Original Article

Fracture Resistance and Failure Modes of Lithium Disilicate or Composite Endocrowns

M Altier, F Erol[1], G Yıldırım[1], Dalkilic EE[2]

Department of Prosthetic Dentistry, Yeditepe University, [1]Department of Prosthetic Dentistry, Yeni Yuzyıl University, [2]Department of Restorative Dentistry, Bezmialem Vakıf University, Istanbul, Turkey

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Abstract

Purpose: The aim of this study was to determine the fracture strength of endocrowns made of lithium disilicate ceramic and two different indirect resin composites. **Materials and Methods:** Forty human mandibular molars were randomly separated into four groups (n = 10 in each group) – Group IN: control group, Group IPS: endocrowns made of lithium disilicate ceramic (IPS e.max CAD, IvoclarVivadent, Schaan, Liechtenstein); Group SL: Endocrowns made of Solidex microhybrid composite (Shofu, Ratingen, Germany); and Group GR: Endocrowns made of Grandia microhybrid composite (GC Europa, Leuven, Belgium). In all of the groups, dual-cure resin cement (Relyx Ultimate Clicker, 3M ESPE, St. Paul, MN, USA) was used to cement the endocrowns. All of the teeth were subjected to fracture by means of a universal testing machine (Instron), and compressive force was applied. The failure type and location after fracture were classified. The data were analyzed using one-way ANOVA, Tukey's *post hoc* test, and Chi-square test ($P < 0.05$). **Results:** Group IPS showed significantly higher fracture strength than Groups SL and GR ($P < 0.05$). There was no significant difference between the SL and GR groups ($P > 0.05$). In Group SL, 80% of the specimens exhibited favorable fractures; also, 60% of the specimens exhibited favorable fracture in group GR, and only 10% of the specimens exhibited favorable fracture in group IPS. **Conclusions:** The lithium disilicate ceramic endocrowns exhibited higher fracture resistance than indirect composite groups. Both of the composite endocrowns showed more favorable failure than the lithium disilicate ceramic endocrowns.

Keywords: *Composite resins, endocrown, lithium disilicate ceramic*

Introduction

Severely damaged coronal structure due to caries or root canal therapy has traditionally been restored with a postcore and extra-coronal full-coverage crowns.[1,2] However, the preparation of a postspace inside of a root canal increases the risk of root perforation. With the development of adhesive technologies and materials, more conservative treatments such as endocrowns have been suggested for posterior teeth as an alternative to postcore.[3]

Endocrowns are a new restorative option for endodontically treated teeth consisting of the entire core and crown as a single monoblock unit made out of ceramic or resin composite. It uses the surface of the pulp chamber to obtain stability and achieves retention through adhesive cement.[4] It consists of a central cavity inside the pulp chamber with a supracervical circumferential circular margin. The retention principle of endocrowns includes macromechanical retention from the pulp chamber and micromechanical retention from adhesive resin cements.[5-7]

Endocrowns can be made of different materials such as dental ceramics and resin composites.[3,5,6,8,9] Several

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Address for correspondence: Dr. Dalkilic EE,
Department of Restorative Dentistry, Bezmialem Vakıf University,
Faculty of Dentistry, Istanbul, Turkey.
E-mail: eeliguzeloglu@hotmail.com

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authors have described the clinical procedure for fabricating endocrowns made of modern ceramics in case reports.[3,5,6,8] In a previous study, the survival rate and clinical quality of 19 ceramic endocrowns were determined, and only one endocrown failed after 2 years.[6] Recently, indirect resin composite materials have been suggested as an alternative to ceramics, since they have more biomimetic properties with a similar elasticity modulus to tooth structure. Furthermore, these composite resins are repairable in the mouth and are not as abrasive to opposing tooth structures as ceramic restoration is.[10]

The aim of this study was to determine the fracture strength of endocrowns made of lithium disilicate ceramic and two indirect resin composites. The null hypothesis of this study was that fracture strength of endocrowns is not affected by different materials such as ceramic or composites.

