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Evaluating The Effect of Varying Occlusal Thicknesses on The Fracture Resistance of The Lithium Disilicate Endocrowns: An In-Vitro Study

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Abstract
Purpose: To evaluate the effect of varying occlusal thickness on the fracture resistance of lithium disilicate endocrowns
Material and Methods: Endocrown preparation was done on the mandibular first molar typodont tooth and a metal die was obtained. A total of 30 specimens, were divided into three groups with varying occlusal thickness of endocrowns; Group 1 (G1) = 2mm occlusal thickness, Group 2 (G2) = 4mm occlusal thickness, and Group 3 (G3) = 5.5mm occlusal thickness were fabricated. Specimens were placed on the Universal Testing Machine (UTM) and subjected to axial load. The maximum force which led to the fracture of endocrowns was recorded. One-way analysis of variance (ANOVA) was used for intergroup comparisons and turkey's post hoc test for pairwise comparison was used.
Results: Maximum fracture resistance was seen in group 3 (G3) with an occlusal thickness of 5.5mm (4253.5 N), followed by group 2 (G2) with an occlusal thickness of 4mm (2876.2 N) and least in group 1 (G1) with an occlusal thickness of 2mm (836.2 N). ANOVA for the intergroup comparison showed a high statistically significant difference in fracture resistance of lithium disilicate endocrowns between all the 3 groups ($p<0.001$). A statistically high significant difference was found in the fracture resistance of lithium disilicate endocrowns via post hoc Tukey's test among all three groups.
Conclusion: The fracture resistance of endocrowns fabricated from lithium disilicate increases with the increasing occlusal thickness of the endocrowns upon the axial loading.

Keywords: Occlusal thickness, Fracture resistance, Lithium Disilicate, Endocrowns

INTRODUCTION:

For the long-term success of any dental treatment especially the restorative one, preservation of the healthy dental structure is very important, as it helps in the mechanical stabilization of the tooth and restoration integrity. It increases the number of tooth surfaces that are available for the adhesion of restorative material to the tooth. Endodontically treated teeth are at higher risk of biomechanical failure than vital teeth because of changes in biomechanical properties due to water loss after the extraction of pulp during the endodontic treatment. The prosthetic rehabilitation of the Endontotically Treated Tooth (ETT) becomes somewhat clinically challenging when the amount of the natural tooth structure supporting the restoration is less or when there is a large amount of tooth surface destruction. Initially, the functional and aesthetic recovery of extensively damaged endodontically teeth was done by using cast metal posts and core or pre-fabricated posts that supported the final coronal prosthesis/crowns. Over the years, many studies have shown that using intra-radicular posts does not solely increase the restoration's retention. A good filling core has to be fabricated to provide greater stability to the final coronal prosthesis or the final restoration Moreover, the placement of posts in root canals could be limited by root anatomies, such as dilacerations or reduced root portions (short

roots). Therefore, with the advent of adhesive dentistry, it has become acceptable to restore teeth with extensive coronal destruction by performing onlays and overlays, without using intraradicular posts, by using the entire extension of the pulp chamber as a retentive resource. [1]
Pissis in the year 1995 was the first one to do study on endocrown restoration or the (or adhesive endodontic restoration) in which he explained the ceramic monoblock technique for teeth which has extensive loss of coronal structure. However, in 1999 it was Bindle and Mormann who named this restorative procedure "Endocrown".[2]
The endocrown is the total porcelain crown fixed to a depulped posterior tooth and is anchored to the cavity margins, thus obtaining macro mechanical retention (provided by pulpal walls) and micro retention (by using adhesive cementation) [2]. Hence, endocrown as a post-endodontic restorative option can be advantageous and effective when there is large coronal tissue destruction, inadequate inter-arch space, short clinical crowns, short roots, and calcified root canals.
There are a few contraindications of the endocrown one is, if the adhesion of endocrown restoration cannot be assured, secondly if the pulpal chamber depth is less than 3 mm deep, as well as if the cervical margin or the ferrule is less than 2 mm wide for most of its circumference.[3]
The type of material used for the fabrication of endocrown might have some effect on its mechanical properties. The first clinical endocrown report was published in 2008 by Lander and Dietschi [4] and in 2009, acid etchable ceramic were considered the material of choice for these restorations over composite resins because they provide mechanical strength good enough to resist occlusal load and adequate bond strength to the tooth structure. [5] Lithium disilicate demonstrates high mechanical strength, excellent adhesion properties to tooth structures, and excellent aesthetics, as the thickness and quantity of the ceramic material used for an endocrown are greater than that of a conventional ceramic crown.
Therefore, this study was conducted with the objective of evaluating the effect of varying occlusal thicknesses on the fracture resistance of the lithium disilicate endocrowns. The proposed null hypothesis of the study was that occlusal thickness will not affect the fracture resistance of lithium disilicate endocrown.

