COMPARATIVE STUDY ON THE FRACTURE STRENGTH OF METAL-CERAMIC VERSUS COMPOSITE RESIN-VENEERED METAL CROWNS IN CEMENT-RETAINED IMPLANT-SUPPORTED CROWNS UNDER VERTICAL COMPRESSIVE LOAD

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Statement of problem. Fracture of the tooth-colored superstructure material is one of the main prosthetic complications in implant-supported prostheses.

Purpose. The purpose of this in vitro study was to compare the fracture strength between the cement-retained implant-supported metal-ceramic crowns and the indirect composite resin-veneered metal crowns under the vertical compressive load.

Material and methods. Standard implants of external type (AVANA IFR 415 Pre-mount; Osstem Co., Busan, Korea) were embedded in stainless steel blocks perpendicular to their long axis. Customized abutments were fabricated using plastic UCLA abutments (Esthetic plastic cylinder; Osstem Co., Busan, Korea). Thirty standardized copings were cast with non-precious metal (Rexillium III, Pentron, Walling ford, Conn., USA). Copings were divided into two groups of 15 specimens each (n = 15). For Group I specimens, metal-ceramic crowns were fabricated. For Group II specimens, composite resin-veneered (Sinfony, 3M-ESPE, St. Paul, MN, USA) metal crowns (Sinfony-veneered crowns) were fabricated according to manufacturer' s instructions. All crowns were temporary cemented and vertically loaded with an Instron universal testing machine (Instron 3366, Instron Corp., Norwood, MA, USA). The maximum load value (N) at the moment of complete failure was recorded and all data were statistically analyzed by independent sample t-test at the significance level of 0.05. The modes of failure were also investigated with visual analysis.

Results. The fracture strength of Sinfony-veneered crowns (2292.7 ± 576.0 N) was significantly greater than that of metal-ceramic crowns (1150.6 ± 268.2 N) ($P < 0.05$). With regard to the failure mode, Sinfony-veneered crowns exhibited adhesive failure, while metal-ceramic crowns tended to fracture in a manner that resulted in combined failure.

Conclusion. Sinfony-veneered crowns demonstrated a significantly higher fracture strength than that of metal-ceramic crowns in cement-retained implant-supported prostheses.

Key Words
Fracture strength, Composite resin-veneered metal crowns, Vertical compressive load

Implant-supported prosthetic reconstruction[1] involves various types of materials for superstructure as in conventional prostheses. The material of superstructure should have sufficient mechanical strength to resist heavy masticatory force. This becomes more important for the posterior area in the mouth, where the forces are much higher than the anterior area.

Porcelain is a currently well accepted restorative material in implant-supported prostheses due to its superior esthetics. However, fracture of the porcelain in implant-supported metal-ceramic crowns is frequently encountered in clinical situations and one of the main prosthetic complications.[2-6] This porcelain fracture is due to its inherent brittleness, resulting in low fracture resistance and low tensile strength.[7,8]

New dental materials with improved physical property have become available for esthetic restorations as a result of development in research. A variety of composite resins with high mechanical strength and improved properties have been introduced.[9,10] Previous studies suggested the use of composite resins in a substitute of porcelain because of several advantageous properties, such as resilience, flexibility, high fracture strength, easy-repairing property, shock absorbing behavior and simple laboratory procedures.[9,11-18]

Composite resin is currently used as a superstructure material for implant-supported prostheses on the esthetic demanding area. With the usage of composite resins in implant-supported prostheses, more evaluation for its mechanical strength is needed. However, there are few studies about the fracture strength of implant-supported prostheses fabricated with indirect composite resin. Hence, the study on the fracture strength of the material in comparison with porcelain may provide clinicians with meaningful information about the implant-supported prostheses.

The objective of this in vitro study was to compare the fracture strength between cement-retained implant-supported metal-ceramic crowns and indirect composite resin-veneered metal crowns (Sinfony-veneered crowns) under the vertical compressive load. The fracture modes of the prostheses were also investigated.

