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Evaluation of fracture resistance of endodontically treated mesio- occlusally involved premolars restored with ceramic onlay, vonlay and full crown restorations – An Invitro Study

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Abstract

Aim: To evaluate and compare the fracture resistance of endodontically treated mesio-occlusal involved premolars restored with Ceramic onlay, Vonlay and full coverage restorations an invitro study.

Methods: 60 freshly extracted maxillary premolars were used for the study. They were randomly allocated into four groups (n=15) based on the preparation design. Group I: Intact teeth. Group II: onlay with facial reduction as for full ceramic crown. Group III: Vonlay preparation- onlay with facial reduction as for veneers. Group IV: All ceramic crown preparation for the remaining groups Standard mesio occlusal preparations were made with gingival seat 1mm above CEJ, endodontically treated and access preparation was restored entirely using packable composite resin. Cuspal reduction of 2.5mm for functional and 2mm for nonfunctional cusp was made for all the teeth and then the specimens were randomly divided based on their preparation design as per the groups

Results: The mean load at fracture for Intact Teeth was 1325.58 ± 71.12, Onlays was 788.94 ± 66.39, Vonlays was 1026.33 ± 61.56 and for Full Crown group was 689.56 ± 54.83 and there was a statistically significant difference in their mean values ($P<0.001$) between groups.

Intact teeth showed significantly highest mean load at fracture as compared to all other study groups at $P < 0.001$. This was followed by Vonlay, Onlay & Full Crowns. Intact teeth group and Vonlay group predominantly showed favorable Fracture pattern as compared to Onlay & Full Crown

Conclusion: Fracture resistance of ETT maxillary premolars restored with minimally invasive onlay and Vonlay preparations was better compared to full crown restorations. Vonlays provided better fracture resistance as compared onlays. More favourable fractures were seen with vonlays as compared to onlays and full crown restorations.

Keywords: ETT; Premolars; Onlays; full crown restorations; Veneers; Vonlays; Lithium disilicate

Introduction

Endodontically treated teeth (ETT) behave quite differently to natural teeth with vital pulp as it was thought that ETT are more brittle due to loss of collagen cross-linking and water. [1] A retrospective study evaluated 1273 ETT to determine which factors were significant causes of failure and concluded that the presence of cuspal coverage was the only significant restorative variable to predict long – term success.[2] Despite strong evidence of the benefits of cuspal coverage, a study of insurance claims by Scurria et al found that only approximately 50% of endodontically treated, posterior teeth were restored with cuspal coverage restorations.[3] Preservation of tooth structure is important when restoring the coronal portion of the tooth. Coronal tooth structure should be preserved to provide resistance and retention form for the crown.

Amongst the post endodontic restorations available, inlays and onlays have been proposed as minimally invasive alternatives to full crown restorations. Inlay restorations on endodontically treated premolar has shown to produce wedging forces and cuspal deflection leading to fracture of the restored teeth. [4]

Onlays which restore one or more cusps have shown good results as post endodontic restorations for premolars. Restorative materials can be used in innovative ways to provide the minimally invasive dentistry that today's patients demand. One such approach is a combination restoration that the authors call a "Vonlay proposed by Dr. Ronald E Goldstien." Generally, a monolithic structure fabricated from lithium disilicate, a Vonlay is a hybrid of an onlay with an extended buccal veneer surface for use in bicuspid regions where there is mostly enamel to bond to. [5]

However, there is scare literature comparing the fracture resistance and failure mode of ETT with this newer minimally invasive Ceramic Vonlays to Onlays and full crown restorations- hence the study was taken up to evaluate and compare the fracture resistance of endodontically treated mesio-occlusal involved premolars restored with Ceramic onlay, Vonlay and full coverage restorations an invitro study.

Methodology

For this invitro study, caries free, restoration free intact maxillary premolars extracted for orthodontic and periodontal reasons were collected from the department of oral and maxillofacial surgery, Dayananda Sagar college of Dental sciences, Bangalore. The sample size of sixty teeth was calculated with G power software V.1.3 with 80% power of the study and alpha error at 5%. The sample size for each of the 4 groups was 15 teeth.