Materials and Methods

Forty noncarious, unrestored human mandibular molars with similar dimensions (mesiodistal: 9.30 ± 1 mm; buccolingual: 10 ± 1 mm) were used with the approval of the Ethics Committee of the Yeni Yuzyil University, Istanbul, Turkey (Number 27/03/2017/019). The teeth were randomly separated into four groups (n = 10 in each group) [Figure 1]. In Group IN (intact teeth), the samples did not receive any root canal treatment or cavity preparation, and they were considered as the control group. In the other three groups, all of the teeth were endodontically treated.

Endodontic procedures

Endodontic access cavities were prepared with diamond burs at high speed, and the pulp tissues were extirpated. The working length of each tooth was determined using #15 K-files (Kendo, VDW, Munich, Germany), and all of the teeth were instrumented to an apical size of #35 with K-files. The step-back technique was used to give a taper with H-files #40, #45, and #50 (Kendo, VDW, Munich, Germany). During preparation, the canal was irrigated with 5.25% NaOCL. After the instrumentation and irrigation, the root canals were dried with absorbent paper points (Meta Biomed, Chungbuk, South Korea) and obturated with gutta-percha (Meta Biomed, Chungbuk, South Korea) and AH Plus sealer (Dentsply De Trey, Konstanz, Germany) using a cold lateral condensation technique.

Endocrown preparation

Occlusal reduction was done about 2 mm above the cement-enamel junction. After occlusal reduction was finished, the internal cavity was prepared inside the pulp chamber by removing the undercut areas of the pulp chamber and aligning its axial walls with an internal taper of 8°–10° using a green diamond tapered bur with rounded end [Figure 2]. The axial walls were prepared from the pulpal side to provide for a standardized cavity margin wall thickness (circumferential butt margin) of 2 ± 0.2 mm. The depth of the intracoronal cavity in the side pulp chamber was 4 mm, which was measured from the internal cavity margin to the floor of the pulp chamber using a periodontal graded probe [Figure 3]. After the endocrown preparation, the orifice of the canal was closed by light-curing resin-modified glass-ionomer cement (Fusion I Seal, PREVEST Denpro, Kashmir, India), which filled the canals up to the level of the pulp chamber [Figure 4].

Then, the teeth were divided into three groups. The materials used in the present study are seen in Table 1.

Group IPS – In this group, each cavity was restored with an endocrown made of lithium disilicate ceramic (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein). The specimens were scanned with a CAD-CAM scanner. The occlusal thickness of each endocrown was 6 mm. The wax sprues were attached to each endocrown before investing in investment material. The preheating cycle was accomplished at 850°C for one hour; then, the molds were placed in a furnace and pressed with IPS e.max Press ingot (MO1) material at 915°C for 20 min. After that, the endocrown restoration was separated and glazed [Figure 5].

Group SL – In this group, each cavity was restored with an endocrown made of Solidex indirect composite (Shofu, Ratingen, Germany). The separating medium was applied to the cavity; then, Solidex indirect composite increments were condensed into the prepared cavity. The occlusal thickness of each endocrown was 6 mm, and the endocrown was removed after initial curing before additional light polymerization was applied.

Group GR – In this group, each cavity was restored with an endocrown made of Gradia indirect composite (GC Europe, Leuven, Belgium). The separating medium was applied to the cavity; then, Gradia indirect composite increments were condensed into the prepared cavity. The occlusal thickness of each endocrown was 6 mm, and the endocrown was removed after initial curing, before additional light polymerization was applied.

Endocrown cementation

The intaglio surfaces of Group IPS were etched with hydrofluoric acid (9% porcelain etch, Ultra Dent, South Jordan, UT, USA) for 20 s. Then, each surface was rinsed with water and dried. The intaglio surface of Groups SL and GR were sandblasted with aluminum oxide particles for 10 s. A universal silane coupling agent (Ultra Dent Products, UT, USA) was applied to the intaglio surfaces of all of the endocrowns and allowed to dry for 60 s. Then, a thin coat of adhesive agent (Single Bond Universal, 3M ESPE, St. Paul, MN, USA) was applied with a disposable applicator.