MATERIALS AND METHOD

This work was approved by the ethics committee of Mahatma Gandhi Dental College and Hospital, Mahatma Gandhi University Of Medical Sciences and Technology, Jaipur, Rajasthan (MGDCH/IEC/2020-21/T-01)

Preparation of the Metal Die:

A mandibular typhodont (Nissin PRO2001-UL-SP-FEM-32) was prepared for an ideal endocrown. The specifications for the preparation included sectioning of the tooth in the mesio distal direction at the midpoint of the middle 1/3rd, 1mm ferrule (shoulder finish line), central cavity with the dimension of 5mmin diameter and 5mm in depth and 7-degree taper.[6] The prepared tooth was used as a guide for metal die fabrication (Figure 1.)

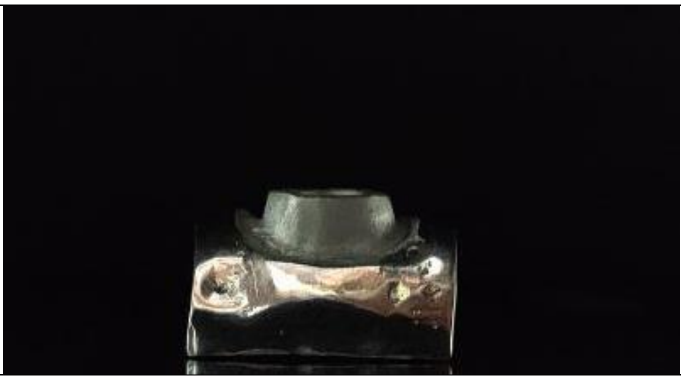

Figure 1: Metal die

Digital Scanning and Designing

The metal die was scanned using an extraoral scanner (Medit Identica T500, Seoul, Korea) to attain a 3D model of the prepared tooth. The lithium disilicate endocrown with different occlusal thicknesses were designed using the designing software (Exo CAD). A computer file in STL (stereolithography/standard tessellation language) format was then generated and imported to the CAD-CAM software which was used to fabricate the test specimens. All specimens were fabricated by a single operator to maintain standardization.

Manufacturing the Test specimen

For the fabrication of the test specimen lithium disilicate was used as the choice of material. It is classified as glass ceramic. The prosthesis of the lithium disilicate ceramics can be fabricated by milling as well as heat pressing which is similar to the lost-wax method used for metal-cast alloys.

Wax patterns for the endocrowns with a different occlusal thickness STL (stereolithography/standard tessellation language) format of the designed specimens which were then exported to the CAD-CAM milling machine (ARUM 5X-500). (Figure 2a, 2b)

Figure 2a: Milling Machine

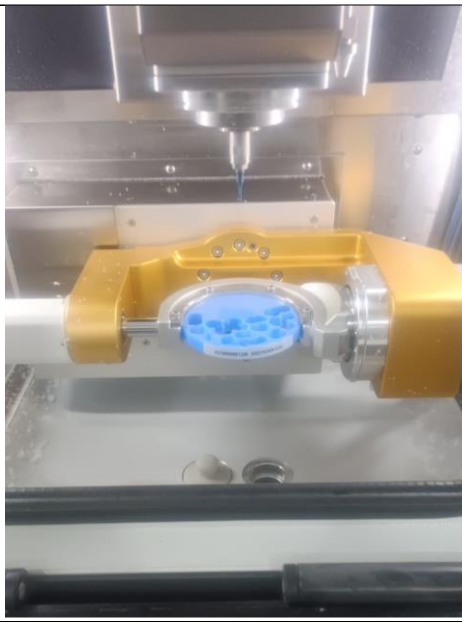

Figure 2b: Wax pattern for the endocrowns being fabricated

Once the wax patterns of different occlusal thicknesses were milled for the endocrowns they were invested using the investment material. After the wax elimination process by heat, the lithium disilicate ingots (IPS Emax press) were inserted into the mold. After that, the mold was placed into the heat press furnace (Dentsply Multimat Cube Press) which pressed the ceramic ingots into the empty cavity taking the shape of the eliminated wax.