Inclusion Criteria

Intact maxillary premolars extracted due to orthodontic or periodontal reasons with complete root formation, Standard buccolingual, mesioocclusal, occlusocervical anatomic crown and root length were selected.

Exclusion Criteria

Teeth with caries, fractures or cracks, teeth with incomplete root formation, calcified canals, root dilacerations, anatomical variations or internal/external resorption were excluded.

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Fig.1: Standardised Mesiocclusal Cavity Preparation with Access Opening

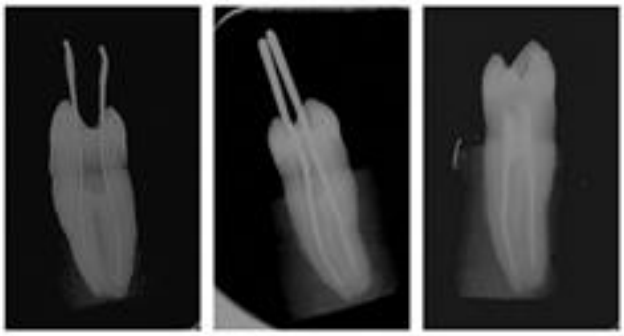

Fig. 2: Intraoral Periapical Radiographs Of Endodontic Treatment

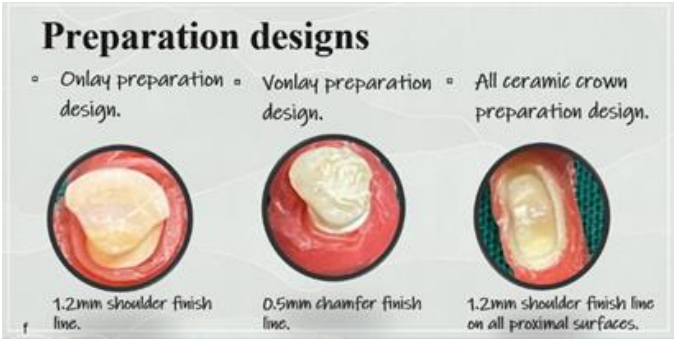

Fig 3: Preparation Designs

Teeth selection and preparation

Post extraction, teeth specimens were cleaned of any calculus and soft tissue deposits using hand scaler (Gracey curette SG; Hu Friedy, Chicago, IL, USA). Specimens were stored in 0.9 % saline solution for 48hours and then transferred to distilled water until the preparation time at room temperature. Standard mesio-occlusal preparations were done using 271 burs (SS White, Lake Wood, NJ, USA) with water spray. Gingival seat was kept 1mm above CEJ, buccolingual width of the preparation was kept as 3mm and distal marginal ridge of 3mm thickness was kept intact for all the specimens.

Access opening was done using high speed aerotor handpiece with air water spray. Working length was was determined using K file, size 15 and kept 0.5mm short of the radiographic apex.

Root canal preparation was accomplished in a crown down technique using Protaper Gold rotary system (Dentsply, Switzerland) till size F2 and obturated with corresponding F2cone coated with AH plus sealer by single cone obturation technique, GP was sheared off 2mm below the CEJ using heated instrument. 3% Hypochlorite alternating with 17 % EDTA were used as irrigants.

Endodontic access preparations were selectively etched with 37% phosphoric acid 30 seconds for enamel and 10 seconds for dentin. Rinsed with water spray for atleast 5 seconds, blot dried and observed for white frosty appearance. Tetric N bond adhesive applied in atleast 2 layers, air dried and cured for 20 seconds (light intensity 1200 mW/cm2.) A thin layer of 2mm thickness of Tetric N flow was applied to seal the access cavity and light cured for 20 seconds followed by restoration of entire preparation using Tetric N ceram and light cured for 20s (light intensity 1200 Mw/cm2). 2.5mm of functional cusp reduction and 2mm of non-functional cusp reduction was done for all the specimens with Flat end tapered diamond point (ISO 171/016, TF-21,Mani, Germany)

The specimens were randomly divided by the website www.randomizer.org into 4 equal groups with 15 teeth in each group as follows: -

Group 1: Intact teeth

Group 2: Onlay with buccal coverage and shoulder finish line- the buccal surface reduction, a tapered flat end diamond point (ISO 171/016, TF-21, Mani,

