Original Article

Comparison of two types of ceromer molar crowns on their fracture resistance: An *in-vitro* study

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GC Gradia and Signum+ are two different types of ceromer available for clinical use in the last few years. They showed an excellent esthetic and clinical success; however, their fracture strength needed further investigation. The aim of this study was to compare the fracture resistance of these two ceromers in a situation that simulates clinical conditions. Twenty extracted human mandibular molars, similar in their dimensions, were selected and prepared. After tooth preparation, impressions were taken and casts were made. Ten molar crowns were fabricated with GC Gradia and the other 10 molar crowns were made of Signum+ at random. All the molar crowns were luted on human molars with a resin cement named Dual-Cement. After all samples were thermally cycled, they were loaded mechanically to fracture using a universal testing machine (Instron). At the fracture moment, data were registered. Statistical analysis was performed and the results showed that the fracture resistance of GC Gradia (2652/75±511N) is higher than Signum+ (2106/09±304N). A Mann-Whitney test showed statistically significant differences between the two systems (P = 0.029). Since both systems exceeded the fracture strength required to withstand the maximum masticatory force in the molar region, they can be used to fabricate single molar crowns, but probably GC Gradia can be used with more confidence in the clinic.

Key words: Ceromer, fracture resistance, fiber-reinforced composite

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INRODUCTION

The crown, a cemented extracoronal restoration, has been used in dentistry for a long time.[1] Different types of material have been used to construct it and there has been a great improvement in their quality in the last few years. Recent concerns on the esthetic aspects of reconstructions have demanded more from new materials. Although all-ceramic restoration is the most esthetic among all materials, its brittleness became a weakness.[2] Another objection to this material is its abrasiveness specially when it is placed opposed to natural teeth. In addition, the preparation for this type of restoration requires the removal of a large quantity of tooth structure.[3]

The recently introduced ceromer / fiber-reinforced composite (Ceromer / FRC) systems, which provide an attractive alternative to ceramic and resin materials have enhanced the physical properties, improved esthetics and increased the durability of the restorations.[4,5] Because of their excellent flexural quality, they can be used for esthetic posterior crowns and anterior fixed partial dentures.[6] Since their main content is the dental composite, they are less abrasive compared to ceramic materials.

Although these materials are new to dentistry, many other industries have found different applications for them because of their desirable characteristics.[7]

Ceromer, a second generation of indirect composite, contains sialinized microhybrid inorganic filler embedded in a light-polymerized organic matrix.[8] Fiber-reinforced composites are sialinized fibers of different material that can be placed in a matrix of composite.[9] Some FRC substructure materials retain a sticky, oxygen-inhibited surface layer that allows for direct chemical bonding with a veneer composite, thereby eliminating the need for mechanical retention associated with metal substructure.[10]

Fracture resistance is one of the most important criteria defining long-term success.[11] This feature of a material is dependent on the elastic modulus of the supporting substructure, properties of the luting agents, tooth preparation design, surface roughness, residual stress and restoration thickness.[12]

Ceramic fracture initiates at flaws and pores. The apparent fracture strength of ceramic restorations increases if they are bonded to dentine with resin cements.[13] One study concluded, as the elastic modulus of supporting material increased the fracture strength increased.[14]

However, very few studies have been performed that investigate the fracture resistance of the ceromer / FRC crowns. Targis / Vectris, sculpture, Belle Glass, GC Gradia, Signum+ are some of the examples of many FRC systems that have been introduced, and a few clinical trials have investigated their successes. Signum+ and GC Gradia are the two new ceromers available for clinical use in recent years. In contrast to much research on the fracture resistance of ceramic crowns, providing clinical guidelines for their uses, ceromer / FRC systems have very few reports on their fracture strength.

The aim of this study was to compare (*in-vitro)* the fracture resistance of a single molar crown made of two different ceromer / FRC systems. The hypothesis stated that there are significant differences in fracture resistance of these two systems due to many differences in the composition of materials and techniques that were used for their preparation.

