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Effect of the Crown Preparation Margin and Die Type on the Marginal Accuracy of Fiber-reinforced Composite Crowns

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Abstract

Aim: The objective of this laboratory investigation was to determine the effect of different preparation designs (light chamfer, deep chamfer, and shoulder) and die-making materials (stone and epoxy) on the resulting margin misfit for fiber-reinforced composite crowns using a measuring microscope.

Methods and Materials: Sixty standardized FibreKor crowns were made on stone and epoxy resin dies (n=30 each) duplicated from three metal master dies representing complete crown tooth preparation with a total convergence of 5°. For each die group, three of the tooth preparation designs were established in relation to the type of finish line (n=0 each) as follows: Group A (0.5-mm light chamfer finish line); Group B (1.0-mm deep chamfer finish line); and Group C (1.0-mm shoulder finish line). Marginal accuracy was evaluated by measuring the distances between each of four pairs of indentations on the crowns and on the dies with a Nikon measuring microscope.

Results: Analysis of seating measurements with parametric analysis of variance and Tukey's Studentized Range (HSD) disclosed a statistically significant difference for both tooth preparation design and die material ($p < 0.001$). However, the interaction effect was not significant ($p=0.9073$). The least marginal opening value was for FibreKor crowns made on epoxy resin dies with a light chamfer finish line (57 μm), but the difference was not statistically significantly different from crowns made on epoxy resin dies with a deep chamfer light chamfer finish line (61 μm). However, crowns made on epoxy resin dies with a shoulder finish line (81 μm) had significantly higher values ($p < 0.05$). FibreKor crowns made on stone dies with the shoulder finish line (95 µm) had statistically higher marginal opening values ($p < 0.05$). The least marginal opening value was for crowns made on stone dies with a light chamfer finish line (66 μm), but the difference was not statistically significantly different from crowns made on stone dies with a deep chamfer light chamfer finish line (70 μm).

Conclusions: Significant differences were found among the die material used for the shoulder margin design. However, there was no significant difference between light chamfer and deep chamfer margin designs for both die materials.

Keywords: Marginal accuracy, fiber-reinforced crowns, die type, preparation margins

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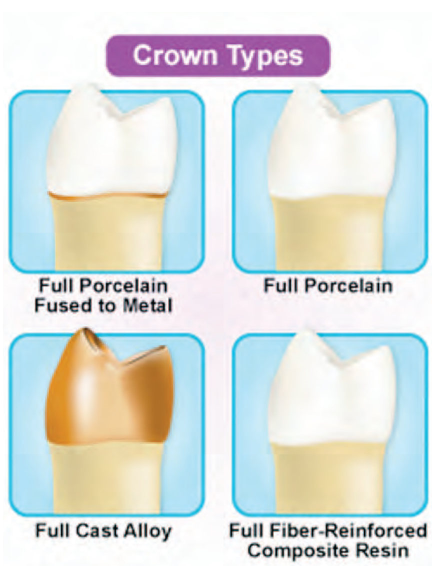
Introduction

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.[1]

Fiber-reinforced composite restorations have the potential to address some of the problems associated with conventional 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 chair side and laboratory fabrication.[2,3] Moreover, these materials have advantages over ceramic materials including higher flexural strength and lower opposing tooth wear; also, intraoral repair is less complicated.[4,5]



Marginal accuracy is considered a crucial factor in the success and longevity of an indirect restoration because an inadequate adaptation of the restoration may be detrimental to both the tooth and supporting periodontium.[6-10] However, no definite understanding exists regarding what constitutes clinically acceptable marginal accuracy. There have been many studies regarding the marginal fit of crowns. McLean and von Fraunhofer[11] proposed a restoration would be successful if marginal gaps and cement thicknesses of less than 120 μm could be achieved. Testing Celay In-Ceram™, Beschnidt et al.[12] reported mean marginal gaps of 78 μm in maxillary incisor crowns. However, Groten et al.[13] reported a lower value of 18.3 μm. Beschnidt et al.[12] tested the marginal fit of IPS Empress 2™ and found the marginal opening to be 62 μm. Sulaiman et al.[14] and Gery et al.[15] evaluated the marginal gaps of conventional In-Ceram™ crowns which were 160.66 μm and 123 μm, respectively.

The precision of fixed prosthodontic restorations depends mainly on accuracy during die fabrication which in turn is directly dependent on the quality of the impression and working cast.[16] Despite reported disadvantages, dental stone continues to be the most widely used material in dentistry for producing dies for the fabrication of restorations. Epoxy resin die materials are an alternative reported to be dimensionally accurate, stronger than stone, and more resistant to abrasion.[17-19]

Although several publications have characterized the materials science aspects of fiber-reinforced composites,[20-25] little mention has been made in the technical literature about the clinical and laboratory guidelines that might be essential for the success of fiber-reinforced composite crowns.[26-30] The purpose of this investigation was to examine the influence of different preparation designs and die-making materials on the resulting margin misfit for fiber-reinforced composite crowns using a measuring microscope.

