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Evaluation Of Fracture Resistance Of Bonded Ceramic Onlays For Restoring Teeth With Wide Cavities

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Abstract
Background: *This study was conducted to evaluate and compare the fracture resistance of monolithic lithium disilicate glass-ceramic onlays with full coverage metal crowns while restoring posterior teeth with extensive carious lesion involving both the marginal ridges.*
Materials and Methods*: Sixteen molars mounted in acrylic blocks were randomly allocated to two groups(n=8). Group I received bonded partial restoration made from lithium disilicate pressed ceramic involving MOD onlay preparation. Group II received metal crowns. All the specimens were subjected to occlusal load at a crosshead speed of 0.5mm/min until fracture using universal testing machine.*
Results: *A statistically significant difference was found in fracture resistance of lithium disilicate onlays (1194.75 ±165.95 N) as compared with metallic full coverage crown (1877.37±155.48 N). (P value < 0.001).*
Conclusion*: Study concluded that fracture resistance of lithium disilicate onlays for restoration of tooth with wide cavities is well above the average masticatory force of natural teeth. Therefore, they can be used as an alternative to metallic full coverage crown with higher reported fracture resistance.*
Keywords: *Fracture resistance; bonded ceramic restoration; onlays; full coverage crowns; wide cavities*

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I. Introduction

Optimal option to restore posterior teeth with caries, fracture, or endodontic therapy, include direct amalgam or composite restorations, indirect inlays, onlays, or crown. When there is minimal loss of tooth structure, direct restorations are successful. However, when there is moderate or severe loss of tooth structure, indirect restorations work better[1].

Teeth with more than 3–5 mm deep mesial-occlusal-distal (MOD) preparations cannot be restored to the physiological fracture strength with a direct composite restoration without cusp coverage.To overcome the structural weakness of the posterior teeth, full coverage crowns have been used traditionally[1].

When preparing posterior teeth for crowns, axial walls of 4 mm or more in length are required to ensure proper resistance and retention.In certain situations, pre-prosthetic endodontic therapy, crown lengthening surgery, or orthodontic extrusion may be required to lengthen the axial walls available and optimize the outcome of teeth planned for crowns[1]. However, additional removal of tooth structure especially axial enamel, loss of pulp vitality, and alteration of the crown-to-root ratio associated with these procedures can increase the risk of complications and early failure[1].

Preservation of tooth structure is one of the most important factors to reduce the risk of tooth fracture. With the advancement in bonded partial restoration, tooth preparation is more conservative and does not require extensive retentive feature. Tooth preparation for onlays requires 20% to 45% less removal of coronal tooth structure than tooth preparation for full crown.[1] Use of glass ceramics like lithium disilicate with adhesive bonding protocol ensures high fracture resistance of restored tooth. Literature on success of bonded ceramic restorations is divided[1].

A study by Gupta *et al.*, using extracted premolars suggested that onlays, especially those involving only non-functional cusps, showed higher fracture resistance than PFM crowns. Authors attributed this to the more conservative tooth preparation required for onlays[2]. Despite the importance of preserving tooth structure and ensuring restoration durability, no previous study has directly compared these specific restorative options for extensive carious lesions involving both marginal ridges.

Partial or complete fracture of restoration has been the main reason in majority of clinical trials on bonded partial ceramic restoration. Tooth preparation geometry is one critical factor in long term survival of these. Ahlers *et al.,* and Arnetzl *et al.,* gave simplified flat occlusal surface design of tooth preparation for ensuring uniform thickness of ceramic restoration avoiding sharp line and point angles to achieve maximum bond strength with the tooth substrate[3-5].

In light of the above, the aim of the present study was to evaluate and compare the fracture resistance of MOD ceramic onlay, fabricated on teeth with a flat occlusal surface design and metallic full coverage crowns for restoring extensive carious lesion involving both the marginal ridge.

II. Materials And Methods:

This study was carried out on 16 molars extracted within last month without cracks, caries and restoration were collected. All specimens were stored in 0.1% thymol solution to prevent them from drying out and thereby becoming brittle. (Figure 1)

Figure 1. Recently extracted molars

Study design: In vitro

Study Location: Department of Prosthodontics, Dr Harvansh Singh Judge Institute of dental sciences and hospital, Chandigarh India

Study Duration: December 2023 to May 2024

Sample size: 16 extracted molars

Sample size calculation: The sample size was calculated using software G*power version 3.1.9.4 .The sample size was calculated to be 8 in each group (n).