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Germany) was used to obtain a 1.2mm thick shoulder finish line-1mm above the CEJ providing

Group 3: Vonlay with chamfer finish line- For the labial surface reduction, a tapered chamfer diamond point (ISO 199/016, TR-12, Mani, Germany) was used to obtain a 0.5mm thick chamfer finish line 1mm above the CEJ providing the required taper in continuation with the gingival seat on the mesial side. The facial surface preparation was similar to that of a veneer preparation. Palatal surface was left untouched

Group 4: All ceramic crown with shoulder finish line- Axial tooth reduction was done to result in 1.2 mm thick shoulder finish line, 1mm above CEJ, using a tapered flat end diamond point (ISO 171/016, TF-21, Mani, Germany) . All specimens were stored in a humidor at 100 percent relative humidity for 24 hours.

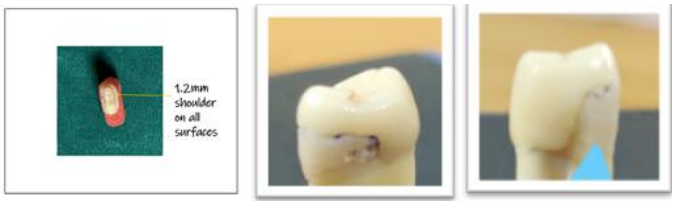

Fig 04: Full crown preparation design & lithium disilicate vonlay

Impression of prepared specimens were made using polyvinylsiloxane impression material (Virtual, Ivoclar-Vivadent) and master dies were fabricated with type V dental stone (Jad Stone; Whip Mix, Louisville, KY). Indirect wax patterns were fabricated and wax sprues were attached. The constructed patterns were invested in E max press investment material (Ivoclar Vivadent, schaan, leichtenstein) and blocks were preheated to 850°C for 60 min, before injecting with the ceramic material in a furnace at 910°C for 20 min. After divesting, finishing and glazing of the constructed crowns, their intaglio surfaces were etched with 9% hydrofluoric acid (Ultradent Porcelain Etch) for 20 seconds then rinsed with water spray and air dried for 30 seconds. Then a single layer of silane coupling agent was applied to the fitting surface using fine brushes allowed for 60 seconds then air dried with oil free air spray. Followed by which, all the constructed crowns were cemented on their corresponding teeth using self-adhesive resin cement and tack cured for 5 seconds, excess resin cement was removed with sharp scaler, and subjected to additional exposure to the curing light for 15 seconds.

Specimen preparation for testing

A thin layer of polyvinyl siloxane was applied on to the root surfaces of all the specimens to simulate the PDL. Teeth were mounted in auto-polymerizing resin 2 mm to 3 mm below the margin of the preparation to simulate the biologic width. All teeth were stored in 100 percent relative humidity (RH) at 37ºC for 24 hours and subjected to thermocycling 500 cycles/sec ranging from 5°C to 55°C using 30 second dwell time.

Fig 05: Thermocycling

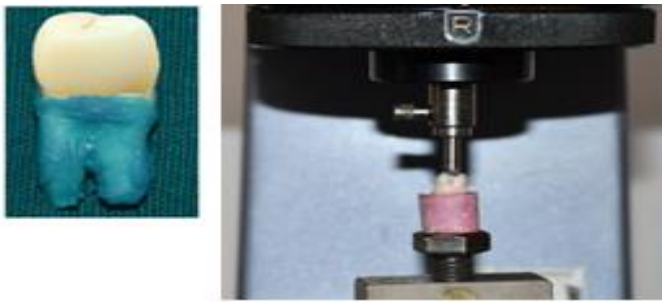

Fig 6: Simulation of PDL withpoly vinyl siloxane impression material & plunger

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Fracture resistance testing

For each group, the specimens were placed into a jig and attached to the stationary member of the testing machine. The specimens were then loaded using a flat ended plunger, on the palatal cusp at 135 degrees to the long axis of the crown using universal testing machine. The samples were subjected to static loading with a crosshead speed of 1mm/minute until fracture. The load at which the specimens fractured were recorded in Newtons.After mechanical failure, all specimens were observed under stereomicroscope (x2 magnification) to visualize the fracture lines in the restoration and the tooth. **'Favourable fractures'** were defined as repairable failures coronal to the level of CEJ. '**Unfavourable fractures'** were defined as non-repairable failures apical to the level of CEJ.