After completion of the heat pressing process of the lithium disilicate ingots (IPS Emax press), the endocrowns were retrieved. These specimens were then trimmed followed by sandblasting and glazing. (Figure 3a, 3b, 3c)

Figure 3a: Lithium disilicate endocrowns of 2mm occlusal thickness	Figure 3b: Lithium disilicate endocrowns of 4mm occlusal thickness	Figure 3c: Lithium disilicate endocrowns of 5.5mm occlusal thickness

All the specimens were placed in artificial saliva (1L double distilled H2O, 1.6802g NaHCO3, 0.41397g NaH2PO4•H2O, and 0.11099 g CaCl2) at 37°C for 7 days

Fracture Resistance testing:
A fracture resistance test was performed on all 30 specimens using the universal testing machine (ACME Engineers, India., Model: UNIEST 10). Each endocrown was adapted to the metal die and subjected to an axial load at a crosshead of 0.5 mm/min. A plunger of diameter 2mm was used to loading the centre position of the endocrown parallel to the long axis of the tooth until a fracture occurred. (Figure 4)

Figure 4a: Specimen testing under Universal Testing Machine

Figure 4b: Placement of the plunger in the centre of the specimen

Statistical Analysis:
The data were analysed by using descriptive and inferential statistics. The normality of data distribution and homogeneity of variances was evaluated using Kolmogorov-Smirnov Test. The non-parametric test one-way ANOVA and Tukey tests were used to analyze the data. The significance level was set at $p<0.05$

RESULTS
The mean fracture resistance of each group is shown in Figure
Group G1 (crown thickness of 2mm) had a mean of 836.2 N, Group G2 (crown thickness of 4mm) 2876.2 N, and Group 3 (crown thickness 5.5mm) 4253.5 N. Facture resistance of 5.5mm crown thickness is maximum followed by 4mm crown thickness and then 2mm crown thickness.
The minimum and maximum fracture loads, mean and standard deviation at the different crown thicknesses of 2mm, 4mm, and 5.5mm are shown in Table 1

Table 1: Fracture Load at crown thickness of 2 mm , 4 mm and 5.5 mm

	N	Minimum	Maximum	Mean	Std. Deviation
Crown Thickness: 2mm	10	452.00	1214.50	836.2000	253.62058
Crown Thickness: 4 mm	10	2685.00	3100.00	2876.2500	128.82638
Crown Thickness 5.5 mm	10	3980.50	4581.00	4253.5500	174.44268

The mean difference, SD value with a 95% internal of the maximum force of each group are shown in Table 2

Table 3: Intragroup comparison of fracture load

Groups		Mean Difference (I-J)	P value	95% Confidence Interval	
				Lower Bound	Upper Bound
Crown Thickness 2mm	Crown Thickness 4 mm	-2040.05000*	**<0.001***	-2253.6735	-1826.4265
	Crown Thickness 5.5 mm	-3417.35000*	**<0.001***	-3630.9735	-3203.7265
Crown Thickness 4 mm	Crown Thickness 2mm	2040.05000*	**<0.001***	1826.4265	2253.6735
	Crown Thickness 5.5 mm	-1377.30000*	**<0.001***	-1590.9235	-1163.6765
Crown Thickness 5.5 mm	Crown Thickness 2mm	3417.35000*	**<0.001***	3203.7265	3630.9735
	Crown Thickness 4 mm	1377.30000*	**<0.001***	1163.6765	1590.9235

The fracture resistance of three test groups as a graphical representation of mean force (N) is shown in Figure 5

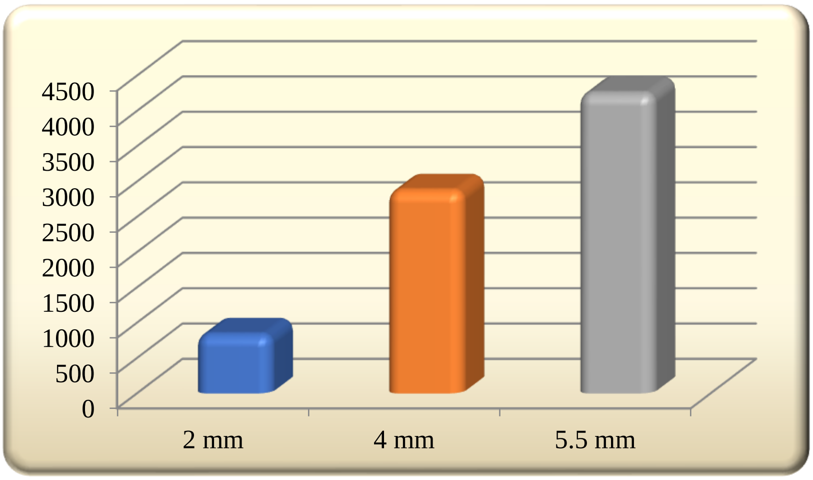

Figure 5: Fracture Load (in Newtons) at crown thickness of 2mm, 4mm and 5.5mm

ANOVA for intragroup comparison showed a statically significant difference in the fracture load between 2mm, 4mm, and 5.5mm crown thickness respectively ($p<0.001$). Also, post hoc Tukey's test showed high statistical significance among all the three groups

DISCUSSION

With the introduction to adhesive dentistry the requirement of intraradicular post and core has been reduced to do prosthodontic rehabilitation of severely damaged endodontically treated teeth. The prosthetic restoration of severely damaged posterior endodontically treated teeth, especially molars without any intraradicular posts has became possible with the introduction of ceramics restorative materials with superior durability as well as mechanical properties. [7]

