Flexural strengths of implant-supported zirconia based bridges in posterior regions

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PURPOSE. Impact forces in implant supported FDP (fixed dental prosthesis) are higher than that of tooth supported FDPs and the compositions used in frameworks also has a paramount role for biomechanical reasons. The aim of this study was to evaluate the flexural strength of two different zirconia frameworks. **MATERIALS AND METHODS.** Two implant abutments with 3.8 mm and 4.5 mm platform were used as premolar and molar. They were mounted vertically in an acrylic resin block. A model with steel retainers and removable abutments was fabricated by milling machine; and 10 FDP frameworks were fabricated for each Biodenta and Cercon systems. All samples were thermo-cycled for 2000 times in 5-55˚C temperature and embedded in 37˚C artificial saliva for one week. The flexural test was done by a rod with 2 mm ending diameter which was applied to the multi-electromechanical machine. The force was inserted until observing fracture. The collected data were analyzed with SPSS software ver.15, using Weibull modulus and independent t-test with the level of significance at α=.05. **RESULTS.** The mean load bearing capacity values were higher in Biodenta but with no significant differences (P>.05). The Biodenta frameworks showed higher load bearing capacity (F_0=1700) than Cercon frameworks (F_0=1520) but the reliability (m) was higher in Cercon (m=7.5). **CONCLUSION.** There was no significant difference between flexural strengths of both zirconia based framework systems; and both Biodenta and Cercon systems are capable to withstand biting force (even parafunctions) in posterior implant-supported bridges with no significant differences. ***[J Adv Prosthodont 2014;6:346-50]***

KEY WORDS: Implant-supported prosthesis; Zirconia; Flexural strength; Weibull modulus

INTRODUCTION

Porcelain fused to metal (PFM) has become a conventional technique and a gold standard in fixed dental prosthesis (FDP).[1,2] As the request for esthetic increases every day and the biocompatibility of some metals and alloys seem to be questionable, the restorative treatment plans were changed.[3] Yttrium oxide partially stabilized tetragonal zirconia polycrystalline (Y-TZP) has been invented as a core in full ceramic restorations by using CAD/CAM technique. Y-TZP has superior mechanical properties than other ceramic systems due to their flexural strength (900-1200 MPa) and fracture toughness (9-10 MPa·m$^{1/2}$).[4-6]

The contemporary materials and techniques have introduced important solutions toward many problems in fixed prosthodontics in combination of esthetic qualities of porcelain with high strength, accuracy, and marginal adaptation

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of frameworks.[7]

One clinical study reported the failure rate of metal-ceramic FDP was 4% after 5 years, 12% after 10 years and 32% after 15 years.[8] Some factors which are important in terms of success or failure of metal-ceramic FDP include: improper support of ceramic veneer, inappropriate design of framework, thickness of ceramic layer in contact areas of connectors, direction, magnitude and frequency of forces.[9]

As mentioned before, metal-ceramic restoration is widely used but they cannot provide the transparency and translucency patterns of teeth.[10-12] Full ceramic restorations have modified aesthetic, biocompatibility, color stability, resistance to abrasion and lower thermal conductivity.[12-15]

Implant-supported prosthesis is a great treatment option for patients with lost teeth. Since impact forces in implant supported FDP are higher than that of tooth supported FDPs, different result is logical.[16]

The compositions used in framework fabrication have been stated to be very important for biomechanical reasons. When loads are subjected on the superstructure, stresses are transferred to the bone-implant interface, implant and prosthetic components and might affect the survival of the restoration.[17]

In a study, Sailer *et al.*[18] claimed that success rate of zirconia frameworks was 100% but it reduced to 84.8% due to technical and clinical problems such as secondary caries and marginal adaptation.

Okabayashi *et al.*[19] conveyed a study to find out the relationship between fracture loads and supportive designs of proximal region in zirconia framework. The result showed that supportive design affected the fracture load.

