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ORIGINAL RESEARCH

Fracture Strength of Posterior Crowns made of Adoro and Gradia Fiber-reinforced Composites

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ABSTRACT

Aim: The aim of this study was to assess the fracture strength of posterior crowns made of Adoro and Gradia fiber-reinforced composites (FRCs).

Materials and methods: In this *in vitro*, experimental study, extracted sound 37 maxillary first and second premolars were selected. A celluloid index was taken from teeth and the teeth received crown preparation. Impressions were made and poured. Composite crowns were fabricated of Adoro and Gradia composite resins. After curing, the teeth were immersed in distilled water for 24 hours and thermal cycled for 6,000 cycles between 5 and 55°C. Load was applied at a crosshead speed of 1 mm/minute and the fracture strength was measured. Specimens were inspected under a stereomicroscope to determine the mode of failure.

Results: The fracture strength was 1,631.77 N for Gradia and 1,569.84 N for Adoro. The difference between the fracture strength of the two groups was not significant ($p > 0.05$). The mode of failure was cohesive in composite in 7 specimens and adhesive between composite and fiber in 12 specimens in the Gradia group. In the Adoro group, the mode of failure was cohesive within composite in 11 specimens and adhesive between composite and fiber in 7 specimens. Complete tear of fiber did not occur in any group.

Conclusion: The fracture strength of Gradia and Adoro composites is not significantly different.

Clinical significance: Cohesive fracture within the fiber did not occur in any case in our study and the mode of failure was adhesive at the fiber–composite interface or cohesive within the composite in most specimens.

Keywords: Composite resin, Crown, Gradia, Laboratory.

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INTRODUCTION

One important goal in prosthetic dentistry is to replace the missing teeth and restore the lost tooth structure. In dentistry, tooth restoration is the art and science of replacing the lost tooth structure with a restorative material.[1] Prosthetic dentistry aims to improve the quality of restorative treatments in terms of esthetics and preservation of tooth structure.[2,3] The patients' high demand for esthetic restorations and high strength of composite resins play an important role in the extensive use of direct composite resins. Restorations should be able to tolerate forces and must be biocompatible.[4-7]

Porcelain fused to metal (PFM) restorations were introduced about 30 years ago and are still one of the most popular restorations due to their longevity, acceptable esthetics, and high clinical success.[8-10] Porcelain fused to metal crowns have a 97% 10-year survival rate. Failure of these restorations mainly (65%) occurs in the anterior region (impact or traumatic zone).[11] Clinical examinations have shown that PFM restorations may cause allergic reactions or have toxic side effects (metal ions are released into the periodontal tissue) and have poor esthetics in margins because of metal exposure.[5,12-14] Some of their components may have acute or chronic health risks for the laboratory staff.[15,16] Metal alloys are firm and strong, but they do not have the desired esthetics and also need overpreparation of tooth, especially in marginal areas. Metal-free restorations like ceramics and resin materials were introduced to dentistry to improve esthetics. All-ceramic restorations have favorable esthetics but they are hard and brittle. They can cause wear or fracture of the opposing teeth as well[17] and in comparison with PFM restorations, the former group has a higher failure rate and lower mechanical properties.[10,18,19] Also, they require greater removal of sound tooth structure. All-ceramic restorations are not very conservative and their utilization is costly and time consuming.[8,10,20] Studies have shown that PFM restorations have a survival rate of 92% in 10 years, 75% over 15 years, and 93% in 5 years. In all ceramic fixed partial dentures, the survival rate is over 5 years.[11]

Fiber-reinforced composites have optimal esthetics and mechanical properties, and easier reparability in the oral environment. Fiber-reinforced composites enable adhesive, esthetic, and metal-free restoration of molar teeth.[21] They are heterogeneous and anisotropic, which means their properties are related to forces and position of fibers. Unidirectional fibers in FRCs have the highest strength in their direction and the lowest strength perpendicular to their fiber direction. Therefore, in single crown restorations, multidirectional fibers, unidirectional fibers, or braided or woven fibers with 45° angle play the role of metal in single crowns and help in load distribution; therefore, the strength and stiffness of FRC crowns depend on the type of fibers and composites and it is better to use glass fibers.[17,22]