MATERIAL AND METHODS

Stainless steel block (40 mm × 40 mm × 40 mm) was cast with standard implant of external type (AVANA IFR 415 Pre-mount; Osstem Co., Busan, Korea) embedded perpendicularly. This stainless steel block ended 3 mm below the platform of the fixture which was the nominal bone level recommended by the manufacturer.[19]

A superstructure was fabricated according to the following procedures. Customized abutments were fabricated using plastic UCLA abutments (4mm Esthetic plastic cylinder; Osstem Co., Busan, Korea). Dimensions of the customized abutments were 8.5 mm in height, 5.5 mm in buccolingual width and 6 degree in taper. Then, thirty coping patterns were fabricated, invested and cast with non-precious metal alloy (Rexillium Ⅲ; Pentron, Wallingford, Conn., USA). Measurements and adjustments with a caliper were made to get a uniform thickness in 0.3 mm of metal. Then, wax pattern reproducing natural premolar forms was made and the silicone impression served as a mold to duplicate the external shape of crowns. Silicone matrices were sectioned in half through the long axis to allow recovery of the dimension of the wax pattern and the prosthesis. These fabricated copings were divided into two groups of 15 specimens each (n = 15).

For Group I specimens, metal-ceramic crowns were fabricated according to routine dental laboratory processes. Porcelain (Super Procelain EX-3; Noritake Co., Osaka, Japan) application and condensation were conducted within usual laboratory techniques for metal-ceramic crowns.

Opaque, dentin and enamel porcelain were adapted to the metal coping and crowns were fired and glazed. Same dimensions of specimens were standardized with silicone mold, and measurements were made to ensure that the total thickness of porcelain and metal was a uniform 2.0 mm as much as possible. For Group II specimens, composite resin-veneered metal crowns were fabricated with Sinfony (Sinfony, 3M-ESPE, St. Paul, MN, USA) according to the manufacturer' s instructions. Same dimensions of specimens were standardized in the previous manner. Dimensions of the final crown were 10 mm in bucco-lingual width, 8 mm in occlusal table width, and 7 mm in height.

All customized abutments were placed on each implant and tightened to 30 N with an abutment screw by using a torque control device. Fabricated crowns with the same dimensions were cemented on each abutment with temporary cement (Temp-bond, Kerr, Orange, CA, USA).

Fracture strength tests were carried out for all specimens. Fracture strength tests were evaluated according to the specified test[19] (ISO 14801). All crowns were subjected to a vertical compressive load with an Instron universal testing machine (Instron 3366, Instron Corp., Mass., Norwood, MA, USA) (Fig. 1).

For the experiment, a custom-made metal shaft with stainless steel ball in 18 mm diameter was attached to the vertical arm of the testing machine. After aligning each specimen in the testing machine, a compressive load was applied to a specimen at a crosshead speed of 1 mm / min until failure. The stainless steel ball on the metal shaft was placed on the center of the occlusal surface (Fig. 2). The load was directed parallel to the long axis of each specimen.

The maximum load values at the moment of complete failure were recorded. The value of strength was expressed in Newton (N). In this experiment, the fracture of the crown was defined as being separated or falling out of any portion of the material.

All data were statistically analyzed by independent sample t-test using SPSS software (Version 11.0, SPSS Inc., Chicago, USA) whether there was a significant difference in the fracture strength between the Group I (metal-ceramic crowns) and the Group II (Sinfony-veneered crowns). The modes of failure were also investigated with visual analysis.

Fig. 1. Instron universal testing machine (Instron 3366, Instron Co., Mass., USA).

Fig. 2. Specimen loaded to failure.

