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Evaluation of Fracture Resistance and Fracture Pattern in Endodontically Treated Maxillary Premolars with MOD Preparation Restored by Direct Composite Onlay and Direct Composite Vonlay

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ABSTRACT

Aim: To compare the fracture resistance of direct composite vonlays, with intact teeth, full-coverage crowns, and direct composite onlays (2.5 P / 1.5 B cuspal reductions).

Materials and Methods: Sixty intact, non-carious human premolars extracted for orthodontic and periodontal reasons were collected. Occlusal stents were prepared for reproducing occlusal anatomy during post endodontic restoration. Standardized MOD cavities were prepared, followed by root canal treatment. Teeth specimens were then prepared for vonlay, onlay, and full crowns.

The teeth were divided into four groups (n=15):

1. Group I – Intact teeth;
2. Group II – PFM crowns;
3. Group III – MOD onlay;
4. Group IV – Vonlay.

The specimens underwent thermocycling (500 cycles, 5°C to 55°C) and were subjected to fracture testing using a Universal testing machine delivering compressive static loading with a cross head speed of 1mm/min until fracture of the samples. Statistical analysis was done. Mean fracture resistance between different groups was done using Kruskal Wallis Test and Comparison of fracture mode between different study groups was done using Chi Square Test.

Results: The mean fracture resistance values were: Group I – 1325.582 ± 71.118 N, Group II – 1026.327 ± 61.561 N, Group III – 788.945 ± 66.388 N, Group IV – 689.561 ± 54.825 N. The differences were statistically significant (P<0.001). Intact teeth showed the highest fracture resistance, followed by PFM, onlay, and vonlay restorations. Fracture mode analysis showed that vonlay restorations had the highest rate of unfavourable fractures.

Conclusion: While vonlays had lower fracture resistance than onlays, the difference was not statistically significant. Vonlays may be considered for intermediate restorations in cases with economic and time constraints.

Keywords: *Vonaly, direct restoration, cusp capping, composite.*

1. INTRODUCTION

Post endodontic restoration of teeth (ETT-endodontically treated teeth) is a challenging task due to structural loss, loss of proprioception, and altered biomechanics. Among all the dentition maxillary premolars, are at high risk of fracture due to their anatomic configuration, subjecting them to wedging forces and functional stresses. The final restoration in a tooth should provide function, esthetics, marginal integrity and preserve the remaining tooth structure from breaking. Cavity preparation pattern and kind of restorative material are among the important factors influencing the fracture resistance of restored teeth.

Endodontic access cavity preparation reduces the stiffness of the tooth by only 5%. This is much lesser than that of an occlusal cavity preparation, which reduced the relative stiffness by 20%. Marginal ridges sustain the structural integrity of the tooth. The significant loss in stiffness was related to the loss of marginal ridge integrity. (MOD) cavity preparation results in 63% loss of relative stiffness of the tooth. [(2)] Thus, MOD preparation in an endodontically treated tooth is the worst clinical scenario, hence such a cavity design was chosen in this study. [(3)]

Traditional method of restoring endodontically treated teeth include full crowns which involves excessive removal of sound tooth structure diminishing its strength and ability to resist loading. These teeth often require post for core retention thereby making the tooth vulnerable to further risk of root perforation, fracture, dislodgement. Complex restorations after endodontic treatment are laboratory-made, which is time consuming and extremely expensive.

The true breakthrough in the restoration of badly broken teeth has been the introduction of adhesive bonding, impelled by the development of efficient dentinal adhesives. Resin-based restorations reinforce the weakened teeth. They are minimally invasive and meet the aesthetic and functional demands of ETT in a more minimalistic approach. Adhesive restorations, such as direct composite onlays and vonlays, are a conservative alternative than traditional full crowns.

There are studies which have reported that teeth prepared with anatomic cusp reduction designs and thicknesses of at least 2.5 mm exhibited greater fracture resistance and more frequent restorable fractures. Another study reported that cuspal reduction should be at least 1.5 mm to ensure sufficient strength of the material used for restoration.

The premolars undergoing endodontic treatment could be associated with buccal enamel defects, cervical caries, hypoplastic defects or white spot lesions and so on. Esthetic rehabilitation of premolars are important due to their presence in the esthetic zone. This can be achieved with nano-hybrid composites with good esthetic qualities. These have good fracture resistance and excellent polishability due to nano-hybrid fillers.