Adoro and Gradia are the two commonly used FRCs. Adoro composite is micro-filled and homogeneous. In order to increase its strength and decrease its shrinkage, this copolymer is mixed with mineral micro-fillers. Its monomer is urethane dimethacrylate (UDMA), which has low water sorption and improved mechanical and physical properties. Gradia composite is a micro-filled hybrid composite with UDMA monomer and silica fillers, which are prepolymerized and improve its mechanical and physical properties.[23]

Gradia Direct is a composite that is polymerized with light (light-cured). This composite has many desirable properties, such as optimal esthetics, polish ability, wear resistance, and fracture toughness. This composite is tooth-colored and supersedes enamel properly. Some *in vitro* studies showed that FRC restorations have better fracture strength and marginal adaptation than some ceramic restorations.[24,25] The fracture strength of FRC single crowns depends on various factors, such as the component's modulus of elasticity, luting agent, restoration thickness, and mechanical properties of fiber, type of fiber and matrix, adhesion of fiber and resin matrix, and composite type.[26-28]

The aim of this study was to assess the fracture strength of posterior crowns made of Adoro and Gradia FRCs.

MATERIALS AND METHODS

A total of 37 first and second maxillary human premolar teeth extracted for orthodontic or periodontal reasons were collected and immersed in 0.1% chloramine solution. All teeth were mounted in putty (Speedex, Colene, Germany) and evaluated by a surveyor. A celluloid index was made for adequate composite thickness in all crowns (Figs 1 and 2). For tooth preparation, according to the manufacturer's instructions, preparation depth was 1.5 mm in cusps, 1 mm in central fossa, and 0.8 mm in finish line. The finish line had shoulder preparation.

Preparation of both teeth was done using a flat-end tapered diamond bur (0.8 fissure bur, Prima, UK) with 3 mm length underwater spray. For tooth preparation, an index was made with half of diamond bur diameter in cusps and one-third of bur diameter in central fossa and occlusal surface.

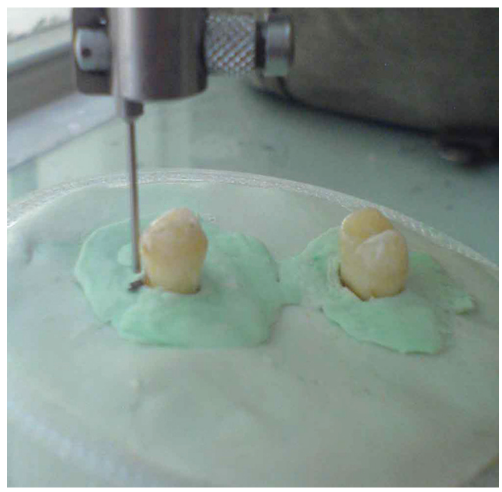


Fig. 1: Specimen surveying in the putty

Fig. 2: Celluloid shell fabrication

We used a 0.8 mm flat-end tapered bur for the shoulder finish line. After preparation, the diamond bur was placed completely in the finish line space to simulate the clinical setting impression that was made with an addition of silicon (President, light body polyvinyl siloxane, Colten, Germany) and poured with type IV dental stone (Fuji rock, GC, Japan). The finish line was distinguished on the die and the die spacer was used.

Adhesive C was used in the mold and on the die and the fiber was placed in the mold. This complex was vacuumed for 2 minutes and cured for 6 minutes. In this step, fiber coping was separated from the die and cured with light cure for 5 minutes (Fiber x-lab, Angelus Dental Properties, Ruagoias 2200, Londrina PR, Brazil).

For polishing, the outer surface of coping was sandblasted. The distance from the coping margin to the finish line was painted on the coping (G-Bond, GC Tokyo, Japan; Excite, Ivoclar-Vivadent AG, Schaan, Liechtenstein) and dried for 1 minute. Next, a thin layer of Adhesive F was applied on the coping to improve the adhesion of composite resin and cured for 3 minutes. Finally, a mold releaser was applied on the die and the composite was placed on the coping. After the restoration was fabricated on the die, excess material was removed with a hand piece and crowns were cemented with dual cure cement (Panavia 2.0, Kuraray, Japan); 0.5 to 1 mm of the margin was shortened and after the seating of crown, margins were reformed.