Specimen Preparation:

Each tooth was embedded in a block of self-cure acrylic resin (DPI,India) using a stainless-steel mold (30 × 20 × 20 mm) with the long axis perpendicular to the base of the block and with the acrylic ending 2 mm below the cemento-enamel junction (CEJ). Putty index (Coltene; President) of the intact tooth was made to establish the occlusal contour of the tooth[2].

Preparation Design

Group O (MOD Onlay): The occlusal surface was reduced by 2mm with a butt margin joint and a shallow 0.5 mm bevel on the cavosurface margin[6]. Peripheral enamel zone was cut slightly oblique to enhance bond strength[7]. Pulpal floor depth of 2 mm maintaining an isthmus width of 2.5 mm was prepared. Gingival wall depth of 2 mm was created for the onlay material in the gingival aspect of the preparation. (Figure 2)

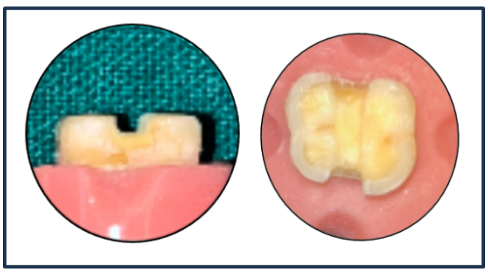

Figure 2. MOD Onlay design

Group MC (Full metal crown)*:* The occlusal surface was reduced by 2mm on functional cusp and 1.5 mm on non-functional cusp using a round end tapered diamond bur. A wide bevel was placed on the functional cusp, using the round end tapered diamond bur. Axial reduction with 0.5mm chamfer finish line 1 mm above the CEJ was done[8]. (Figure 3)

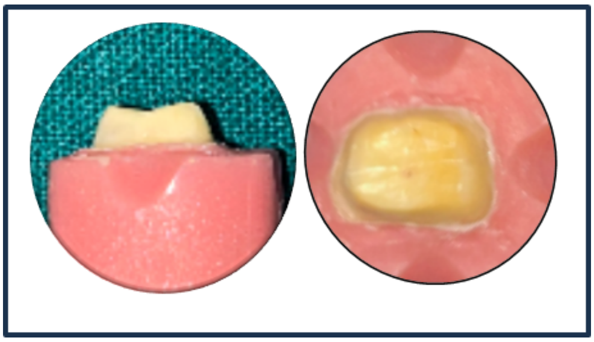

Figure 3. Full metal crown Design

Fabrication and Cementation of restoration

A single-step impression was made using polyvinyl siloxane impression material (Coltene President) and master dies were fabricated with type IV dental stone (Kalabhai;Kalrock). (Figure 4)

Figure 4. Master dies for Onlay and Crown

Group O (MOD Onlay): The restorations were waxed in pattern wax to final contours using putty index, sprued, and invested. Ceramic ingots (Ivoclar) were pressed into a refractory mold made using the lost wax technique, employing a press ceramic furnace. After pressing the restoration were recovered and refitted onto the dies. Finishing, staining and glazing procedures were performed.

All onlays were sandblasted with 100um Al203 particles at 1 bar pressure and glazed for the final placement. The internal surface of restoration was treated in accordance with the recommended technique i.e. application of 9% hydrofluoric acid for 90 seconds, washing with water and air dried for 30 seconds, application of the silane coupling agent for 1 minute.Each tooth was acid etched (37% phosphoric acid for 15 second) followed by application of bonding agent and respective restoration was cemented with self-adhesive resin cement (3M ESPE RelyX U200)[2]. (Figure 5)

Figure 5. Cementation of Onlay

Group MC (Full metal crown): Metal crowns were waxed in pattern wax to final contours using putty index to and casted with cobalt-ceramic alloy (Ivoclar 4all) in Casting machine. (Bego Fornex)

All restorations were fitted, finished and polished. Surfaces of teeth were cleaned with wet pumice on a rubber cup.The pumice was rinsed away and the prepared surfaces were dried. All restorations of this group were cemented, following manufacturer's instructions, using glass ionomer luting cement. (GC Gold Label) Excess cement was removed after setting, using a hand scaler[2]. (Figure 6)

Figure 6. Cementation of Crowns

Fracture Resistance Test

All specimen was inserted into the holding device, and a controlled load was applied using a stainless-steel rod with a 5-mm-diameter tip. (Figure 7)

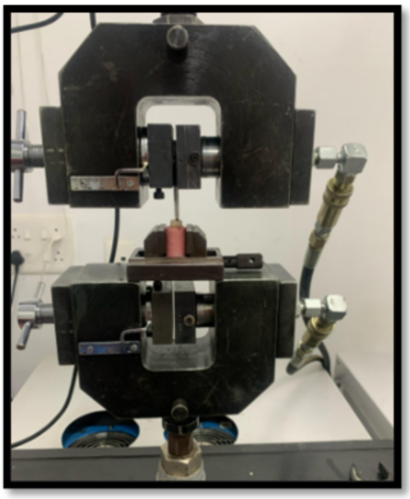

Figure 7. Controlled load was applied using a stainless- steel rod with a 5-mm-diameter tip using a universal loading machine.

