

REINFORCEMENT OF FIBER-REINFORCED COMPOSITE CROWNS WITH VARIANT MARGIN DESIGNS

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ABSTRACT

Fiber-reinforced composite restorations provide excellent esthetics; however, little is known regarding the influence of margin design on marginal accuracy and breaking strength for this type of crown. This study evaluated the effect of variations in tooth preparation design on the marginal accuracy and breaking strength of fiber-reinforced composite crowns. Three metal dies with a total convergence of 5-degrees and different margin designs (0.5-mm light chamfer, 1.0-mm deep chamfer, and 1.0-mm shoulder) were prepared. Sixty standardized crowns (FibreKor) were made on duplicated base metal alloy dies (n=20 for each margin design). Marginal accuracy was stereoscopically evaluated by measuring the distances between each of four pairs of indentations on the crowns and on the dies. The specimens were then compressively loaded to failure dies using a universal testing machine. The data were analyzed with 1-way ANOVA followed by Ryan-Einot-Gabriel-Welsch multiple-range test ($\alpha = .05$). Analysis of marginal accuracy and breaking strength disclosed a statistically significant difference for tooth preparation design ($P < .001$). The marginal adaptation of preparations with the 0.5-mm light chamfer ($66 \mu\text{m}$) and 1.0-mm deep chamfer ($69 \mu\text{m}$) were significantly better than preparations with a shoulder finish line ($92 \mu\text{m}$) ($P < .001$). The fracture strength of the preparations with the 0.5-mm light chamfer (15.8 MPa) and 1.0-mm deep chamfer (15.1 MPa) were significantly greater than those of the preparations with the 1.0-mm shoulder (13.7 MPa) ($P < .001$). Marginal accuracy of fiber-reinforced crowns was adversely affected by tooth preparation design. The marginal gaps were greater for the shoulder margin specimens than in the light or deep chamfer margin specimens. However, the fracture strength of the chamfer margins specimen was greater than that of the shoulder margin specimens.

Key words: Fiber-reinforced composite, margin design, breaking strength, marginal accuracy.

INTRODUCTION

Metal-ceramic restorations continue to be a popular option for fixed prosthodontics, based on their clinical longevity and acceptable esthetics. However, concern has been expressed regarding corrosion of metal alloys and unwanted allergic or toxic side effects affecting patients and laboratory personnel.¹ Moreover, degradation of Magnetic Resonance Tomography (MRT) and Computer Tomography (CT) images has been mentioned as a disadvantage of fixed intraoral metal restorations.²

Recently introduced high-strength ceramic restorations have proved popular due to their outstanding esthetics. These restorations allow light transmission and achieve an exceptionally life-like appearance. In addition, the discoloration of the gingiva caused by

metallic systems can be avoided.³⁻⁵ However, improved esthetics have been associated with increased failure rates due to increased fracture properties of all ceramic crowns compared with metal ceramic crowns. Moreover, increased costs and more complex cementation techniques have restricted extensive use of all ceramic crown systems.⁶⁻⁹

Demand continues within the dental profession for restorations that exhibit high strength, natural color, good wear resistance, marginal integrity, and ease of fabrication. With the introduction of new composite resins, including fiber-reinforced systems, the restoration or replacement of a single tooth or multiple teeth with a fiber-reinforced crown or metal-free partial dental prosthesis is now an option.¹⁰ Fiber-reinforced composite restorations have the potential to address some of the problems associated with conventional

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restorative materials. The systems have impressive mechanical properties, leading to extensive engineering applications. Their strength-to-weight ratios are superior to those of most alloys. When compared to metals they offer many other advantages including the lack of corrosion, translucency, good bonding properties and ease of repair. They also offer the potential for chairside and laboratory fabrication.¹¹ Moreover, these materials have advantages over ceramic materials including higher flexural strength and lower opposing tooth wear; also intraoral repair is less complicated.^{12,13}