RESULTS

The resultant values of the maximum load at fracture measured on all specimens are on the Table I and Fig. 3. The mean fracture force of the Sinfony-veneered crowns (2292.7 ± 576.0N) was higher than the mean fracture force of the metal-ceramic crowns (1150.6 ± 268.2N). The outcome of the statistical analysis demonstrated that there was a significant difference in the fracture strength between two groups ($P < 0.05$, Table II). With respect to the fracture mode, the exposed metal surface of Sinfony-veneered crowns showed more adhesive manner than the surface of the metal-ceramic crowns which showed combined manner. The modes of failure in each group are on the Fig. 4.

The greater standard deviation of the Sinfony-veneered crowns group may be the result of the lack of technical uniformity in the laboratory process.

Table I. Fracture force values (N), mean values and standard deviations (SD) in parenthesis of specimens

Specimen No.	Metal-ceramic crown	Sinfony-veneered crown
1	1174	1744
2	1245	3213
3	718	1328
4	1263	2878
5	1341	3409
6	1529	2223
7	1528	2306
8	952	2360
9	1019	2324
10	1215	2396
11	1381	1873
12	881	2027
13	1199	1805
14	1197	2736
15	617	1768
Mean	1150.6	2292.7
(SD)	(268.2)	(576.0)

DISCUSSION

For this experiment, a stainless steel ball connected to the testing machine was used and allowed to make contact with the both cusps when applying the load. The failure was defined as separated or falling out of the material, excluding the initial crack. As the slightly decreased load value increased again right after the initial crack, the maximum load values at the complete failure were recorded and analyzed. Besides, the study was conducted using cement-retained implant-supported prostheses on which the crown was luted.

The fracture strengths of Sinfony-veneered crowns were significantly greater than those of metal-ceramic crowns. The results of this study are in close agreement with the similar previous studies[15,20], although those studies were carried out in conventional fixed partial denture prostheses. Those comparative studies demonstrated that composite resins had higher fracture force than porcelains. In a comparative study between fiber-reinforced composite crowns and full ceramic crowns, it was concluded that the fracture force of fiber-reinforced composite crowns was significantly higher than that of full-ceramic crowns.[20] Andrazo Tarozzo et al[21] demonstrated that,

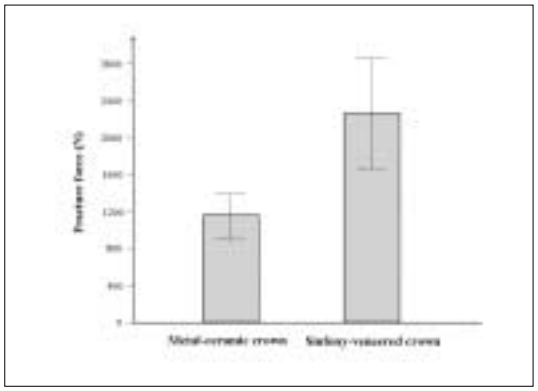

Fig. 3. Means and standard deviations of the specimens investigated ($P < 0.05$).

Table II. Results of Independent sample t-test

	t-test for equality of means						
	t	df	Sig. (2 tailed)	Mean difference	Std. error ce differen	95 % Confidence interval of the difference Lower	Upper
Equal variances assumed	-6.961	28	.000	-1142.05	164.052	-1478.092	-806.002
Equal variances not assumed	-6.961	19.796	.000	-1142.05	164.052	-1484.479	-799.615

(a) fractured metal-ceramic crown. (b) fractured Sinfony-veneered crown.

Fig. 4. The mode of failure.

although it was lower than that of metal-ceramics, the bond strength of composite to metal was high enough to be used as an alternative to porcelain, suggesting improvement of the bonding system.[31,32]

The relatively high fracture strength values of Sinfony-veneered crowns in this study may be the result of their resilience and shock absorbing properties[9,11,15,17,18,22] as well as increased volume of inorganic fillers[9] in composition of the composite resin. It was pointed out that the composite resin had lower elastic modulus than porcelain, so it transmitted less applied load to the underlying structure.[15] Gracis[18] also found in his study that the composite resin showed reduced impact force compared to the porcelain in implant-supported prostheses, indicating that it has shock absorbing capabilities.