For teeth with aforementioned enamel defects on facial surface occlusal veneers or vonlays with lithium disilicate have been advocated with good results due to the inherent quality of the material. However, this is associated with high cost and multiple appointments. Therefore, a direct composite vonlay design with 1.5mm buccal cusp reduction with facial veneer preparation was designed. They were subjected fracture resistance in universal testing machine to ascertain their suitability for intermediary restoration.

2. METHODOLOGY

2.1 Specimen Selection and Preparation:

Sixty extracted intact non-carious human premolars indicated for orthodontic and periodontal reasons were collected. After visual and microscopic examination, teeth free of caries, cracks or other defects and almost similar dimensions were selected. Teeth were cleaned of soft tissue debris and calculus and stored in 0.5 % chloramine T solution until use. Occlusal stents were prepared using polyvinyl acetate night guard sheets by vacuum pressed machine to aid in reproducing occlusal anatomy of each tooth during post endodontic restoration. Poly vinyl siloxane lining light body elastomeric material was applied to the roots of the teeth 2mm below the CEJ to simulate periodontal ligament. Teeth specimens were then mounted with self-cure acrylic resin 2mm below CEJ using a rectangular plastic mold.

2.2 Standardisation of mod cavity

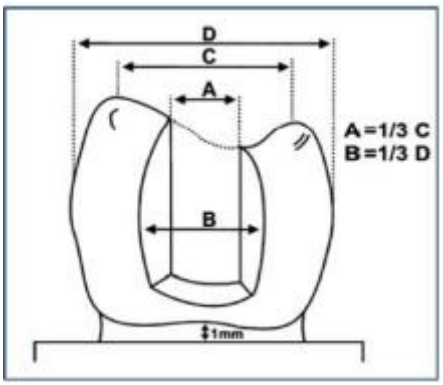


Fig.1

Standardized through and through MOD cavities were prepared with straight fissure abrasive with airotor handpiece to result in preparations 3mm wide buccolingually and gingival seat was kept 1mm above CEJ.

2.3 Endodontic treatment

Access opening was done and later the root canal orifices were enlarged using Gates Glidden drills #3 and #2 and #1. Working length was kept 1mm short of the radiographic apex. Cleaning and shaping was done with rotary Protaper files to #F2 using 3% sodium hypohlorite and 17% EDTA and were obturated using F2 Protaper cones and AH plus sealer. The gutta-percha cones were seared off 2mm below CEJ using a heated instrument and the obturation was confirmed later radiographically. The root canal orifices were sealed with Tetric N flow following standard bonding protocol. Teeth specimens were then subjected to different thicknesses of cuspal reduction and grouped as follows with 15 teeth in each group.

2.4 Grouping of specimens

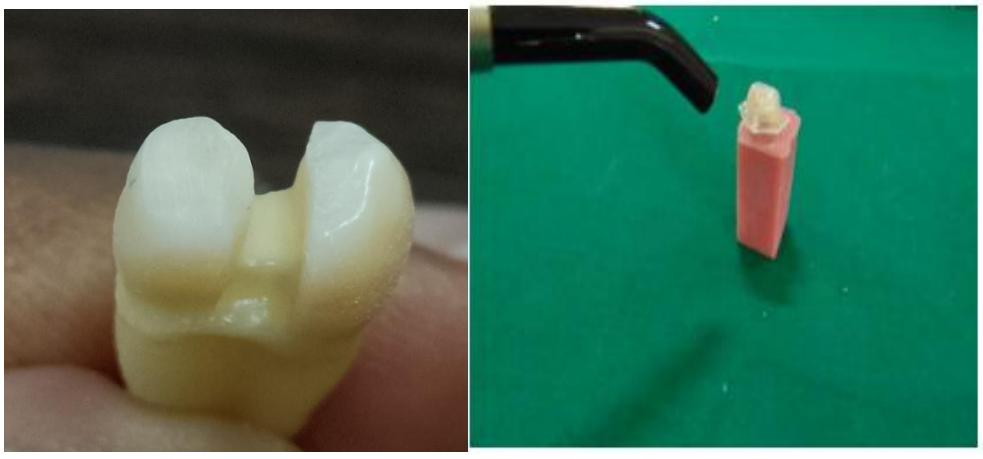
The specimens were divided into the following five groups:

1. Group I – intact teeth
2. Group II – PFM
3. Group III – MOD overlay (2.5P/1.5B) restored with nanohybrid composite resin.
4. Group IV – Vonlay – 2.5mm of palatal cusp reduction and 1.5mm buccal cusp reduction and facial surface prepared for veneer with chamfer finish.