Marginal accuracy and fracture resistance are considered crucial factors in the success and longevity of an indirect restoration.¹⁴ Studies examining the effect of the finish line on the marginal fit reported conflicting results. Pera et al¹⁵ reported that improved marginal fit was obtained with In-Ceram ceramic crowns fabricated on chamfer and 50-degree shoulder margins. However, other studies reported that cast crown fit was not influenced by the margin design.^{16,17} Also, it was shown that tooth preparations with a 1.2-mm shoulder margins produced the strongest Dicor crowns, while 0.8-mm deep chamfer margins produced the weakest restorations when cemented to metal dies.^{18,19} However, other studies reported that Dicor crowns luted with a resin luting agent was unaffected by the type of margin design prepared.^{20,21}

Although several publications have characterized the materials science aspects of fiber-reinforced composites²²⁻²⁹, little mention has been made in the technical literature on the breaking strength and marginal accuracy of fiber-reinforced composite crowns.^{13,25} The purpose of this investigation was to evaluate the effect of variations in tooth preparation design on the marginal accuracy and breaking strength of fiber-reinforced composite crowns. The null hypothesis was that margin design modification of tooth preparations would have no influence on marginal accuracy and breaking strength of fiber-reinforced composite crowns.

METHODOLOGY

Three metal master dies with 3 different cervical margins were designed to simulate complete fiber-reinforced composite crown preparations with the dimensions (Fig 1). These comprised 0.5-mm light chamfer margin, 1.0-mm deep chamfer margin and 1.0-mm shoulder margin (control) with sharp axiokingival line angle (Fig 2). Sixty impressions (20 impressions for each margin design) of the master metal dies were made with poly (vinylsiloxane) (Examix; GC America

Inc, Chicago, Ill) using a single-mix technique in individual polycarbonate trays (Ash Instruments, Potters Bar, UK). The impressions were poured with type IV die-stone (Jade stone; Whip Mix Corp, Louisville, Ky). A custom cellulose acetate crown index of an intact ivory molar tooth was used to standardize the fiber-reinforced composite crown dimensions.

Die hardener (Surface hardener; Renfert GmbH, Hil-Zingen, Germany) and die separator (Picosep; Renfert GmbH) were applied to the stone dies. Die spacer (Picosep, Renfert GmbH) was applied to all dies. 1-mm thick copings made of Conquest/Sculpture

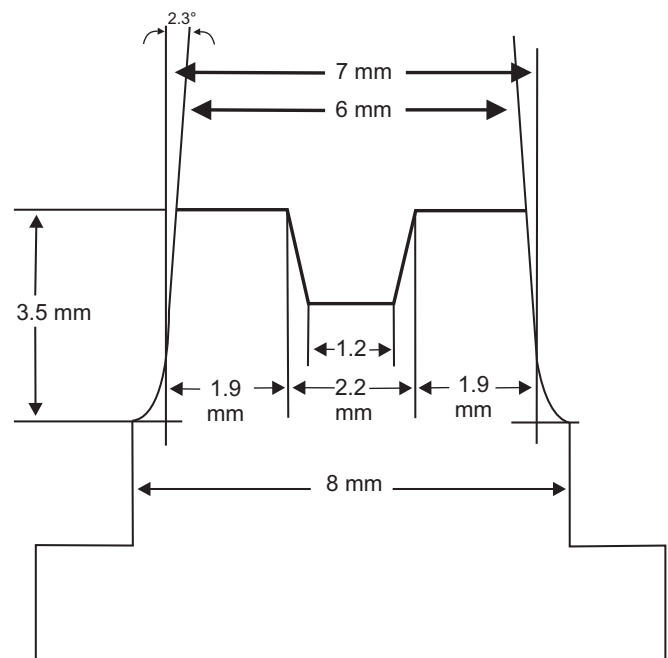


Fig 1: Longitudinal cross-section of master complete crown tooth preparation



Fig 2: Master metal dies with different finish lines; From right light chamfer (0.5 mm, deep chamfer (1.0 mm); and shoulder (1.0 mm)

(Jeneric/Pentron, Wallingford, Conn.) were photo polymerized for 5 minutes on each die (Cure-light device). Then, one layer of the unidirectional-fiber pre-impregnated FiberKor (shade clear, 6 mm width) was manually wrapped around the coping and further photo polymerized for five minutes. The crown was shaped using dentin and enamel facing material from Conquest/Sculpture. The fabrication procedure was completed with the cellulose acetate index. The completed restoration was post polymerized in the Conquestomat device for 10 minutes at 107° C. After post polymerization, final finishing was performed with stone points, rubber, and wheel instruments (Polieriset; Ivoclar Vivadent) following the manufacturer's recommendation. A total of 60 (20 for each margin design) FiberKor/Sculpture crowns were fabricated.