Force was applied perpendicular to the longitudinal axis of the restored teeth, using a universal loading machine at a crosshead speed of o.5 mm/minute.All specimens were loaded until fracture, and the maximum breaking loads were recorded in Newtons.(Figure 8)

III. Results

A statistically significant difference was seen for mean fracture load resistance between the groups ($p<0.001$) with higher values in group MC (Full Metal crowns). (Figure 9,10, Table1) However the mean load values for Lithium disilicate glass-ceramic MOD onlays (1194.75N) were much above the average masticatory force (400 N)[9].

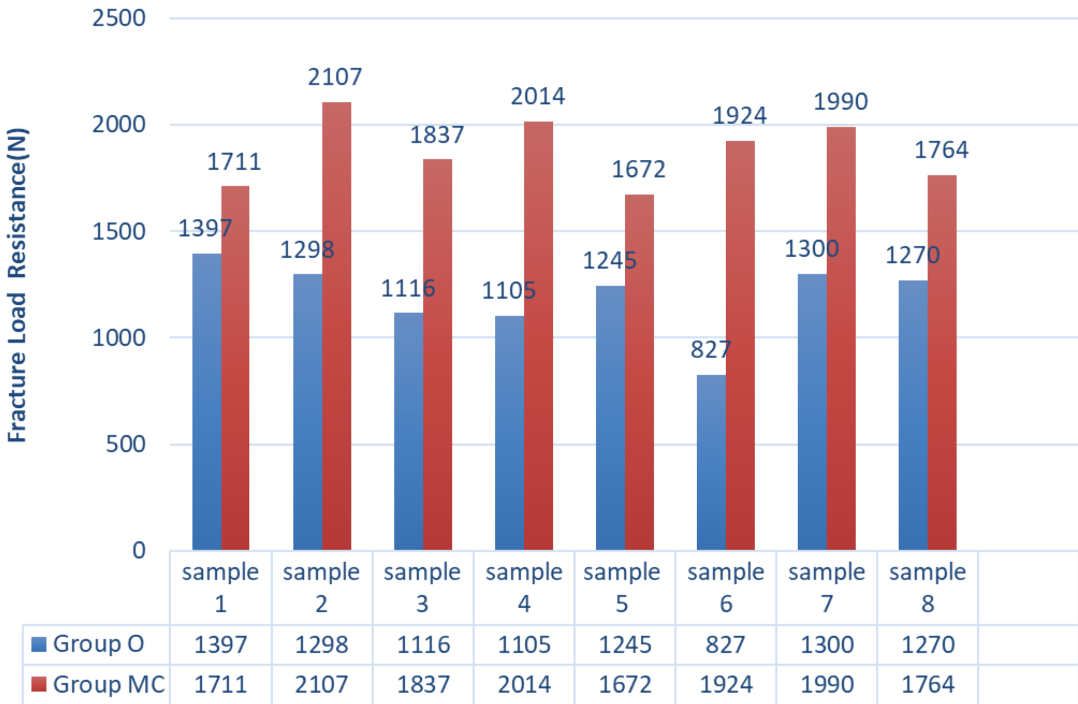

Figure 9. Fracture load resistance values (in Newton) of samples in each group (Group O: MOD Onlays; Group MC: Full metal crowns)