MATERIALS AND METHODS

Twenty extracted human third mandibular molars were selected with respect to their dimension and intactness (no apparent caries). They were stored in 0.1% hypo chloride solution no more than one month.[15]

The teeth were cleaned and their roots were covered with a 1 mm thick elastic layer of polyether impression material (ESPE, Impregum, Germany) to stimulate the function of periodontium and to give teeth a slight mobility similar to the normal oral condition,[16] then all 20 teeth were inserted in PMMA resin (self cure acryle, Acroparse) blocks which were designed to have a step 1 cm from the top. This step acted as an indicator for the correct tray placement during the impression phase.

For preparation, a flat-end-tapered diamond bur with 1 mm diameter was used. The preparation applied for all teeth was a 2 mm occlusal reduction and 1 mm axial reduction with the creation of a 1 mm wide shoulder margin in enamel 1 mm above CEJ? as a finishing line.

For preparing all the teeth close to the original design, we used a putty index made of heavy body impression material (Speedex Putty, coltene). In the restorative phase we reused these indices to even the thickness of the composite material in construction of the crowns.[2] One of the concerns was to provide a definite standard convergence angle for all the preparation and to achieve this purpose a milling machine was used [Figure 1].[17] Each mounted tooth was placed on the horizontal plate of the device and a high speed hand-piece hung from the top and parallel to the long axis of teeth refreshed all the margins to sustain a 3 to 5° of tapering [Figure 2].

Then all of the samples were kept in normal saline, since research by Insou *et al*. has shown that sodium hypochlorite can have some etching effect on dentine that may change the bonding strength of adhesive resin cement.[18]

An initial impression was taken from each tooth by using alginate, then all of them poured with plaster stone, and the primary casts of all teeth prepared. A specific type of tray for taking the final impression of these single models was fabricated on these primary casts using self-curing acryle (Acroparse, Iran). When all casts were ready, the prepared parts of the teeth were covered with a 2 mm thick wax sheet to create an even relief for the impression material. The impressions were taken using the specific trays with a condensational silicon impression material (speedex putty and light body, coltene).

Every impression was checked on its occlusal and marginal surface for any bubble or inaccuracy. All the impressions were poured with vacuumed type IV dental stone within 10 minutes after the impressions were taken.

Master dies (n = 20) were randomly divided into two groups. One group was used to make single crowns made of Signum+. GC Gradia, a microceramic composite, was the other material used to build up single crowns for the second group.

The casts of the first group were insulted with a 0.1 to 0.2 mm thickness separator about 1 mm above the finishing line. The finishing line was marked with a special color pencil, carbon free. The margins were covered with Signum+ margin paste and polymerized for 90 seconds with Heraflash unit (Heraeus Kulzer, Germany). Then, a 1 mm thick cap made of Signum+ dentine paste was light-cured for 90 seconds.

Another layer was placed on the first one and processed in Heraflash unit (Heraeus Kulzer, Germany) for another 90 seconds. For the final polymerization every sample was processed in Unix unit (Heraeus Kulzer, Germany) for an additional 3 minutes. After controlling the thickness of every sample with a digital gauge, final polishing was performed with stone points, rubber, and wheel instruments following the manufacturer's recommendations (Polier set, Ivoclar). A total of 10 Signum+ single crowns were fabricated. Before cementation procedure started, the inner surface of every crown was abraded with 50 µm Al2o3 at 15 Psi for 20 seconds and steam cleaned.

In the second group, the 0.1 to 0.2 mm thick insulator was used to cover the casts down to 1 mm above the margin. One mm of margin was constructed, using shoulder dentine paste, and cured for 10 seconds, then a 1 mm think composite was formed on dies down to 1 mm of margin and initially cured for 10 seconds with GC step light SL-1(GC, Germany), and 1 minute with GC labolight LV III (GC, Germany). For final polymerization all samples were put in

Figure 1: A milling machine, with a holding plate and a hanging handpiece

Figure 2: In final refreshing of the finishing line, a milling machine was used to parallel the bur to long axis of the teeth

