs in group II (c) (i.e., dentures treated with 37% phosphoric acid) was 1977.60±5.32N and 1175.80 ± 5.81N, respectively. A comparison of these groups revealed a statistically significant difference at the 5% level (i.e., $p = 0.001$). A comparison between group I (b) and group II (d) (i.e., dentures sandblasted with 50 micron aluminum oxide) showed no statistically significant differences (Table 3)

Table 3: The mean and standard deviation of the fracture load in Newtons (N) for milled ceramic three- and four-unit FPDS

Phosphoric acid treatment	Mean ± SD		SEM	*p*
3-unit	Group I (a)	1977.60±5.32	2.38	<0.001*
4-unit	Group II (c)	1175.80 ± 5.81	2.60	
Sandblasting treatment				
3-unit	Group I (b)	2295.80±4.97	2.22	0.059
4-unit	Group II (d)	1289.34±3.01	1.35	

p = *p* value for the Student t-test *: Statistically significant at $p \leq 0.05$

A comparison of the fracture strength in three-unit FPDs treated with phosphoric acid and sandblasting showed a significant difference (*P*=0.001). Also, significant changes were observed between group II (c) and (d) (*P*= 0.001) as shown in Table 4 .

Table 4: Comparison between the fracture load (N) of FPDs treated with phosphoric acid versus those treated with sandblasting

No. of units	Groups	Mean ± SD	SEM	*p*
3-unit	Group I (a)	1977.60±5.32	2.38	<0.001*
	Group I (b)	2295.80±4.97	2.22	
4-unit	Group II (c)	1175.80 ± 5.81	2.60	<0.001*
	Group II (d)	1289.34±3.01	1.35	

p = *p* value for the Student t-test *: Statistically significant at $p \leq 0.05$

Infrared Spectroscopy

Infrared spectroscopy was done to study the interaction of Cercon with Panavia cement and Cercon with veneer. The results were recorded photographically and shown in Figures 6, 7, and 8.

The infrared spectrum revealed the disappearance of some bands, minor shifts in some with increasing intensity bands, and minor shifts in others. Only a minor percentage appeared in the range of 1088cm^{-1} and 1014cm^{-1}.

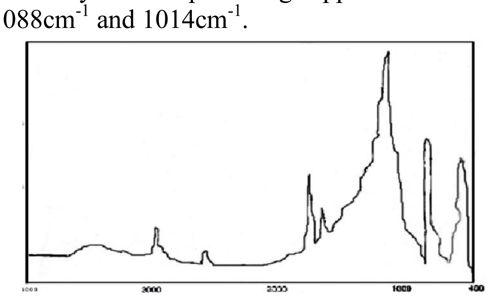

Figure 6: Infrared spectrum of the Cercon framework

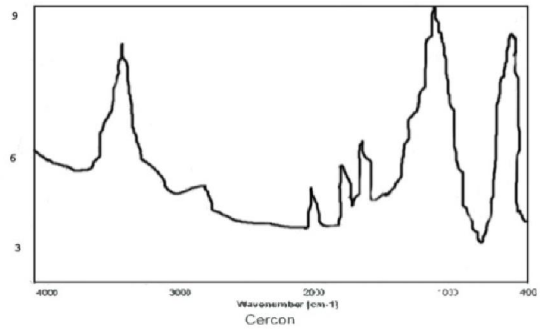

Figure 7: Infrared spectrum of the Panavia cement

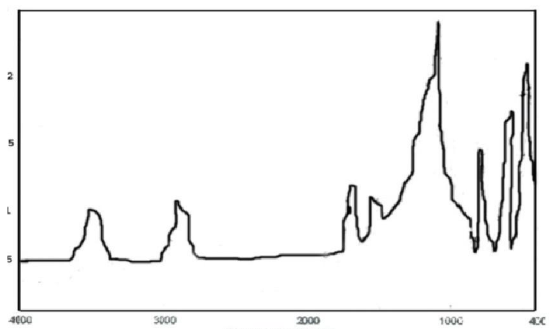

Figure 8: Infrared spectrum of the Cercon and cement

4. Discussion

In recent years, the clinical use of all-ceramic crowns has increased due to their excellent qualities in terms of aesthetics and biocompatibility. The success of all-ceramic crowns has led to the use of three- and four- unit all-ceramic FPDs. Advances in CAD/CAM systems have allowed dentists to use 3 vol% yttrium stabilized tetragonal zirconia polycrystals (Y-TZP). In our study, yttrium oxide was added to pure zirconia as a stabilizer and to form a new material known as Y-PSZ, which is sufficiently hard to be used in the molar region.[31] This material has improved optical and mechanical properties and differences in its microstructure and mechanical properties due to the reduction of undesirable transformations (i.e., from the tetragonal to the monoclinic phase), thereby protecting against flaw propagation.[32] Also, Y-PSZ has a polycrystalline microstructure that resists crack propagation. For the construction of Cercon fixed partial dentures, a wax pattern constructed by laser beam amplified the size by about 30% to compensate for the shrinkage from sintering. The Cercon block was partially sintered to facilitate a faster milling process. Then, the block was sintered after milling to increase the strength properties.[32, 33]

The results of this study revealed that the differences in fracture load was significant between three- and four-unit FPDs treated with phosphoric acid, but no significant changes were observed in three- and four-unit FPDs that were sandblasted. The increase in the fracture load in the case of sandblasting the Cercon core may be caused by the increase in the surface area of the Cercon core. More specifically, the increased surface area may permit a more intimate contact between The Cercon core and the Cercon crown. These results are in agreement with the results of Champman *et al.*[26] who evaluated the fracture resistance of Y-TZP FPDs under static load and found that failures under loads for all-ceramic FPDs typically were initiated at the gingival embrasure. Therefore, the radius at the gingival embrasure must be increased and standardized in all specimens.[30] Also, he found that the crown margin; shoulder or chamfer, types of cement, cement thickness, direction of load, and magnitude of load affect the stress distribution within the luting cement.[26] Stress at the margins was higher than in the shoulder margins. The cement film thickness minimally affected the magnitude of stress as well as the stress distribution.

Infrared spectroscopy showed the appearance of new bands, the disappearance of other bands, and the minor shifting of yet other bands. Infrared spectroscopy was also done for Panavia cement and Cercon to assess the chemical reaction of resin cement with the silica oxide with the band appearing at 1041cm. However, silica is a minor component of the ceramic (i.e., the Cercon framework), and the results indicated that the bond between the resin cement and the Cercon is mainly mechanical. Infrared spectroscopy of the resin cement and Cercon showed a minor shift in some bands, which indicates a minor chemical reaction between them. The bond strength is mainly from mechanical interlocking; i.e., the resin cement flows into the surface irregularities of core ceramic material. This clarifies the importance of sand blasting the Cercon core before cementing.

5.Conclusions:

From the previous results, we concluded the following:

- Cercon FPDs can easily be milled with a high degree of marginal accuracy.
- Sandblasting the Cercon core increases the fracture strength better than treating the surface with 37% phosphoric acid.
- The bond between the Cercon core and the resin cement is mainly due to mechanical interlocking.

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