In another study, Bacchi *et al.*[20] claimed that zirconia and retention form caused significant decrease in the framework deformation. Also, framework materials showed relevant influence on the stresses distribution, so the aim of this study was to evaluate the flexural strength between two different zirconia frameworks with different compositions (Cercon and Biodenta) in implant supported FDPs.

MATERIALS AND METHODS

In this *in vitro* observational-experimental study two implant abutments (XiVE, Dentsply, Friadent GmbH, Mannheim, Germany) with 3.8 mm and 4.5 mm platform were used as premolar and molar. They were mounted vertically in an autopolymerized acrylic resin block (Meliodent, Heraeus Kulzer GmbH, Hanau, Germany) with 18 mm distance by using a surveyor (Ney Surveyor, Dentsply, York, PA, USA). So the entire model was scanned (Breuckmann GmbH, Meersburg, Germany) and the parameters were determined for CAD/CAM machine then steel retainers with removable abutments were manufactured by milling machine (Arico GmbH, Dietzenbach, Germany). So 10 FDP frameworks were fabricated for each Biodenta (Biodenta Swiss AG, Bernek, Switzerland) and Cercon systems (Degudent, Hanau, Germany)(a total of 20 frameworks). After designing and fabricating Cercon samples, one of them was chosen as a model for fabricating Biodenta spices and sent to Biodenta Company for confirming its adaptation and similarity. Then the frameworks were sintered to make the eligible size with 9 mm^2 cross-section areas in connectors. All samples were thermo-cycled for 2,000 cycles in 5-55ºC temperature and embedded in 37ºC artificial saliva (Bio-x Healthcare, Les Isnes, Belgium) for one week.

In the next step, the samples were fitted with the abutments without any cementation and a Teflon disk with 5 mm diameter and 2 mm height were placed on the bridge to protect framework and equivalent the loading force. The flexural strength test was done by a rod with 2 mm ending diameter which was applied to the multi-electromechanical machine (Type LFM-L, Waler+Bai, AG, Lohningen, Switzerland)(Fig. 1). The force was inserted exactly in the middle of the frameworks with were measured by a digital coulis and it was continued until observing fracture. The collected data were analyzed with SPSS software ver.15 using Weibull and independent t-test with the level of significance at 0.05. The Weibull parameters, characteristic force at failure (F_0) and the Weibull modulus (m) were determined for each sample. F_0 is load bearing capacity for the samples with probability of 63.2% failure. The modulus (m) is an indication of the force scattering at failure, also reliability of the examined material.[21-24]

RESULTS

The analyzed data are shown in graphs and a table. As Fig. 2 shows, the load bearing capacity values were higher in Biodenta system in comparison with Cercon system but no significant differences were observed (P=.47). Also the lines in the top and bottom of the graph show the highest and lowest values.

Table 1 and Fig. 3 represent reliability (m) and load baring capacity values (F_0). The Biodenta frameworks showed higher load bearing capacity (F_0=1700 N) than Cercon

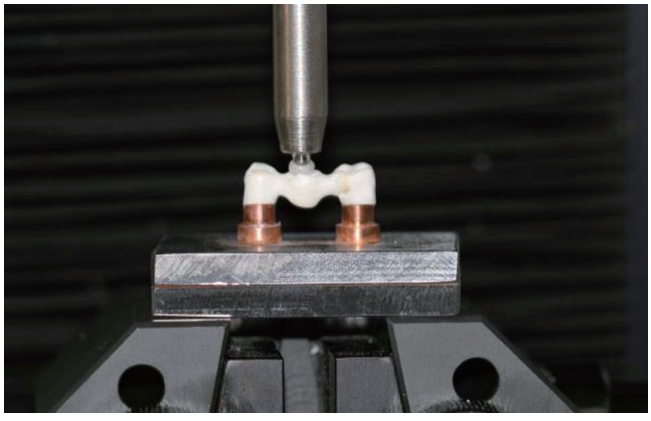

Fig. 1. One sample ready for force insertion.