Statistical Analysis

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses. Descriptive statistics was performed for expression of fracture resistance in terms of mean and standard deviation (SD), whereas in terms of frequency and proportion for types of failure pattern.

One-way ANOVA test followed by **Tukey's HSD post hoc Analysis** was used to compare the

fracture resistance between 04 groups. **Chi Square Test** was used to compare the different types of failure pattern between different study groups. The level of significance [P-Value] was set at $P < 0.01$.

Results

The statistical analysis was performed after the data was obtained from the laboratory and entered into Microsoft Excel worksheet. The normality of data was checked with Shapiro-Wilk test and parametric tests were applied. The mean and SD values for fracture resistance were obtained and compared between 4 groups with one-way ANOVA. The Chi square test of association was applied for assessing the favorable and non-favorable fracture mode between the 4 groups.

Table 1: Comparison of mean Fracture Resistance (in N) b/w 4 groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Intact Teeth	15	1325.58	71.12	1169	1415	<0.001*
Onlay	15	788.94	66.39	629	869	
Vonlay	15	1026.33	61.56	946	1177	
Full Crown	15	689.56	54.83	615	821	

* - Statistically Significant

The test results demonstrate that the mean fracture resistance for Intact Teeth group was 1325.58 ± 71.12, Onlay group was 788.94 ± 66.39, Vonlay group was 1026.33 ± 61.56 and for Full Crown group was 689.56 ± 54.83. (Table 1, graph 1)

Table 2: Multiple comparison of mean diff. in Fracture Resistance (in N) b/w 4 groups using Tukey's Post hoc Test

(I) Groups	(J) Groups	Mean Diff.(I-J)	95% CI for the Diff		P-value
			Lower	Upper	
Intact Teeth	Onlay	536.64	474.99	598.28	<0.001*
	Vonlay	299.25	237.61	360.90	<0.001*
	Full Crown	636.02	574.37	697.67	<0.001*
Onlay	Vonlay	-237.38	-299.03	-175.74	<0.001*
	Full Crown	99.38	37.74	161.03	<0.001*
Vonlay	Full Crown	336.77	275.12	398.41	<0.001*

* - Statistically Significant

The test results showed that Intact teeth group showed highest fracture resistance as compared to all other study groups at $P < 0.001$. This was then followed by Vonlay group, Onlay & Full Crown groups at $P<0.001$. (Table 2)

Table 3: Comparison of Fracture mode between 4 study groups using Chi Square Test

Fracture Mode	Intact Teeth		Onlay		Vonlay		Full Crown		P-Value
	n	%	n	%	n	%	n	%	
Favorable	13	86.7%	11	66.7%	12	80.0%	8	60.0%	0.33
Unfavorable	2	13.3%	4	33.3%	3	20.0%	7	40.0%	

The test results demonstrated that Intact teeth group and Vonlay group predominantly showed favourable fracture with 86.7% & 80.0% of specimens fracturing above CEJ, as compared to Onlay & Full Crown group which showed relatively more of Unfavourable fracture with

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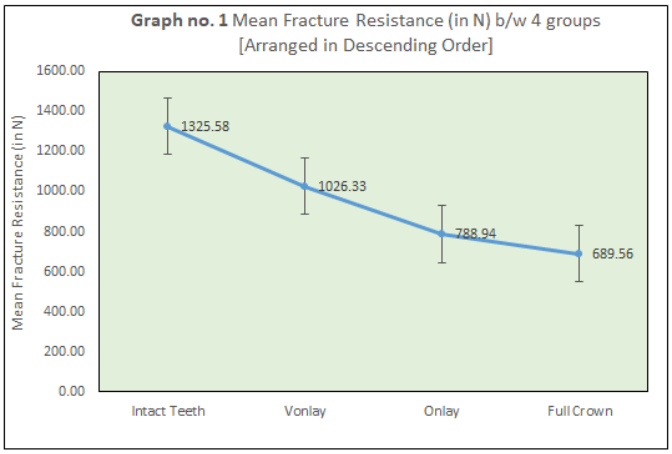
33.3% & 40.0% teeth fracturing below CEJ. However, the difference in the mode of fracture between 4 study groups was not statistically significant [P=0.33] (Table 3)