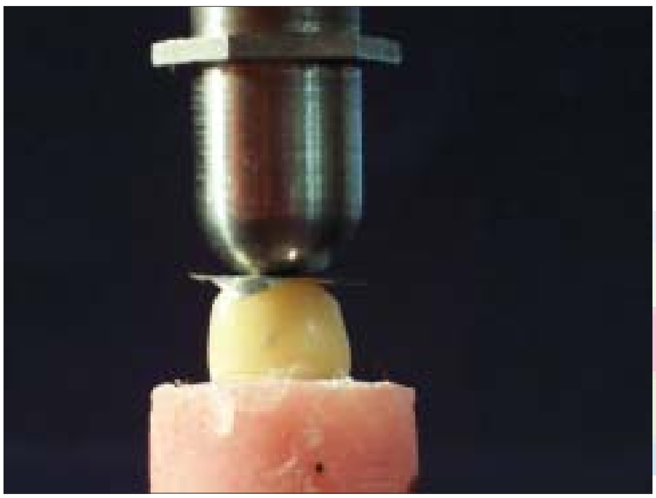

Figure 3: In the interface of the steel ball of Instron machine and the crowns, a tin foil was inserted to avoid local force peak

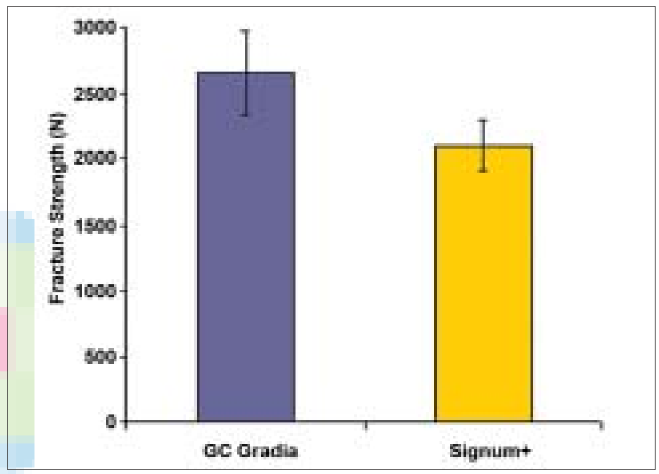

Figure 4: Comparison of the fracture strength of the two materials of interest with 2 SE indicator

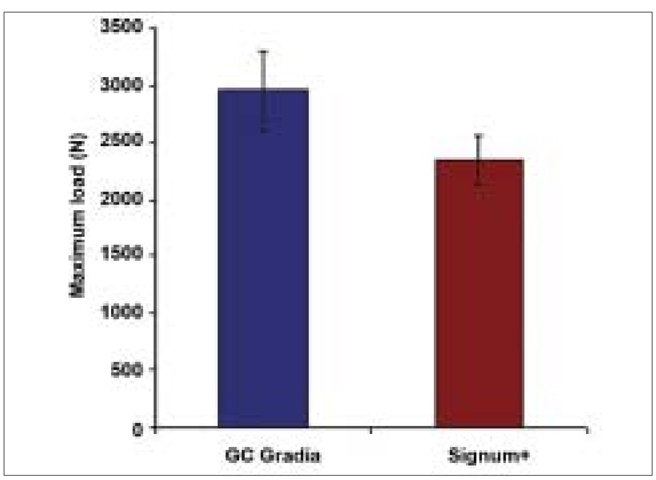

Figure 5: Comparison of the maximum load of the two materials of interest with 2 SE indicator

labolight LVIII for 3 minutes. Finally all the crowns were checked for appropriate thickness with a digital gauge and final polishing was performed with stone points, rubber and wheel instruments (Polier set, Ivoclar Vivadent).