The prepared tooth surfaces were etched with 37% phosphoric acid gel (Fine Etch 37, Spident, Incheon, South Korea) for 15 s and then rinsed and dried. The adhesive resin single bond was applied and light cured for 20 s. Then, all of the endocrowns were cemented with dual-cure resin cement (Relyx Ultimate Clicker, 3M ESPE, St. Paul, MN, USA). The cement was coated onto the inner surface of the endocrowns, which were seated with light finger pressure and excess luting cement was removed. The resin cement was light activated at the buccal, lingual, mesial, distal, and occlusal directions for 20 s.

Testing procedure

Before testing, each tooth was vertically mounted in self-cured acrylic resin, in customized stainless steel mounting rings. The roots were embedded in resin up to 2 mm below the cementoenamel junction (CEJ). All of the specimens were stored in saline at room temperature for 24 h before testing. The fracture test was carried out in a universal testing machine (3345J7324, Instron, USA), and a stainless-steel ball (6 mm in diameter) was applied vertically perpendicular to the occlusal plane and centered on the occlusal surface of the restoration. Force was applied through a ball with a cross-head speed of 1 mm/s until fracture occurred. The maximum force to produce fracture was recorded in Newtons (N). The fracture surfaces of all of the samples were examined under a stereomicroscope at magnification of ×20 (Serial No: 405-050713152, EMS-405, Chinese), and the fractures were divided into two groups: 1 – favorable fractures at the CEJ level and above and 2 – unfavorable fractures at a level below the CEJ.

Statistical method

Statistical analyses were done with Number Cruncher Statistical System 2007 statistical software (UT, USA) program for Windows. Besides standard descriptive statistical calculations (mean and standard deviation), one-way ANOVA was also used to compare the groups. A *post hoc* Tukey multiple comparison test was utilized to compare the subgroups, and a Chi-square test was performed to evaluate the qualitative data. The statistical significance level was established at $P < 0.05$.

Results

The mean fracture strength of the groups is seen in Table 2. According to results, no significant differences were determined between Group IN and the other experimental groups ($P > 0.05$). When the experimental groups were compared, Group IPS showed significantly higher fracture strength than Groups SL and GR ($P < 0.05$). There was no significant difference between Groups SL and GR ($P > 0.05$).

The results of the groups' failure modes are shown in Table 3. Regarding the mode of failure, the results showed that 80% of the specimens in Group SL exhibited favorable fractures, 60% of the specimens in Group GR exhibited favorable fractures, and only 10% of the specimens exhibited favorable fractures in group IPS.