Discussion

Greatest loss in tooth's fracture resistance has been directly ascribed to the loss of marginal ridge. Endodontic access cavity preparation alone resulted in only 5 % reduction in tooth's fracture resistance. However, a tooth with multi surfaced/complex caries resulted in 46%- 63% loss of relative stiffness of the tooth. So, in planning for a final restoration for such teeth, utmost importance should be given to conserve as much sound tooth structure as possible.1 Hence, this study was done to compare the fracture resistance of this newer preparation design with the conventional full crown restorations and onlays, as against intact natural tooth.

In the current study, the roots were surrounded with polyvinyl siloxane material upto 1mm below the CEJ to simulate 0.3mm periodontal ligament space. Periodontal ligament, 0.1-0.3mm thick absorbed occlusal load effectively. Whether milled or pressed, all-ceramic restorations contribute to good marginal integrity, lower marginal discoloration, low failure rates and optimal esthetics. Therefore, lithium disilicate was chosen for fabrication of onlays, vonlays and full crown restorations in this study. [6]

The results of the present study showed that the intact teeth withstood highest mean load at fracture (1325.58N) followed by Vonlay (1026.33), Onlay (788.94) and the least mean fracture load was observed with full crown group (689.56). The difference in the fracture resistance between the groups was statistically significant.

Group I (intact teeth) presented a mean load at fracture as 1325.58 N. Similar values were observed in other studies done by Soares et al (2008)-1224N, K Bitter et al (2010)- (882N), MJMC Santos et al (2005)-1357N and several other studies. [7-9] A slight variation in the fracture load seen in our study, could be due to the difference in contact device, specimen preparation, test speed and tooth storage method.

Biomechanical preparation, use of intracanal irrigants and medicaments and Obturation techniques generate undue stresses that may also result in cracks and fracture of the tooth. [3,10]

Bonded indirect restorations with cuspal coverage such as onlays are proved to have a beneficial effect on fracture strength of ETT compared to direct adhesive restorations or inlay restorations, as the indirect restorations with cuspal coverage show a more homogenous distribution of biting forces during function. Moreover, some studies show a certain protective effect of onlay restorations against irreversible fractures. [11-13]

Although the mean load at fracture of group 2,3 and 4 was lower than that of group 1, their values were much higher than the normal masticatory forces borne by natural premolars which was between 222 and 447 N. However, the mean load at fracture for groups 2 and 4 were not sufficient enough to withstand forces of 900N

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in parafunction such as bruxism and other heavy occlusal loading situations. [14]

Further, the mode of failure was assessed by observing the fracture location. Goel et al suggested that the stress pattern and failure mode depends mainly on the remaining sound tooth structure and the preparation design and dimensions. [15] Since the occlusal cavity dimensions, cuspal reduction thickness were kept constant in all the groups, there was not much of a statistically significant difference seen in their failure mode. However, vonlay showed favourable failure pattern compared to onlay and full crown.

Hence, within the limitations of this study it can be concluded that the vonlay design provided significantly higher fracture resistance as compared to onlay and full crown designs for ETT. Vonlays being more conservative can safely be advocated for ETT premolars which require reduction of buccal surface of the tooth for various other reasons such as hypoplasia, caries, developmental anomaly & discoloration.

Fracture resistance of ETT also depends on the elastic modulus of supporting substructure, properties of luting agent, thickness of restoration and the preparation design. In this study, various post endo design features were assessed. Further invitro and invivo studies need to be conducted before routinely advocating vonlays in place of onlays and full crown restorations for ETT premolars.

Conclusion

Fracture resistance of ETT maxillary premolars restored with minimally invasive onlay and vonlay preparations was significantly higher as compared to full crown restorations. Maxillary premolars restored with minimally invasive vonlays were better compared onlays. More favorable fractures were seen in ETT maxillary premolars restored with vonlays as compared to onlays and full crown restorations, however it was not statistically significant.

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