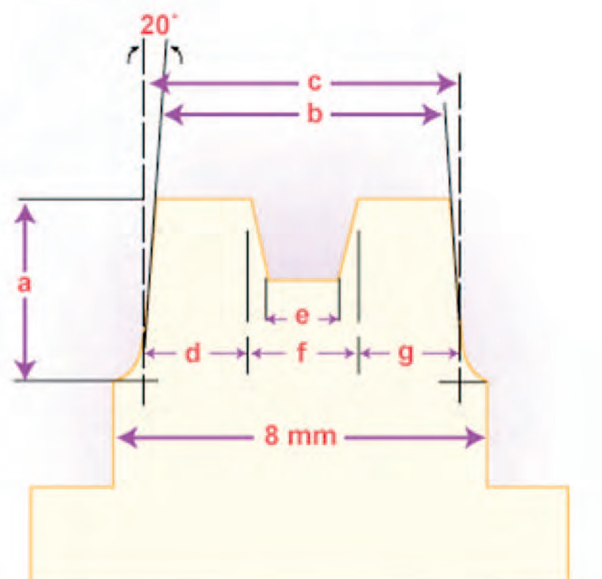
Materials and Methods

Three metal master dies were used with one of the three different cervical margins designed to simulate complete fiber-reinforced composite crown preparations with the dimensions presented in Figure. 1.

These master dies were designated as Group A (0.5-mm light chamfer finish line); Group B (1.0-mm deep chamfer finish line); and Group C (1.0-mm shoulder finish line) with rounded axio-gingival line angle (Figure 2).

Sixty impressions (20 impressions in each group) were made of the master metal dies with Examix™ polyvinylsiloxane (GC America Inc., Chicago, IL, USA) using a single-mix technique in individual polycarbonate trays (Ash Instruments, Potters Bar, UK) at room temperature. The impressions were poured with epoxy resin (Epoxy-Die, Ivoclar-Vivadent, Leicester, UK), and Type IV die-stone (Jade Stone, Whip Mix Corp., Louisville, KY, USA) with ten dies in each subgroup. A custom cellulose acetate crown index was used to standardize the fiber-reinforced composite crown dimensions. Die hardener (Surface Hardener, Renfert GmbH, Hil-Zingen, Germany) was applied to the stone dies and two layers of Picosep™ die spacer (Renfert GmbH, Hilzingen, Germany) were applied to all dies. Copings made of 1-mm thick Conquest/Sculpture (Jeneric/Pentron, Wallingford, CT, USA) were photopolymerized with a curing light for five minutes on each die. Then one 6 mm wide layer of clear unidirectional-fiber pre-impregnated FiberKor® (Nobel Biocare Deutschland GmbH, Cologne, Germany) was manually wrapped around the coping and photopolymerized for a another five minutes. The crown was shaped using dentin and enamel facing material from Conquest/Sculpture (Jeneric/Pentron, Wallingford, CT, USA). The fabrication procedure was completed with the cellulose acetate index. The restoration was postpolymerized in the Conquestomat device (Jeneric/Pentron, Wallingford, CT, USA) for ten minutes at 107°C. After postpolymerization, final finishing was performed with stone points, rubber, and wheel instruments (Polierset, Ivoclar-Vivadent, Leicester, UK) following the manufacturer's recommendation. A total of 30 (ten for each of the three finish lines) FiberKor/Sculpture crowns were fabricated for each die type.

For measurement of marginal accuracy, the finished crowns were placed passively onto their respective metal master dies. Four pairs of index



Tooth Preparation Dimension (mm)							20°
a	b	c	d	e	f	g	
3.5	6	7	1.9	1.2	2.2	1.9	4.6

°Convergence angle (degrees)

Figure 1. Longitudinal cross section of master complete crown tooth preparation.

Figure 2. Metal master dies with different finish lines; left, deep chamfer (1.0 mm); middle, light chamfer (0.5 mm); right, shoulder (1.0 mm).

Table 1. ANOVA procedure for the dependent variable marginal discrepancy.