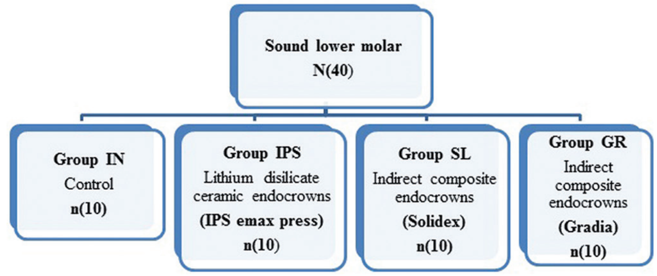

Figure 1: Representation of the groups used in the present study

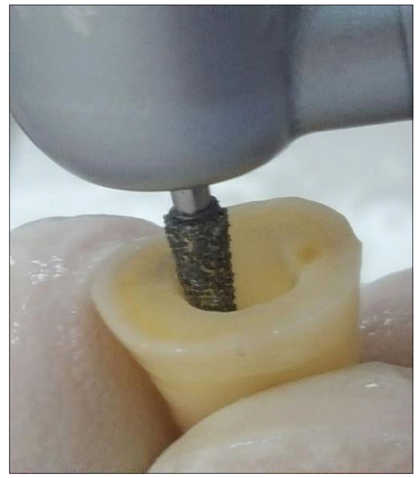

Figure 2: Preparation of axial walls of the pulp champer is seen

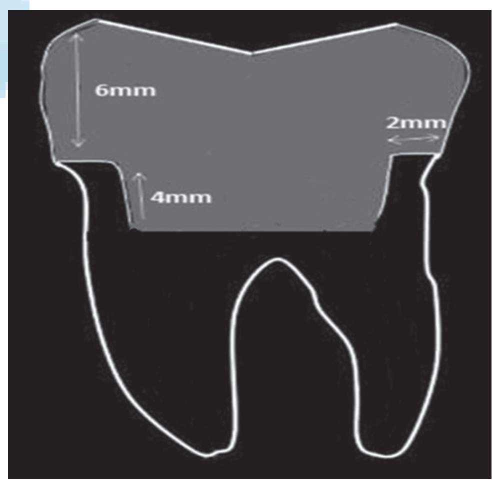

Figure 3: Representation of endocrown cavity preperation

Table 1: Materials tested in this study

Brand	Type	Chemical composition	Manufacturer	Batch number
IPS e.max press	Lithium disilicate glass ceramic	SiO_2 57%-80% Li_2O 11%-19% K_2O, P2O5, ZrO_2 Other oxides and ceramic pigments	Ivoclar vivadent	L19011
Solidex	Light-curing ceramic filled, microhybrid indirect composite	Matrix - 25 wt% copolymers of multifunctional resins and 22% conventional resins/light-initiators. Filler - 53 vol% inorganic ceramic micro filler	Shofu inc. Japan	081331
Gradia	Light-cured ceramic filled micro-hybrid indirect composite	Matrix - UDMA, filler - silica powder, silicate glass powder, prepolymerized filler	GC Corporation, Japan	150804A

UDMA=Urethane dimethacrylate

Table 2: Fracture strength results (mean±standard deviation) (Newton) of experimental groups

Groups	*n*	Mean±SD	Minimum	Maximum
Group IN	10	$2596.19^{a,b}$±459.96	2164.75	3724.19
Group IPS	10	3320.35^{a}±961.21	1898.49	4915.54
Group SL	10	2222.14^{b}±938.50	1102.52	4126.31
Group GR	10	2366.50^{b}±420.86	1802.60	3312.21

Groups with different letters show a statistically significant difference ($P<0.005$). SD=Standard deviation

Table 3: Fracture modes and percentage of repairable and irrepairable teeth

	Irrepairable (%)	Repairable (%)
Group IN	8 (80.00)	2 (20.00)
Group IPS	9 (90.00)	1 (10.00)
Group SL	2 (20.00)	8 (80.00)
Group GR	4 (40.00)	6 (60.00)

Figure 4: Endocrown preparation and light-curing resin-modified glass-ionomer which was used for closing the orifice of the canal is seen

Figure 5: Lithium disilicate ceramic endocrown is seen

Discussion

Endocrowns appear to be the best choice for restoring endodontically treated posterior teeth with inadequate remaining coronal structure, especially molars. The clinical success of molar endocrowns was better than that of premolar endocrowns.[11] Bindl *et al.*[11] evaluated the survival rate of cerec endocrowns for premolars and molars, and after approximately 55 months, they determined that the molar endocrowns had fewer failures than the premolar endocrowns. It is believed that the pulp chamber of premolars is smaller than that of molars, so the surface for adhesive bonding is smaller than that of molars. In the present study, molar teeth were used to evaluate and compare the fracture resistance of endocrowns.

Lithium disilicate glass ceramic and microhybrid resin composite materials are widely used as indirect restorative materials. Lithium disilicate ceramic provides adequate mechanical strength and esthetics.[12] Hence, it is now considered one of the best restorative materials available today for single-unit indirect restorations. In a previous *in vitro* study, it was determined that lithium disilicate ceramic endocrowns showed better fracture strength than composite endocrowns.[13] Similarly, in the present study, when the materials were compared, lithium disilicate showed higher fracture strength than the composite groups. However, El-Damanhoury *et al*.[7] compared the fracture resistance of three different endocrowns made of feldspathic porcelain, lithium disilicate, and multiphase resin composite (Lava Ultimate) and determined that the Lava Ultimate resin composite endocrowns had significantly higher fracture resistance than the lithium disilicate and feldspathic porcelain endocrowns. The different results between these studies may be because of the discrepancy between the structure of the resin composites used as well as discrepancies between the test method (crosshead speed, type of load application device, ball diameter, etc.) and the cementation techniques.