For marginal accuracy measurements, the finished crowns were fit passively to their respective metal master dies. Four pairs of index indentations were placed with a ½ round bur at equal distances around the circumference of each specimen and the metal master dies; these represented mesial, lingual, buccal, and distal locations. These indentations served as specific points for determining marginal discrepancies. A spring-loaded holding device with a force of 98 N which permitted axial rotation of the specimen was used to ensure that the crowns are fully seated on the master dies. Using a ×100 magnification light microscope (Nikon Measurement, MM-11; Nikon Inc, Garden City, NY), direct measurements in micrometers of the marginal gap were measured. The measurements for each specimen were averaged. Gap distance was defined as the distance along a line perpendicular to the most cervical extent of the marginal level and the most cervical extension of the fiber-reinforced crown. One investigator prepared all specimens and measured the discrepancies.

For breaking strength, each crown was luted to its master metal die with dual polymerizing resin luting agent (Nexus 2; Kerr Corp, Orange, Calif) according to the manufacturer's instructions. Luted crowns were light polymerized for 3 minutes under 4.9 N of axial loading (LTC; Chatillon LTC, Greensboro, NC). Light intensity was 730 mW/cm², as measured by a radiometer (Optilux Model 100; SDS Kerr, Danbury, Conn) at a 10-mm distance from the specimens. Excess cement was cleaned off the restoration margin. The failure loads for luted crowns were determined with a 1/8-inch diameter cylindrical steel bar brought into contact with the center of the buccal and lingual triangular ridges in a universal testing machine (Model 4202; Instron Corp,

Canton, Mass) in compressive mode with a cross head speed of 0.05 mm/min. The maximum load it could withstand were recorded and divided by the surface area of the tooth preparation to obtain an estimate of the breaking strength in megapascals (Breaking strength in MPa = load/surface area) The data were analyzed with 1-way analysis ANOVA followed by Ryan-Einot-Gabriel-Welsch multiple-range test ($\alpha=0.05$).³⁰

RESULTS

The 1-way ANOVA revealed a statistically significant difference among marginal accuracy ($P<.001$) and between breaking strength of each margin design ($P<.001$) (Table 1). The results of the marginal accuracy and the breaking strength are summarized in Table 2. The lowest mean marginal gap and standard deviation (SD) was obtained from preparations with the 0.5-mm light chamfer [66.2 (10.9) μ m] and 1.0-mm deep chamfer [69.7 (7.4) μ m]. However, marginal gap (SD) for preparations with 1.0-mm shoulder margin [92.8 (15.8) μ m] was significantly higher ($P<.001$). The highest mean breaking strength and SD was found for the preparations with the 0.5-mm light chamfer [15.8 (1.7) MPa] and 1.0-mm deep chamfer [15.1 (1.7) MPa] margins. However, breaking strength and SD for preparations with 1.0-mm shoulder margin [13.7 (2.1) MPa] was significantly lower ($P<.001$).

TABLE 1: 1-WAY REPEATED MEASURE ANOVA FOR MARGINAL ACCURACY AND BREAKING STRENGTH

Source	Df	MS	F	P
Margin gap	2	419.1	29.66	<.001
Error	57	141.4		
Strength	2	22.2	6.59	<.001
Error	57	3.4		

df = degree of freedom; MS = Mean square; P = Probabilities; F = Ratio

TABLE 2: MARGIN GAP AND BREAKING STRENGTH AMONG DIFFERENT PREPARATION DESIGN (MEAN (SD)) (n = 10)

Margin design	Mean + Standard deviation	
	Margin gap (μ m)	Fracture load (MPa)
Light chamfer	66.2(10.9)a	15.8(1.7)c
Deep chamfer	69.7(7.4)a	15.1(1.7)c
Shoulder	92.8(15.8)b	13.7(2.1)d

Values with the same lower case letters are not significantly different at $P<.05$.