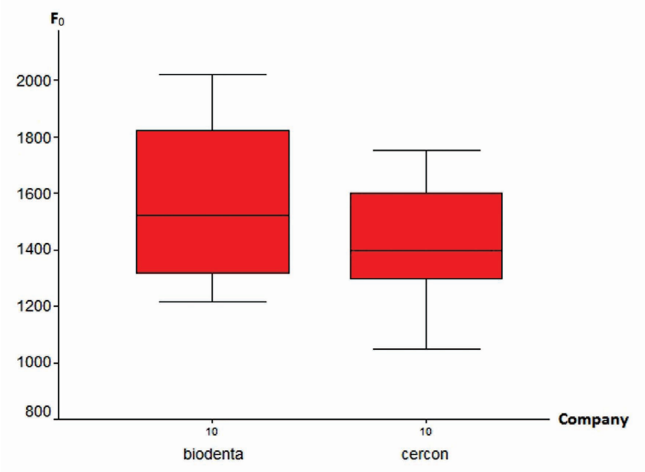

Fig. 2. The mean load bearing capacity values (F_0)(N) of frameworks in both systems.

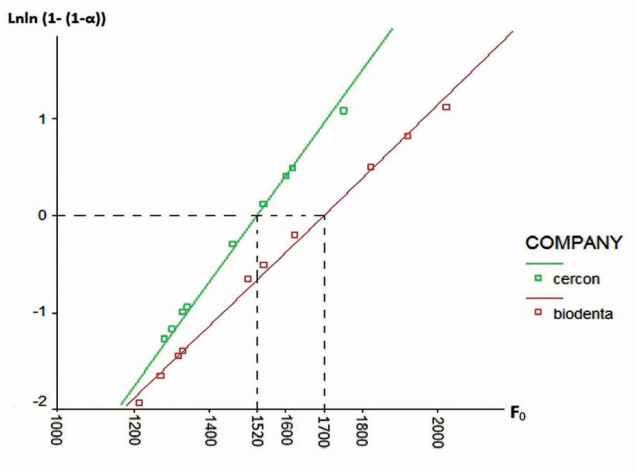

Fig. 3. The diagram of Weibull modulus (*m*) and load baring capacity values (F_0)(N) of systems.

Table 1. Weibull modulus (m) and load baring capacity values (F_0) of two systems

System	F0 (N)	Weibull modulus (m)
Biodenta	1700	6.0
Cercon	1520	7.5

Table 2. Composition and mechanical properties of two systems

System	Material	Composition	CTE ($\times 10^{-6}$/K)
Biodenta	Zirconia	ZrO_2, Al_2O_3, Y_2O_3	9.8
Cercon	Zirconia	ZrO_2, Y_2O_3, HfO_2, SiO_2, Al_2O_3	10.5

frameworks (F_0=1520 N). However, the reliability (*m*) was higher in Cercon (*m*=7.5). The Biodenta frameworks showed more scattering pattern and caused lower Weibull modulus (*m*=6). The fracture lines in Biodenta frameworks were occurred in: 7 cases between pontic-premolar contacts, 2 cases between pontic-molar contacts and one case in both contacts.

The fracture lines in Cercon samples were placed in: 5 cases between pontic-premolar contacts, 4 cases between pontic-molar contacts and one case in both contacts.

DISCUSSION

In medium-term follow up studies, outstanding success rate was reported in anterior and posterior zirconia frameworks.[9,25,26] In two different studies, Raigrodski *et al.*[9] and Sailer *et al.*[25] stated that survival rates of zirconia frameworks were 100% after 5 years following up. In another *in vitro* study, the fracture strength and fracture toughness of zirconia were reported as 900-1200 MPa and 9-10 MPa·$m^{1/2}$.[4] The mean load bearing capacity values are higher in Biodenta system in comparison with Cercon system but with no significant differences (*P*>.05). This might be due to different compositions and properties (Table 2).