Before cementation all crowns were seated on their teeth and checked for their fitness by using a fit-checker material. They were cemented using dual polymerizing resin cement. First all the internal surfaces of the crowns were cleaned using an oil free cleaning steam, then a thin layer of sialine (monobond-s, Ivoclar Vivadent) was applied to these surfaces and left to dry for 60 seconds.[19]

All teeth were acid etched using phosphoric acid 37% (Total Etch, Ivoclar Vivadent) for 25 to 30 seconds, then they were cleaned and dried, but attention was paid to avoid excessive drying. A thin layer of bonding was applied to the internal surface of crowns (Excite, Ivoclar Vivadent) and cured for 20 seconds with light cure unit (Coltolux, Coltene, 530 watt / cm^2). Then a thin layer of bonding material (Excite, Ivoclar Vivadent) was applied. After waiting for 20 seconds, the bonding layer was cured with light cure unit for

Table 1: Fracture strength of ceromer crowns

Mean (N)	SD	Ceromer type
2652/75	511	GC Gradia
2106/09	304	Signum +

Table 2: Maximum load bearing of ceromer crowns

Mean (N)	SD	Ceromer type
2947/5	567	GCa Gradia
2340/8	337	Signum +

40 seconds. For cementation, even portions of catalyst and base of dual cement (Dual, Ivoclar Vivadent) were mixed and applied to the internal surfaces of crowns, and the crowns were put back on their related teeth and after assurance of the fitness and removing all the excessive cement around the margins, all the surfaces of crowns were cured for 40 seconds with a light curing unit (coltolux 500/coltene, 530 watt/cm^2). Then, all the samples underwent thermal cycling for (6000 cycles), and re-stored in a dry room for 24 hours before fracture loading.[2]

Fracture strength testing of ceromer crowns was performed using a universal testing machine (Instron-corpMA-4302R). Force was axially applied to the crown center with a steel ball of 12 mm diameter at a cross-head speed of 1 mm/min.[20] A tin foil with 0.4 mm thickness was inserted between the steel ball and the crown to avoid local force peak [Figure 3].[21] All crowns showed abrupt failure. The force was registered at the fracture moment. Failure strength was set at 10% below the maximum registered load force, since fiber reinforced/ceromer crowns demonstrated decreasing load bearing capacity and increasing deformation of the crown caused by de-lamination of the fillers and matrix.[20]

RESULTS

The statistical analysis was performed using the program SPSS 8.0 (SPSS In, Chicago, IL), and means and standard deviation were calculated [Table 1 and 2]. Statistical differences were calculated with the Mann-Whitney test. The level of significance was set at P = 0.05. Fracture strength of both ceromers as posterior single crowns was high. Both showed values more than the masticatory force in the molar regions; however, fracture strength of microceramic composite, GC Gradia, was higher compared to Signum+ (2106.09 $\pm$ 304), an organic glass containing composite [Figures 4 and 5]. The difference between two groups was statistically significant (P = 0.029).

DISCUSSION

The type and percentage of fillers' content, types of resin, coupling between fillers and matrix, condition of polymerization and some other factors affect the mechanical properties of composites. Other than mechanical properties of composite, the type of bonding, and the level of adhesion between the tooth and the composite are important factors affecting the physical properties of a crown.[22]

Marginal leakage, abrasion resistance, polishability, and flexural strength are some of the criteria for validating the clinical success of a dental material. The fracture resistance which is the basis of our research is one of the most important criteria that define the clinical success of a crown or a bridge.[23] Fracture resistance in a clinical crown is influenced by several factors such as the material used, cementation condition, loading manners, prior artificial aging, and elastic modulus of the supporting material.[12]

Sherrer *et al.* concluded that as the elastic modulus of the supporting material increased, the fracture strength shows higher values.[14] If metal dies were used as the supporting model, their fracture strength would be higher compared to using natural tooth as supporting material, since elastic modulus of natural teeth (12 Gpa) is very much lower than metallic dies (100 Gpa).[24] According to Lee Ra Cho *et al.*, in a pilot test, non-axial loading produced fracture of the cervical portion in natural teeth and in the epoxy resin dies compared to metal dies. Also, natural teeth showed a lot of variations that make the comparison difficult. They concluded that metal dies are a better choice for investigating the fracture resistance.[2] On the other hand, in a study by Rosentritt *et al*, they declared that the high *in-vitro* fracture value of all-ceramic crowns on artificial materials may lead to a misinterpretation of tested restorative material, accepting ("except"? Or "given the"?) mechanical properties of material in the first preclinical estimations. Human teeth or materials with a comparable modulus of elasticity are therefore preferred for *in vitro* fracture resistance testing.[25]