Considering the mean maximal occlusal loads, the resultant values of both groups exceeded data represented in the studies for normal biting forces.[23-25] Waltimo and Kononen[24] reported that the maximal biting force of 847 N for men and 597 N for women in the molar region. Gibbs et al[23] reported that the mean forces during swallowing and chewing were 297 N and 263 N, respectively. Therefore, it meant that both the porcelain and the Sinfony as a occlusal material could survive under the functional load.

According to the previous studies[21,26,27], fracture modes are divided into two types. Those are adhesive failure and cohesive failure. It was

called adhesive failure if failure occurred at the junction of the metal and the veneering materials. If the failure occurred within the body of the veneering material, it was classified as cohesive. With regard to fracture mode in this study, two groups exhibited different fracture appearance. The exposed metal surface of the metal-ceramic crowns showed less clear appearance than that of the Sinfony-veneered crowns which had a clear exposed metal surface. It meant that the Sinfony-veneered crowns exhibited adhesive failure mostly, while metal-ceramic crowns tended to fracture in a manner that resulted in combined failure mode. These results are in good agreement with similar previous studies.[21,28-30] The cause of difference in the fracture mode between two groups may be due to lower adhesive bond strength[21] of the composite resin-metal interface than that of metal-ceramic interface. Another comparative study[12], investigating the shear bond strength of composite resin veneers on metal substructure, showed that it was appreciably lower than that of metal-ceramic specimens in spite of the improved material's properties and bonding methods. These results of the fracture mode in this study also represented that the failure of ceramics occured both at the interface of core-metal and within the materials. In those previous studies concerning the fracture behavior of dental ceramics[28,30], it was reported that failures involved interfacial stress with crack propagation at or near the core-veneer interface[28], and the internal surface of ceramics was also found to be failure site, indicating that it might be the location of the highest tensile stress and technical/inherent flaws.[30]

As mentioned in the introduction, the main drawback of porcelain includes low tensile strength due to their inherent brittleness which can be one of the causes of clinical failure on implant-supported prostheses. According to the results of this study, Sinfony may be a good alternative to porcelain so as to overcome its potential problem on the load bearing area. Other previous studies[9,33] also support the use of composite resin in this aspect. Touati and Aidan[9] mentioned its application to implant-supported prostheses. Another in vitro study[27] demonstrated that the probability of failure of resin-veneered implant-supported restorations was not significantly different from that of the metal-ceramics. Thus, it can be considered that Sinfony may be used in the treatment of implant-supported prostheses on the area of high masticatory force or the posterior region. However, when this material is selected for implant-supported prostheses in clinical conditions, other properties of the material, such as wear resistance, fitting accuracy, marginal adaptation and color stability, should also be considered.

There are limitations of the present study. Occlusal loading force is not pure axial force and multi-directional complex forces including lateral oblique forces are encountered in clinical situations. Hence, lateral forces should be considered. The specimens were loaded to failure in a single cycle and dry environment in this study, but the prostheses may fail through cyclic fatigue loading in wet environment clinically. In addition, aging processes[33-35], such as thermal stress, corrosion and wear, were not considered. It may affect the fracture strength in clinical situations. Therefore, it is not possible to draw direct comparison with the results of long-term clinical studies. However, this study may provide the useful information about the load bearing capacity of implant-supported prostheses in simulated clinical situations.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions were drawn.

1. The load required to fracture Sinfony-veneered

crowns was significantly greater than that of metal-ceramic crowns in cement-retained implant- supported prostheses.

2. The failure loads of both types of crowns greatly exceeded previously published average values of the maximum masticatory force.
3. The failure of metal-ceramic crowns occurred in both adhesive and cohesive mode, while that of Sinfony-veneered crowns showed only adhesive mode.

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