Tsumita *et al.*[27] claimed that the mean fracture load was 916.0 ± 150.1 N for the conventional shape; also Lüthy *et al.*[23] revealed that flexural strength of 4 united tooth-supported Corcon FDPs was about 700 N. Our results showed that higher values in comparison with those two studies might be due to different cross-section areas in attachments of abutments to pontics. This area was 9 mm^2 in the present study whereas it was 7 mm^2 in their study. Manufacturer recommended the 7-11 mm^2 attachment areas in Cercon zirconia frameworks.[3] The more attachment area decreases, the more aesthetic of full ceramic bridges increases. Also the curvature in gingival embrasure needs to be wide enough to withstand against fractures.[28,29] Although 7.3 mm^2 area is sufficient for a three-unit bridge, adding one pontic needs higher areas in connectors.[6] Since inserted impact forces are higher in implants, more cross-section area is essential in implant supported FDPs. So the area in our frameworks (9 mm^2) was appropriate apparently. Also implants should be firm without any mobility to provide high survival rate. Scherrer and de Rijk[30] concluded that as the elastic modulus of supporting materials increased, the fracture toughness increased too. The present examination

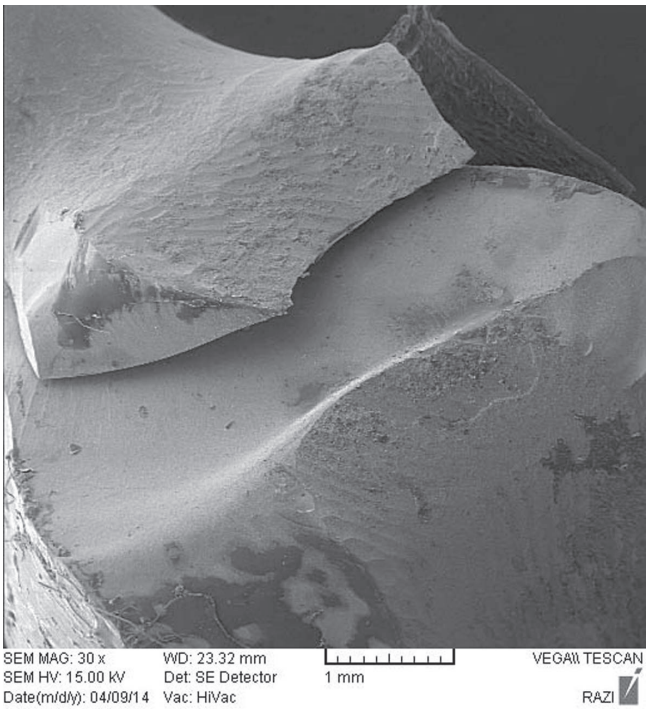

Fig. 4. SEM image of fracture site in one zirconia framework (×30). The fracture has been occurred in pontic-premolar contact obliquely from gingival to occlusal sides.

was similar to biologic situation of implant by fitting implants to steel model without any secondary material.

The force loading during biting is reported to be 50-250 N, and 500-800 N in parafunctions like bruxism[31] moreover, it might reach to 1000 N in some conditions.[32] Fig. 3 illustrates that if an 880 N force loaded on a three-unit bridge with zirconia framework and 9 mm^2 cross-section area, the survival rate would be 100%.

Weibull failure probability is useful in predicting reliability and life time of brittle materials like ceramic.[33,34] Weibull modulus (m) is 6.3 to 8.6 for ceramic restoration which is in accordance with our results. Also the Weibull modulus (m) of Cercone system was similar to results of Lüthy *et al.* (m=7.0).[23]

Fractures in ceramic restorations are rarely diagnosed clinically. They mostly initiate from gingival sides of connector which resist against high tensions,[35,36] and this was confirmed by our SEM analysis (Fig. 4). The fracture in our samples showed the same pattern. Marginal maladaptation was observed in more than 50% of FDPs and secondary caries was the main reason of replacing FDPs in 10.9% of cases.[18] However, no occurrence of caries is another factor which has increased the survival rates of implant-supported FDPs.

CONCLUSION

With the limitations of *in vitro* studies with small sample size it can be concluded that both Biodenta and Cercon systems can withstand biting force (even parafunctions) in posterior implant-supported bridges and no significant differences was observed between two systems.

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