Microhybrid indirect composites are often preferred as endocrown material because they have lower cost and better stress-absorbing properties.[10] In the present study, Solidex and Grandia composites were applied as endocrown material. Solidex is a ceramic-filled, micro-hybrid composite (ceramic portion of more than 53%). The specially designed filler particles give the material higher wear-resistance along with elasticity.[14] Grandia contains prepolymerized filler (75 wt/%) with high strength, brightness, and translucency-like porcelain.[15] In the present study, both of these composite materials showed similar fracture strengths as endocrown material.

The results from the present *in vitro* study showed no significant difference between the endocrown groups and the control group, which emphasizes the potential of endocrowns made of either lithium disilicate ceramic or microhybrid indirect composites to withstand a considerable amount of compressive loads, similar to the unrestored control group. Similar to these results, Gresnigt *et al*.[16] determined similar fracture strengths between endocrown samples made of lithium disilicate ceramic and indirect composites on intact teeth. In addition, in the present study, the mean fracture strengths of all of the groups under axial loading were above the possible mean fracture strengths of human masticatory forces in the molar regions, which are reportedly arranged from about 600–900 N for females and males, respectively.[17-19] Axial loading may represent occlusal forces, for which the elasticity modulus and thickness of the restorative material may be decisive for the survival of a restorative material.

In the present study, the fracture modes of each group were also analyzed. Our results indicate that the fracture modes recorded for the Solidex and Gradia composite endocrowns were more favorable, with the fracture mode above the CEJ. However, the patterns of fracture modes recorded for the lithium disilicate glass ceramic endocrowns were more unfavorable because the fractures involved the root and left the tooth unrestorable. These results were agreement with El-Damanhoury *et al*.[7] The difference between the fracture modes of lithium disilicate glass ceramic and composite endocrowns may be due to the difference in the modulus of elasticity of these materials. The elasticity modulus of composite materials is compatible to that of dentin, so the composite materials tend to bend under load, distribute stresses more evenly, and have stress-absorbing properties.[10] By contrast, lithium disilicate ceramics are rigid materials that produce stress concentrations at critical areas, which might cause catastrophic failures.

The study has some limitations and did not completely simulate the clinical situation. Although fracture resistance was considered, the biomechanical properties of the periodontium were not included. Previous studies have even that periodontal ligament could serve as a shock absorber and change the fracture strength results positively.[20] The forces applied in this study were at a constant direction and speed, while forces produced intraorally differ in their magnitude, speed of application, and direction. Aging with thermocycling has been controversion in the dental literature. While some authors have found no significant effect on adhesion, others have.[21-24] Its effect on bond strength is contradictory. In the present study, thermocycling was not applied in all of the groups. Thus, the clinical relevancy of such aging methods has to be correlated with clinical studies in the future. Future studies should also focus on the performance of the tested materials for endocrowns under dynamic loading, both axially and laterally, before prospective clinical studies can commence.

Within the limitations of the study, the null hypothesis is rejected, and it is concluded that:

- All of the endocrown groups showed similar fracture strength to that of the intact teeth group (control group)
- The lithium disilicate ceramic endocrowns exhibited higher fracture strength than the indirect composite groups (Solidex composite and Gradia composite)
- The Solidex and Grandia composite endocrowns

showed similar fracture strength
- Both of the indirect composite endocrowns exhibited more favorable failure than the lithium disilicate ceramic endocrowns.

Conclusions

Although lithium disilicate ceramic endocrowns showed higher fracture resistance than composite endocrown, they showed more unfavorable failure.

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Conflicts of interest

There are no conflicts of interest.

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