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In vitro Comparison of Flexural Strength of a Bioactive Composite and a Reinforced Hybrid Glass Ionomer

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A B S T R A C T

Objectives: The present study was conducted to compare the flexural strength of a bioactive composite and a reinforced hybrid glass ionomer (GI).

Materials and Methods: In this in vitro experimental study, 10 rectangular-shaped specimens were fabricated from Activa Bioactive composite (N=5) and EQUIA Forte Coat GI (N=5) using stainless steel molds with internal dimensions of 2×2×25mm according to the manufacturers' instructions. The flexural strength of the specimens was measured with a universal testing machine with the three-point bending test using a load of 50±16N/min at a crosshead speed of 0.75±0.25mm/min. The data were analyzed using the Mann-Whitney U test (α=0.05).

Results: The mean flexural strength was 57.91MPa for the bioactive composite and 19.20MPa for the reinforced hybrid GI. The mean flexural strength of the bioactive composite was significantly higher than that of hybrid GI (P=0.008).

Conclusion: Within the limitations of this in vitro study, the results indicate that the Activa Bioactive composite exhibits greater flexural strength compared to EQUIA Forte Coat GI.

Keywords: ACTIVA BioACTIVE-RESTORATIVE; Flexural Strength; Glass Ionomer Cements

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INTRODUCTION

Inadequate flexural strength of restorative materials is a common concern in restorative dentistry [1]. Adequate flexural strength is an essential prerequisite of all restorative materials and plays an essential role in their long-term durability and clinical service [2]. Since the introduction of hybrid glass ionomers (GIs) as a restorative material for the posterior teeth, their mechanical properties have been the topic of many investigations to estimate their clinical durability [3].

In the synthesis of hybrid GIs, the resin is added to the glass matrix as filler [4-8]. The volume and amount of filler are the most important determinants of the flexural strength of GIs. Higher flexural strength confers resistance against the masticatory forces [9] The recommended indications for Equia forte according to the manufacturer's instructions include core buildup and class I, stress bearing and non-stress bearing class II, intermediate, class V, and root surface restorations.

Fracture is among the leading causes of the failure of restorations. Restoration fractures occur when cracks created during the

application of restorative material or polishing propagate as the result of the exertion of tensile forces [10]. The microstructural properties of restorative materials are the most critical factor in the initiation of cracks since they can cause stress accumulation on the surface and crack formation [11].

Bioactive composite resins contain bioactive ionic shock-absorbing rubberized resin matrix and bioactive fillers. According to some studies, the use of bioactive fillers in the composition of ActivaTMBioActive restorative composite resin affects its flexural strength, producing a flexural strength comparable to that of conventional composites and even higher than that of conventional and resin modified GI cements [12-14]. However, some other studies refuted this statement and reported that adding bioactive glass fillers to composite resins decreased their flexural strength [15-17]. A study showed that adding bioactive glass fillers to composite resins resulted in adequately high flexural strength [18]. Considering the controversies in the results of studies and the small number of studies that investigated the flexural strength of Activa Bioactive composite compared to other restorative materials, the present study was conducted to compare the flexural strength of Activa Bioactive composite resin and EQUIA Forte Coat GI. The recommended indications for Activa Bioactive in the absence of pulp involvement according to the manufacturer's instructions are cl I, II, III, IV, V restorations.

The null hypothesis was that there was no significant difference in flexural strength of Activa Bioactive composite resin and EQUIA Forte Coat GI.

MATERIALS AND METHODS

In this in vitro experimental study, 10 rectangular-shaped specimens were fabricated from ActivaTMBioActive composite (N=5; Pulpdent, Watertown, MA, USA) and EQUIA Forte Coat GI (N=5; GC, Japan) using stainless steel molds with mm internal dimensions of 2×2×25mm according to the manufacturers' instructions. The A2 shade of the restorative materials was applied in the molds.

Five samples were included in each group according to ISO 40492000 [19].