2.5 Restorative protocol.

The teeth in group III and group IV were etched using 37% phosphoric acid for 30 seconds and later rinsed with water spray for 20seconds and gently blot dried. Bonding agent (two-step etch and rinse) was applied as per manufacturers instruction, cured for 30 seconds, followed by application of Tofflemire (Universal) matrix band. The entire preparation was restored with nanohybrid composite resin in 3mm increments and each increment was light cured for 20secs. Occlusal stents were used to reproduce the occlusal anatomy. The samples were finished and polished and stored in saline for one day.

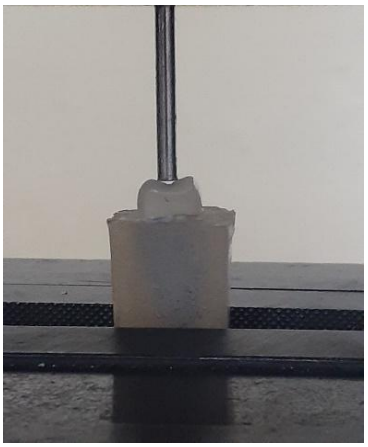
Teeth specimens in group II were prepared for PFM and these were cemented by Type II GIC.



2.6 Fracture testing

All teeth specimens were stored in saline for one day and then subjected to thermocycling at 500 cycles at 5°C+ 2°C to 55°C + 2°C, with a dwell time of 30 seconds.

After thermocycling, the samples were subjected to fracture testing using Universal testing machine. A steel cylinder of 1mm diameter and a cross head speed of 1mm/min was used to apply an occlusal load till fracture.



Sample in Universal testing Machine for fracture testing

3. RESULTS

Comparison of mean Fracture Resistance (in N) between different groups using Kruskal Wallis Test						
Groups	N	Mean	SD	Min	Max	P-Value
Intact Tooth	15	1325.582	71.118	1169.25	1414.72	<0.001*
Onlay	15	788.945	66.388	629.00	869.25	
Vonlay	15	689.561	54.825	615.00	821.00	
PFM	15	1026.327	61.561	945.75	1177.25	

- Statistically Significant

The test results demonstrated the mean fracture resistance for Intact Tooth group was 1325.582 ± 71.118, for Onlay group was 788.945 ± 66.388, for Vonlay group was 689.561 ± 54.825 and PFM group was 1026.327 ± 61.561. These differences in the mean fracture resistance between different groups was statistically significant at P<0.001.

Multiple comparison of mean difference in Fracture Resistance (in N) between different groups using Mann Whitney post hoc Test					
			95% CI for the Diff.		
(I) Groups	(J) Groups	Mean Diff. (I-J)	Lower	Upper	P-Value
Intact Tooth	Onlay	170.153	104.519	235.788	<0.001*

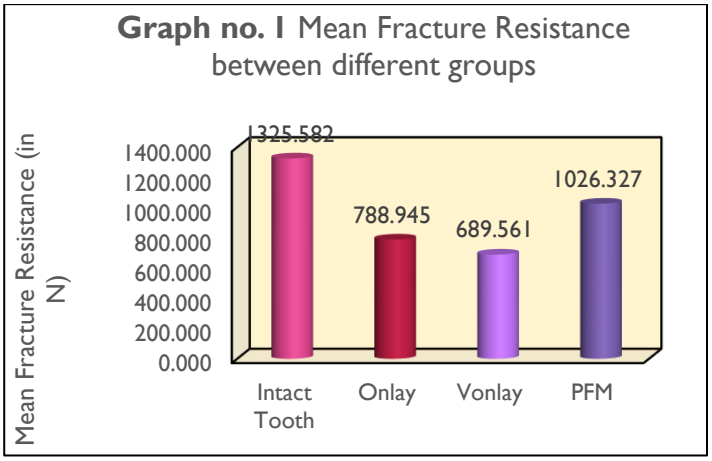
	Vonlay	659.289	593.655	724.923	<0.001*
	PFM	1029.317	963.683	1094.952	<0.001*
Onlay	Vonlay	489.135	423.501	554.770	<0.001*
	PFM	859.164	793.530	924.798	<0.001*
Vonlay	PFM	370.029	304.395	435.663	<0.001*

Table 3. multiple comparison of mean fracture resistance between different groups.