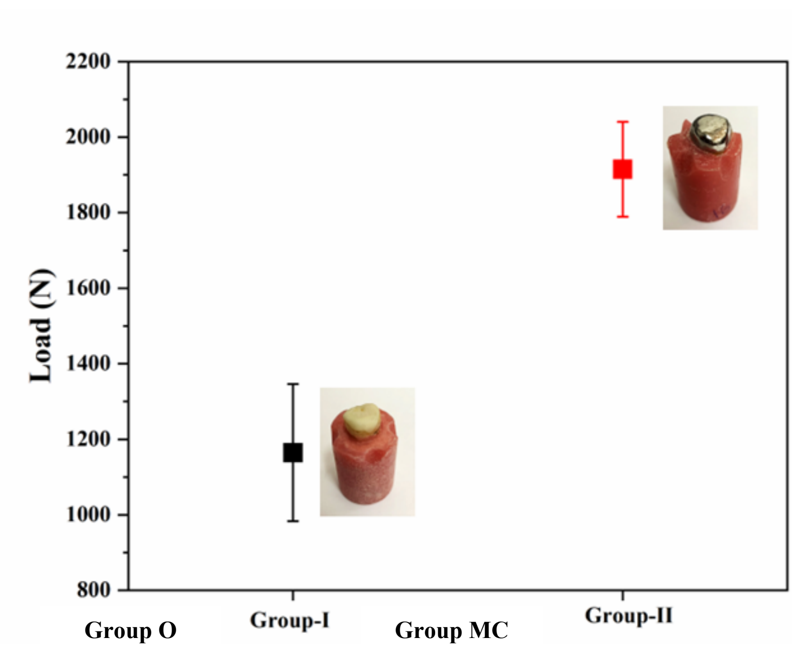

Figure 10. Mean fracture resistance (in Newton) in each group (Group O: onlays; Group MC: Full metal crowns)

Table 1: Shows inter-group comparison between full crown and onlays for occlusal load values

	group	N	Mean (±SD)	p value of t test
Occlusal load values	O	8	1194.75±177.41	.000**
	MC	8	1877.38±156.11	

IV. Discussion

The present study aimed to explore whether bonded partial restoration, specifically onlays, could serve as viable alternatives to conventional full coverage metal crowns for restoring posterior teeth with wide cavities involving marginal ridges. In this study metallic full coverage crowns were used as porcelain fused to metal crowns may give false result due to chipping of porcelain layer at lower load value.

The mean maximum posterior masticatory force in human beings is approximately 400N, with a range of variation from 300 N to 880 N[2,9]. Hence, to achieve a good clinical long-term effect, it is necessary for the posterior restoration to be able to withstand the maximum masticatory stress[1]. In the present study, for vital molars with wide cavities restored using lithium disilicate onlays, the mean fracture loads (1194.75±177.41N) were significantly lower ($p<0.01$) than the mean fracture loads of metal crowns(1877.38±156.11N) but much higher than the maximum masticatory forces(400N)[9].

A previous in vitro study conducted by Yu *et al.,* reported fracture strength of 1757.2 N for onlays and 1790.5N for crowns made of lithium disilicate which is within the range of the present study.[4,10] Another *in vitro* study by Wang and Zhou *et al.,* reported fracture strength of lithium disilicate onlay as 314.9N which was higher than that of metal crowns (267.1 N)[11]. However, the range was much lower than that reported in the present study. A study by Gupta A *et al.,* reported that fracture strength of bonded ceramic onlays involving functional cusps was 463.46N, onlay without functional cusp was 849.33N and PFM crowns was 674.9N[2]. Lower fracture resistance of the full crown group in this study may be due to chipping of layered ceramic much before crown fracture. However, the range for bonded ceramic groups was lower than that in the present study. The difference in the values of the three studies might be due to difference in the angulation of force applied. In studies by Yu *et al.,* and Gupta A *et al.,* force applied was perpendicular to long axis while Wang and Zhou *et al.,* applied force at an angle of 135 degrees[2,10,11]. Other reasons for variation in fracture resistance across literature studies can be different tips size and design used in universal testing machine or variation in the depth and width of the preparation.

Present study involved a flat occlusal surface design of onlay as in large and deep cavities cusps function as a long cantilever arm which might flex during occlusal loading. The preparation also involved slightly oblique peripheral enamel zone to gain advantage of circumferential enamel bonding of ceramic onlays enhancing bond strength and contributing to the antifragile preparation form [5,6,12].

In the present study Lithium disilicate glass-ceramic MOD onlays showed lower fracture resistance than Full coverage metal crowns. Previous studies by Wang and Zhou *et al.,* and Gupta A *et al.,* found ceramic onlays to be more fracture-resistant than PFM crowns, while the study by Yu *et al.,* showed comparable results between onlays and crown both made of lithium disilicate.[2,10,11] Chipping of ceramic in PFM much before metal coping fracture can be the reason for lower fracture resistance values of crowns in their studies.

Lithium disilicate glass-ceramic MOD onlays in present study showed fracture resistance above the average masticatory force and hence can be used as a conservative alternative to full crowns.

V. Conclusion

Bonded partial onlays can be considered as an alternative treatment to full contour crowns preserving the remaining tooth structure and maintaining the vitality of the tooth. Further, long-term clinical studies are needed before definitive conclusions can be drawn with regards to the outcomes of onlays and crowns to posterior teeth with MOD tooth preparation. However, the fracture of teeth with MOD tooth structure loss restored with onlays appears to be less catastrophic than when restored with full metal crowns.

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