Table 1 presents the properties of Activa Bioactive composite and EQUIA Forte Coat GI. The powder to liquid ratio was 0.4 to 0.13 in EQUIA Forte Coat GI capsules. The capsule was first shaken for 2-3 seconds and then placed in an amalgamator (Ultramat 2; SDI) for 10 seconds at 4000rpm. Next, the capsule was placed in its respective syringe (Capsule Applier III; GC, Japan) and its contents were dispensed into the mold. The working time of hybrid GI is 1 minute 15 seconds. Thus, it was rapidly applied to the mold. The surface of the specimens was dried by gently blowing with oil free air. The surfaces that are supposed to be coated should be dry but not desiccate. During the first 2 minutes 30 seconds from the start of mix (final finishing commencing time), moisture contamination or drying out should be avoided. If this is not feasible, EQUIA Forte Coat and light cure should be applied immediately. Therefore, 1 to 2 drops of self- adhesive nano-filled bonding agent (EQUIA Forte Coat; GC, Japan) was applied to the specimens by a micro brush (Denbur, USA). The specimens were then light-cured using a LED curing unit (The Light 405) with a light intensity of >500mw/cm^2 for 20 seconds.

Table 1. Properties of glass ionomer and composite resin used in this study

Material	Details	Fillers
Activa Bioactive	Blend of diurethane and other methacrylate with modified poly acrylic acid (44.6%) Contain no bisphenol A, no Bis-GMA, no BPA derivative	Amorphous Silica (6.7%) sodium fluoride (0.75%) Percentage of filler by weigh :56%
EQUIA Forte Coat	Highly reactive Fluoro-alumino-silicate fillers (<4μm) Higher molecular weight polyacrylic acid: cement matrix made stronger and more chemically stable. Leads to higher flexural strength	Reactive Fluoro-alumino-silicate fillers

To prepare the composite specimens, Activa Bioactive composite was applied to the mold. The samples were placed in a stainless steel mold and the mold was placed over a glass slide. Then a layer of transparent celluloid tape and a glass slip was placed over the samples then enough pressure was applied to the mold to remove the excess and void. Curing was performed for 20 seconds by the overlapping technique using a LED curing unit (Demi™Puls;) with a light intensity of 1100µm/cm^2. Each sample was cured with a minimum of 5 curing cycles. Excess flanges of the composite were removed by 800, 1000, and 1200-grit SIC papers used at a 45° angle. Next, the specimens underwent thermocycling for 1000 cycles (Regensbuger, Kausimulator, EGO, Germany) for aging [20].

Prior to the three-point bending test, the width and height of the specimens were measured with a caliper with 0.01mm accuracy (Mitutoyo, Japan). Measurements were made at three points, and the mean value was calculated. The three-point bending test was performed on specimens immediately after removing them from water without drying. According to ISO 4049, the diameter of the two supports and the load application piston was 2 mm. The distance between the two supports was 20mm. The flexural strength was measured using a universal testing machine (Zwick Roell, Ulm, Germany) and reported in megapascals (MPa). For this purpose, a 50±15N/minutes load was applied at a crosshead speed of 0.75±0.25mm/minutes until a catastrophic fracture occurred. The maximum load immediately before fracture was recorded in MPa [9,12]. The flexural strength was calculated using the following formula: $S=3FL/2bd^2$

where S is the flexural strength, F is the maximum load causing fracture, L is the distance between the two arms (20mm), b is the width of the specimen, and D is the thickness of the specimen.

Statistical analysis:

Considering the non-normal distribution of the data, the flexural strength of the composite and GI groups was compared using the Mann-Whitney U test. All statistical analyses were performed with SPSS version 25 at a significance level of 0.05.

RESULTS

Table 2 shows the mean flexural strength of the two groups. According to the Mann Whitney U test, the mean flexural strength of Activa Bioactive composite was significantly higher than that of GI (P=0.008).

Table 2. Mean flexural strength (MPa) of the two study groups (N=5 in each group)

Group	Mean	SD	SE Mean
Glass Ionomer	19.2	1.82	0.81
Bioactive composite	57.91	7.15	3.2

N: number; SD: standard deviation; SE: standard error

DISCUSSION

Flexural strength is commonly measured to assess the strength of restorative materials and their durability under masticatory forces [21]. Flexural strength can better reveal the mechanical properties of such restorative materials because the fracture of specimens under transverse loads is the result of the application of tensile stresses [21]. Under such circumstances, the flexural strength test can simulate the clinical conditions and loads applied by the opposing teeth in the oral cavity. Cattani-Lorente et al. [22] found that the flexural strength test was more sensitive to superficial defects than other tests and reported that higher flexural strength indicated a lower risk of crack formation and higher resistance of cement against corrosion in the aqueous environment. They concluded that the 3-point bending test could better discriminate the materials compared to the diametrical tensile strength test. Thus, the standard flexural strength test according to ISO 4049 was used in the present study [19].