Lithium disilicate (LS2) has been classified as a glass-ceramic. In the 90s glass ceramics were introduced into the market with commercial name of "IPS Empress 2" (Ivoclar Vivadent, Schaan, Liechtenstein), it was composed of 65 vol% lithium disilicate, small needle-shaped crystals (3–6 μm × 0.8 μm) embedded in a glass matrix, with a 1 vol% porosity (34–36) strength: 350 MPa; fracture toughness (KIC): 3.3 MPa√m; heat extrusion temperature: 920 °C; thermal expansion coefficient (CTE): 10.6 + 0.25 ppm/°C). Earlier when lithium disilicate as restorative ceramic material was introduced it became available commercially in form of ingots, which was utilized according to the "heat-pressing" fabrication procedure, similar to the "lost wax" method for metal-alloy casts, which aimed at producing cores, hot pressed into a mold. To get an appealing reproduction of the optical characteristics similar to natural teeth, the cores are separately veneered with a very translucent fluorapatite ceramic, containing 19–23% of fluorapatite crystals ($Ca_5(PO_4)_3F$) embedded in a glass matrix. [8]

The optimization of the processing parameters has allowed the formation of smaller and more uniformly distributed crystals. A new formulation ofthe lithium disilicate i.e. LS2 was introduced in the year 2005 and was marketed asIPS e.max Press (Ivoclar Vivadent). This new formulation exhibited superior mechanical as well as optical properties (flexural strength: 370–460 MPa; fracture toughness (KIC): 2.8–3.5 MPa√m) which was significantly higher than older glass ceramics. The high mechanical performance of this material is due, to a layered, tightly interlocked distribution of the elongated disilicate crystals which hinders crack propagation across the different planes. [9]

Besides the production of ceramic cores for bilayered crowns, the increase in strength and toughness of IPS e.max Press has allowed it to extend its clinical indication to monolithic restorations, without veneering ceramic, anatomically shaped, colored by surface stains and characterized by a higher fatigue resistance than the bilayered ones. [10]

After hot-pressing due to the extrusion of the lithium disilicate crystals by plastic deformation, the crystals of lithium disilicate ceramic of the IPS e.max press change their orientation. This change in crystal growth led to an increase of stress in the field around the crystals, which affects the mechanical properties of lithium disilicate glass-ceramic. [11] The fracture toughness of these materials is immensely affected by the microstructure of the glass-ceramics. after the hot-pressing process as there is an increase in the grain size of the crystals the fracture toughness of this glass-ceramic also increases.

Tsai et al in 1998[12] did a study about the origin of bulk fracture of glass ceramic disks of variable thickness. In their study 12mm diameter disks with various thicknesses ranging from 0.4mm to 2.4mm were supported on the flat surface and loaded in the center until the crack initiation occurred; following which 3 randomly selected samples for each thickness were loaded beyond the point of crack initiation until Hertzian fracture occurred. Hence, they concluded that the crack initiation force increased with increasing thickness. In accordance with this study; our study also depicted similar results that with an increase in the occlusal thickness of the endocrown, there is an increase in the fracture loads which was found highest with the group G3 of endocrowns with the occlusal thickness of 5.5mm

In a study conducted by Mörmann et al in 1998[13], they compared the effects of preparation and luting systems on all-ceramic computer-generated crowns and concluded that the fracture resistance of endocrowns increased in the occlusal thickness of the 5.5mm than that of the classic crowns with preparation 1.5mm occlusal

thickness. Likewise, in our study maximum fracture loads increased as the occlusal thickness of the endocrowns increased from 2mm to 5.5.mm. The maximum fracture load at 5.5mm was 4581N.
Turkastani A et al in 2019[14] conducted a study in which they evaluated the fracture resistance and failure modes of endodontically treated teeth restored with lithium disilicate endocrowns of different crown thicknesses and concluded that increasing the crown thickness of endocrown reduces the fracture resistance under the oblique forces at 35° contrary to this study in our increase in the mean fracture loads were seen with the increase in the occlusal thickness of the endocrowns under the axial forces.
Many previous studies have favoured the use of lithium disilicate for the fabrication of endocrowns.[15]
Therefore, in the present study, lithium disilicate was used as it plays an integral role in providing high-quality and naturally appearing restoration. When bonded to a prepared tooth, lithium disilicate demonstrates a monolithic strength adequate for posterior single-tooth restoration.[16]
CONCLUSION
Within the limitations of the current study, it can be concluded that:
- Statistically high significance difference was found ($P<0.001$) when the fracture loads at varying occlusal thicknesses were compared.
- Material of choice for the fabrication of the lithium disilicate endocrown via heat pressing method can be effective prosthetic rehab option for severely damaged endodontically treated teeth

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