To simulate the oral environment, specimens were immersed in distilled water for 24 hours and thermal cycled (6,000×; 5–55°C) with a transfer time of 30 seconds. Specimens were mounted in 2 × 3 cm molds filled with acrylic resin (Acropars, Marlik Medical Co., Iran) using a surveyor (Fig. 3).

After thermal cycling, specimens were placed in a universal testing machine (Zwick-Roell, Ulm, Germany) to measure their fracture strength. The load was applied at a crosshead speed of 1 mm/minute. Specimens were then inspected under a stereomicroscope to determine the mode of failure (Zeiss, Göttingen, Germany). Data were analyzed using independent t-test, Kolmogorov–Smirnov test, and Kaplan–Meier analysis.

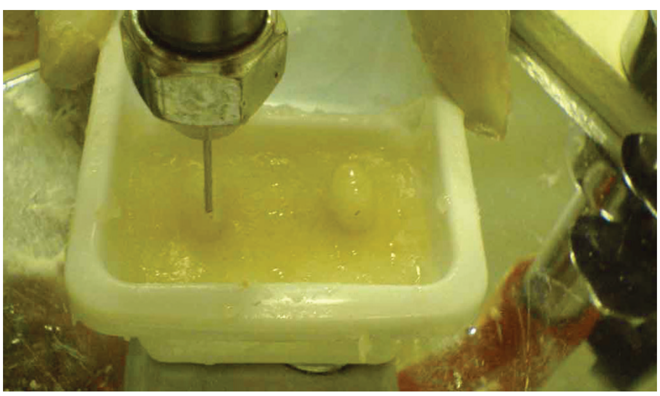


Fig. 3: Mounting in acrylic resin

RESULTS

The fracture strength of the two groups was compared and it was found that the fracture strength of all specimens was above 300 N (Table 1). The normal distribution of data was evaluated using Kolmogorov–Smirnov test, which confirmed the normal distribution of data. Independent t-test found no significant difference between the two groups in terms of fracture strength (Table 2). Assessment of specimens under a stereomicroscope revealed that the mode of failure was cohesive in the composite in 7 specimens and adhesive at the composite–fiber interface in 12 specimens in the Gradia group. The mode of failure was cohesive within the composite in 11 specimens and adhesive at the fiber–composite interface in 7 specimens in the Adoro group. Fibers did not tear completely in any specimen.

Survival graph showed that the two groups had similar fracture strength (the higher the fracture point, the higher the fracture strength) (Graph 1).

DISCUSSION

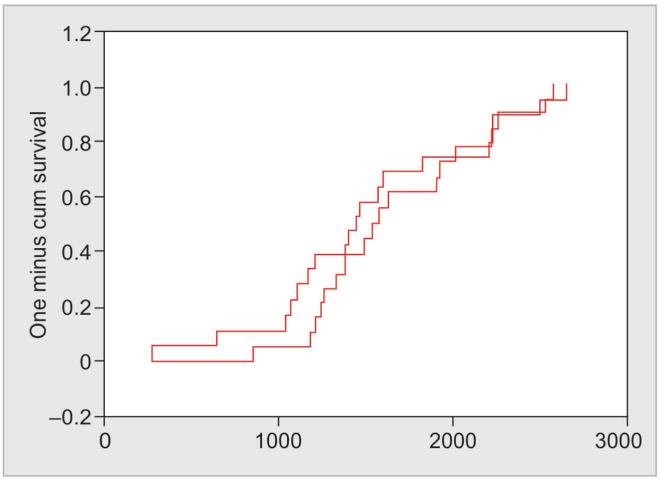
The FRCs has two components of composite and fibers and both composite and fiber type can influence fracture strength.[10,29] Adoro and Gradia composites are two commonly used FRCs. Adoro is a homogeneous, micro-filled composite and Gradia is a micro-filled hybrid composite. They have different fillers but both have UDMA