The setting reaction of GI cements occurs in three overlapping steps including dissolution, gelation, and hardening. This process takes 24 hours, and the cement gradually sets within 24 hours after mixing. Evidence shows that the strength of GI cements depends on the gradual degradation of polyacrylic acid copolymers [23,24].

The primary mechanism of the bonding of Activa Bioactive composite to the dental substrate is based on the ionic bonding of two

carboxyl groups (-COO) of the cement to calcium (Ca^{2+}) in enamel and dentin. Activa Bioactive bonds to the tooth structure chemically and micro-mechanically; on the other hand, ionic resin, due to its acidic nature, alters the smear layer and enhances the bond strength. This mechanism explains the acceptable mechanical properties of this composite [25].

The minimum required flexural strength for occlusal restorations is 80MPa according to ISO 4049 [19]. The obtained values in the present study for both restorative materials were below this threshold. Thus, it appears that neither one is suitable for use in high stress-bearing areas such as occlusal restoration of the posterior teeth.

Several studies concluded that the addition of reactive glass fillers could decrease the flexural strength of composite resins [15-17]. Nicolae et al. [26] demonstrated that the addition of bioactive glass fillers by up to 20wt% increased the flexural strength of composite resins while higher values decreased it., reduction of filler silanization can adversely affect the mechanical properties. Korkut al. [27] demonstrated that the addition of 10wt% and 5wt% bioactive glass to composite did not affect the flexural strength while addition of 30wt% bioactive glass decreased the flexural strength. Khvostenko et al. [28] found that the addition of bioactive fillers by up to 15wt% increased the flexural strength due to an increase in the filler volume relative to the composite resin without bioactive glass. They also showed that ion release from bioactive composite resins could cause filler degradation and decreased the flexural strength of these composites. Valanezhad et al. [25] indicated that the addition of bioactive fillers by 10wt% increased the flexural strength while higher values decreased it. They explained that the addition of bioactive fillers by up to 10% created additional bonds to polyacrylic acid in the matrix by occupying the empty spaces in the matrix and improved the mechanical properties, while higher values increased the surface area of bioactive fillers and decreased the bond to polyacrylic acid and subsequently the mechanical properties. Thus, it appears that adding bioactive fillers in percentages higher than 15wt% to composite resins decreases their mechanical properties. According to the manufacturer, Activa Bioactive composite resin has 21.8wt% bioactive filler, which explains its low flexural strength [29]. Shamszadeh et al. [2] reported that the type of the composite matrix plays a more critical role in flexural strength compared to fillers [2]. The manufacturer of Activa Bioactive composite claims that it has a flexible resin matrix along with elastomeric components, which absorb the energy, and includes UDMA, polyacrylic acid, and water. The rubberized shock-absorbing property of the bioactive matrix confers resistance against masticatory forces [30]. In addition, it increases deflection at the break, which indicates fracture resistance of a material [31]. The results were in line with the findings of a study by Pameijer et al. [12] that compared the mechanical properties of a resin-modified GI and a bioactive composite and found that the bioactive composite had significantly higher flexural strength. Accordingly, they recommended it for posterior restorations. This difference can be attributed to the use of different bioactive materials since we used Activa Bioactive composite while they used Activa GI. The results of a study by Girn et al. [13] were also in line with our findings. They concluded that the mechanical properties of the bioactive composite were similar to those of conventional composite and superior to those of resin-modified GI. Chao et al. [14] assessed the flexural strength of different composite resins and concluded that the bioactive composite had the highest rate of deflection at the break. Pameijer et al. [12] measured the flexural strength and flexibility of resin modified GIs and concluded that the flexural strength of Active GI was significantly higher than that of conventional and resin modified GIs.

These studies had similar findings compared to our study and that is higher flexural strength of Activa Bioactive composite compared to EQUIA Forte Coat GI. Future studies are required to assess the effect of storage in artificial saliva on flexural strength

to simulate the clinical setting. Furthermore, the shear bond strength and microleakage of bioactive composites should be investigated in future studies. Clinical trials are also required to assess and compare the clinical durability of bioactive composite resins and hybrid GIs.

CONCLUSION

Within the limitations of this in vitro study, the results indicate that the Activa Bioactive composite exhibits greater flexural strength compared to EQUIA Forte Coat GI.

CONFLICT OF INTEREST STATEMENT

None declared.

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