In this study we used natural teeth so that the impact of adhesive cementation could be tested, but the variation among natural teeth in their pattern of hydroxyl appetite structure, dimension, history of every tooth, and differences in the preparation is the shortcoming of the method and results in a broad standard deviation of the values.[13] However, according to M. Rosentritt this standard deviation is acceptable in using natural teeth as supporting dies. In our study, all crowns were treated before cementation with sandblast and sialinization.

In their study Behr *et al.* showed that the pre-treatment of the inner surface of the crown has some impact on their fracture strength.[26]As they indicated, without pre-treatment the interface of cement and crown deteriorates markedly. Unresolved composite from the finishing process can be one reason. Also the O2-inhibited layer which impacts the bond strength is often removed by finishing. Besides, sialine and coupling agents are widely used; they condense on the surface of inorganic glass fibers or fillers and bond chemically to them. With their bi-functional groups they offer further bonds to organic monomers of the resin cement.[27]

Doyle *et al*. reported that a larger occlusal convergence angle of abutment increases the fracture strength of all-ceramic crowns. Perhaps a larger angle would result in a thicker axial restoration material in the crown, in addition to decreasing the seating pressure.[28]

In contrast, Lee Ra Cho *et al*. reported that as the convergence angle of preparation becomes less acute, the fracture strength of ceromer crowns decreases.[2] We tried to even the convergence angle in all samples and keep it as standard as possible by using a milling machine for final finishing of tooth preparation. The environment used in this investigation allowed the control of some of the parameters such as the temperature, the loading force, and the tooth movement under loading. However, little is known about the correlation between clinical conditions and the loading parameters provided in the literature, but our study followed established loading and environmental parameters in the literature.

It has been stated that thermocycling and mechanical loading (TMLC):6000 × 5°C / 55°C; 1.2 × 10 × 50 N, 1.66 HZ simulate 5 years of wear.[2] There are still some controversies among different researchers about the effect of the thermocycling and mechanical loading on the physical properties of the crowns. Since the condition was the same for both groups in our study, it made comparison possible. We should remember that our loading axis was unidirectional and parallel to the long axis of teeth. This is different from what occurs during mastication, which has multidirectional forces on the teeth.

Etching and cementation has been done in an ideal condition with minimal contamination, which isn't comparable to oral environment especially with resinous cements; contamination poses a problem to the amount of adhesive strength.

The fracture strength of single crowns made of these two ceromers, GC Gradia and Signum+, was greater than the maximum chewing force of 300 N found in patients with bruxism and markedly higher than the average force of 35-70 N by Eichner in normal patients.[29] However, the maximum occlusal force that has been reported in literature varies widely. The mean adult occlusal force is about 400 to 800 in the molar region, 300 N in the premolar and 200 N in the anterior region.[30]

The fracture resistance recorded here for both GC Gradia and Signum+ was higher significantly than reported in literature for conventional all-ceramic crowns. The apparent fracture strength increases in ceramic restoration bonded to dentine with a resin cement.

There was only one study done to compare these two restorative materials, and that was based on their flexural strength; there were no statistically significant differences between them in contrast to the differences that we found in our research between these two on the base of their fracture resistance. This emphasizes the importance of creating a more realistic situation, closer to the clinical application of the material.

CONCLUSION

Within the limits of this study, the mean fracture strength was 2652.7($\pm$511) for GC Gradia and 2106.09($\pm$ 304) for Signum+. They both showed higher values than what is needed for bearing the normal occlusal force according to the literature. Since GC Gradia showed a higher value, it may be used in the clinic with more confidence. But further investigation is needed to compare other physical properties of these materials, which are very important in clinical success, such as microleakage, wear resistance, esthetic and cosmetic values.

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