Table 1: Fracture strength of two groups

Adoro second group	*Force (Newton)*	*Gradia first group*	*Force (Newton)*
1	1,044	1	1,382
2	1,067	2	1,341
3	1,498	3	1,580
4	2,023	4	2,582
5	1,926	5	2,206
6	1,210	6	1,385
7	1,577	7	1,602
8	1,540	8	1,243
9	1,169	9	1,259
10	2,225	10	2,270
11	1,105	11	1,175
12	1,630	12	1,398
13	1,931	13	1,466
14	2,498	14	2,528
15	2,656	15	1,830
16	280	16	1,216
17	643	17	1,449
18	2,227	18	2,231
		19	852

Table 2: Independent sample t-test

		Levene's test for equality of variances		t-test for equality of means						
									95% confidence interval of the difference	
		F	Sig	t-value	Degree of freedom	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Fracture resistance	Equal variances assumed	0.924	0.343	–0.33	35	0.743	–61.923	187.559	–442.688	318.82
	Equal variances not assumed			–0.328	32.124	0.745	–61.923	188.84242	–446.524	322.67



Graph 1: The survival graph of fracture resistance of two groups

monomer. They have improved mechanical and physical properties.[23] In FRCs, composite component affects the strength of restorations.

The aim of this study was to assess the fracture strength of these two FRCs. In our study, glass fibers were used in both groups. Stiesch-Scholz et al reported that glass fibers can increase the fracture strength even after the fracture of specimens and they reported no breakage in fibers.[22,30] The fracture strength of composites can be improved by unidirectional or multidirectional use of glass fibers. It can change the fracture mode of composite resins.[31] In addition, our study showed equal fracture strength of the two composites in single crowns. Rudo and Karbhari[13] stated that polyethylene fibers have low modulus of elasticity and high flexibility. In our study, fractures occurred at the composite and fiber interface and also within the composites, but none of the specimens showed tear of fibers, which was in line with the results of Behr et al.[22] They also reported fracture at the interface or within the composite.

Based on our results, the fracture strength of Adoro and Gradia composites was not significantly different (Wigren search, Nakayama search). Mange et al revealed that Belle Glass composite, Enamel Plus, Cristobal, and Targis had the highest fracture strength and mechanical and physical properties, while Sinfony composite had the lowest fracture strength. Gradia, Adoro, Dialog, Solidex, and Signum composites had moderate mechanical and physical properties.

The fracture strength of FRC crowns depends on other factors like modulus of elasticity of supportive base, occlusal force, procedural steps, and applied material.[25] In our study, high-temperature polymerization was performed in a laboratory. Song et al reported that the use of high-temperature polymerization may cause a reduction in free monomer amount in the composite resin and may result in better polymerization and mechanical and physical properties in comparison with manual light curing.[26]

Thermal cycling simulates heat shocks and stresses in the oral environment and decreases the fracture strength of restorations. Behr et al[32] claimed that the fracture strength of molar crowns made of Tagris-Vectris and cemented with Variolink 2 decreased considerably after thermal cycling.

Lehmann et al[10] showed that FRC increases the fracture strength of crowns. Manufacturers use impregnated fibers which are well wetted by resin compared with manually impregnated fibers; hand impregnated fibers have lower mechanical properties as well.[17]

Some limitations of our study were related to the performance of the operator in each specimen and possible gap formation during composite packing. Future studies are recommended to use computer-aided design/computer-aided manufacturing systems to minimize procedural errors related to the operator.

CONCLUSION

Our results showed no significant difference in the fracture strength of Gradia and Adoro composites. The fracture in Gradia FRC specimens dominantly occurred at the fiber and composite interface, whereas fractures were mainly within the composite in the Adoro FRC group.

CLINICAL SIGNIFICANCE

Cohesive fracture within the fiber did not occur in any case in our study and the mode of failure was adhesive at the fiber–composite interface or cohesive within the composite in most specimens.

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