Source of Variation	df	MS	F value	P
Model	5	1810.84438	12.49	< 0.001
Die material	1	1525.608375	10.52	< 0.001
Preparation design	2	3750.183375	25.87	< 0.001
Die material x margin design	2	14.123375	0.10	0.9073
Error	27	139.878		

Df = Degree of freedom; **MS** = Mean square; **p** = probabilities.

indentations were placed with a ½ round bur at equal distances around the circumference of each specimen and the metal master dies. These indentations represented mesial, lingual, buccal, and distal locations and 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 the crowns fully seated on the master dies. Using a 100x magnification Nikon Measurement, MM-11 light microscope (Nikon Inc., Garden City, NY, USA), direct measurements in millimeters of the marginal gap were measured. The four 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.

Means and standard deviations were calculated for each group, and the results were compared using a two-way analysis of variance (ANOVA) and Tukey's Studentized range test at 5% level of confidence.

Results

The ANOVA results shown in Table 1 demonstrate a statistically significant difference between tooth preparation design and die material (P<.001). However, results were not significantly different between die material and tooth preparation design combinations (p=0.9073).

Table 2 illustrates the mean differences for tooth preparation designs and die materials separately. The data indicate fiber-reinforced composite crowns prepared on stone dies for complete coverage preparations with a shoulder finish line had a significantly higher mean marginal discrepancy (95±18). This mean value was 26% to 29% higher than deep chamfer and light chamfer finish lines, respectively, with no statistical significant difference between these latter two finish lines. The same comparison for epoxy resin dies revealed that fiber-reinforced

Table 2. Means and standard deviations of marginal gap measurements (μm) for different die materials (n=30) with different tooth preparation design (n=10).

Cervical Margin Design	Mean ± Standard Deviation	
	Stone Die	Epoxy Resin Die
Light chamfer	66 ± 11*	57 ± 13*
Deep chamfer	70 ± 8*	61 ± 6*
Shoulder	95 ± 18	81 ± 15

*Connect values that are not significantly different at P>0.001.

crowns prepared on the resin dies for complete coverage preparations with a shoulder finish line had significantly higher mean marginal discrepancy (81±15). This mean value was 25% to 30% higher than deep chamfer and light chamfer finish lines, respectively, with no statistical significant difference between these two finish lines.

Discussion

Various aspects of tooth preparation design have been cited in the literature. However, considerable focus has still been directed toward the most appropriate finish line to use as new innovative restorative systems are introduced. Manufacturers and authors offer different opinions as to the optimal form, but little scientific data is available. Lin et al.,[26] reported the finish line influenced the marginal adaptation of all-ceramic Procera™ crowns, while Pera et al.[27] demonstrated improved marginal fit was obtained with In-Ceram ceramic crowns fabricated on chamfer and 50° shoulder tooth preparations compared with 90° shoulder margins. Gavelis et al.[28] suggested a specific type of finish line helps cement to escape on seating and improves marginal adaptation in cast metal crowns. However, Syu et al.[29] reported cast crown fit was not influenced by the design of the finish line. A similar result was reported in another study.[30] Shearer et al.[1] reported no significant difference between chamfer and shoulder margins in the fit of In-Ceram crowns. In the present study crowns with a shoulder finish line showed an increased marginal discrepancy prior to cementation than those with a deep chamfer or light chamfer finish line. This may be the result of the fabrication method of fiber-reinforced composite restorations. The marginal discrepancy of the fiber-reinforced composite restoration crowns was similar to all-ceramic crowns and was within a clinically acceptable level of 100 μm.[19] A similar test set up was used when Cho et al.[6] reported a shoulder finish line showed a smaller marginal discrepancy before and after cementation.

McLean and von Fraunhofer[11] proposed a restoration would be successful if marginal gaps and a cement thickness of less than 120 μm could be achieved. Beschnidt et al.[12] reported a marginal gap of 78 μm in maxillary incisor crowns. Kern et al.[31] reported clinically acceptable marginal discrepancies ranged from 8.6 to 82.8 μm for final cementation. The seating discrepancy data of this study was comparable with the results of these studies. An explanation of the lack of agreement may be variation in the methods used by various investigators studying marginal accuracy. Sulaiman et al.[8] 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. This study showed clinically acceptable marginal discrepancy of all groups tested.

There were some limitations in this study. Marginal opening was measured in this experimental design, but the internal fit of the crowns was impossible to measure with the use of metal master dies. Although certain investigations focused on marginal fit, other investigators[1,14,15] 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 present 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 the lack of artificial aging of the crowns via thermal cycling which might affect the results. Further investigations are required to identify the effect of chamfer finish line on the breaking strength of fiber reinforced composite crowns.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. The tooth preparation design of fiber-reinforced composite crowns resulted in different degrees of marginal accuracy.
2. The three tooth preparations tested had marginal openings of less than 100 μm.
3. Significant differences were found among the die material for the shoulder margin design. However, there was no significant difference between light chamfer and deep chamfer margin designs for both die materials.

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