DISCUSSION

The data support the null hypothesis of the study, that margin design modification of tooth preparations appeared most conducive to the development of better margin accuracy and high breaking strength of fiber-reinforced composite crowns. The majority of researchers agree on the importance of margin accuracy and breaking strength for long-term success of restorations.^{1,4,5,7,12,13,15} In the current study, the marginal discrepancy of the fiber-reinforced composite crowns was similar to that of the all-ceramic crowns and was within a clinically acceptable level, 100 μm . However, the amount of discrepancies did not fall within the limit of 25 μm , implied by ADA specification No. 8.¹

Various aspects of tooth preparation designs have been cited in the literature. However, considerable focus has been still directed towards the most appropriate margin design as innovative restorative systems are introduced. Manufacturers and authors offer different opinions as to the optimal form, but little scientific data is available. Lin et al²⁸ reported that the finish line influenced the marginal adaptation of all-ceramic Procera crowns, while Pera et al¹⁵ demonstrated that improved marginal fit was obtained with In-Ceram ceramic crowns fabricated on chamfer and 50-degree shoulder tooth preparations compared with 90-degree shoulder margins. Gavelis et al²⁹ suggested that the specific type of finish line helps the cement to escape and improving marginal adaptation in cast metal crowns. However, Syu et al¹⁶ reported that cast crown fit was not influenced by the design of the finish line. A similar result was reported in another study.²¹ Shearer et al⁴ showed no significant difference between chamfer and shoulder margins in the fit of In-Ceram crowns.

No definite criteria exist regarding what constitutes clinically acceptable marginal accuracy. McLean and von Fraunhofer⁶ proposed that a restoration would be successful if marginal gaps and cement thicknesses of less than 120 μm could be achieved. There have been many studies regarding the marginal fit of crowns. Testing Celay In-Ceram, Beschnidt et al⁵ reported mean marginal gaps of 78 μm in maxillary incisor crowns, which was in agreement with the results found in the present study. However, Groten et al¹⁴ reported a lower value of 18.3 μm . Beschnidt et al⁵ tested the marginal fit of IPS Empress 2 and found the marginal opening to be 62 μm , which was similar to the results of this study. Sulaiman et al⁸ and Gery et al⁹ evaluated the marginal gaps of conventional In-Ceram crowns, which were 160.66 μm and 123 μm respectively. These

results were also in accordance with this study. An explanation of the lack of agreement may be variation in the methods used by various investigators studying marginal accuracy. Sulaiman et al⁸ suggested the cause could be the use of different measuring instruments. Sample size and number of measurements per specimen may also have contributed to the variation. The current study demonstrated that clinically acceptable mean marginal discrepancies could be achieved of all groups tested.

The maximum occlusal force has been reported in the literature to vary widely. The mean adult occlusal force reported to be about 400-800 N.¹ Results of the current study exceed these limits. Moreover, the fracture strength was higher with a light or deep chamfer finish line than crowns with a shoulder finish line. This explained that the marginal bulk of fiber-reinforced crowns used did not contribute to the fracture strength compared to all-ceramic crowns^{18,19}. This results were consistent with the results obtained for the Artglass crowns.²²

The results obtained from this research are only introductory and comparative. A limitation was the use of direct method to measure the marginal accuracy. However, internal fit of the crowns was impossible to measure with the metal master dies. Although certain investigations focused on marginal fit, others^{4,8,9}, also evaluated the internal fit of the crowns. Measuring the internal fit of artificial crowns requires cementing the crowns and sectioning the specimens. In the case of sectioning, the number of measurements per specimen is limited. The current study used a metal die that has merit in standardizing the preparation for all abutments. However, if natural teeth were used as the supporting models, the marginal discrepancies might have been reduced. Another limitation of this study was that the crowns were not subjected to an artificial aging process, such as thermal cycling which might affect the results. Also, the exact point of fracture was not determined. Future investigations are needed to evaluate the long-term retention of posts and to confirm the in vitro findings of the current study.

CONCLUSION

Mean marginal opening of each fiber-reinforced composite crown group was less than 100 μm , which was considered clinically acceptable. Lowest mean discrepancy was recorded for the two chamfer finish line groups. However, the fracture strength of the preparations with 1.0-mm shoulder margins produced

the weakest restorations. However, the values were higher than those considered to be normal occlusal force.

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