* - Statistically Significant

Multiple comparison of mean fracture resistance between different groups showed that the Intact tooth group significantly expressed highest fracture resistance as compared to other groups at P<0.001. This was then followed next by PFM group which showed higher mean fracture resistance as compared to Onlay & Vonlay groups at P<0.001. This was followed later by Onlay group showing significantly higher mean fracture resistance as compared to Vonlay group at P<0.001.

Intact tooth>PFM>ONLAY>VONLAY



Comparison of Fracture Mode between different study groups using Chi Square Test									
	Intact Tooth		Onlay		Vonlay		PFM		
Fracture Mode	n	%	N	%	n	%	n	%	P-Value
Favourable	14	93.3%	8	53.3%	5	33.3%	13	86.7%	0.001*
Unfavourable	1	6.7%	7	46.7%	10	66.7%	2	13.3%	

Table 4. Comparison of fracture mode between different groups

* - Statistically Significant

* - Statistically Significant

The test results showed that Group I with Intact Teeth & PFM groups showed predominantly favourable fracture with 93.3% & 86.7% respectively as compared to remaining Onlay & Vonlay groups which showed predominantly unfavourable fracture Pattern of 46.7% & 66.7% respectively. The difference in the fracture patterns between different groups was statistically significant at P=0.001. Multiple comparison between groups showed that Intact tooth & PFM groups exhibited significantly highest favourable fracture pattern as compared to Onlay group at P=0.01 & P=0.04 respectively and Vonlay group at P=0.001 & P=0.003 respectively. This was then followed next by Intact tooth & PFM groups exhibited significantly highest favourable fracture pattern as compared to Vonlay group at P=0.001 & P=0.003 respectively. However, no significant difference was observed between Intact Tooth & PFM groups and also between Onlay & Vonlay groups. [Refer fig no. 9]

4. DISCUSSION

Excellence of the quality of post endodontic restoration will have a direct impact on the survival and success of root canal treated tooth. A good definitive coronal restoration not only reduces microleakage into the endodontically treated tooth, but also prevents tooth from fracturing. A well-fabricated coronal restoration will return the endodontically treated tooth to its proper form and function, re-establishes proximal contacts and occlusal stability. [14]

ETT are prone to fracture due to coronal and radicular tissue loss owing to prior pathology, endodontic treatment, and/or restorative procedures. There is evidence that these teeth have reduced levels of biomechanical feedback during mastication which could impair normal protective reflexes [15]). Also a few other factors have been attributed for the decrease in fracture resistance, like the loss of free unbound water from the lumen and dentinal tubules, age induced changes in dentine, effect of endodontic irrigants, medicaments and bacterial interaction with dentine substrate. [13] However, coronal destruction from dental caries, previous restorations/fracture, and endodontic access preparation is considered to be the main cause. [15]

Maxillary second premolars were chosen for this study as they are the second most common teeth prone to fracture after the mandibular first molars. [17]. This could be due to features like the cervical constriction of these teeth, their position in the arch, occlusal anatomy and steep cusps. Additionally, these teeth when treated endodontically showed increased incidence of fracture due to removal of pulp chamber roof [18], which contributes to a dome-like structure which bears the majority of the occlusal forces thus protecting the inner structure; according to the "compression dome "concept of the tooth. Additionally when the marginal ridge is thin or totally removed [19] during crown preparation there is again a decrease in the fracture resistance of the tooth.

MOD preparation was chosen in this study, because that would be the worst clinical scenario in a root-canal treated premolar which poses a significant challenge to the restorative dentist. Steele and Johnson also reported that the mean fracture strength for unrestored teeth with MOD preparations was 50% less than that of unaltered premolar teeth. (6) For these reasons, the fracture resistance of endodontically treated premolars with MOD cavity was chosen for this study.

Prognosis of ETT depends not only on satisfactory endodontic treatment, but also on the restorative material and the technique employed for post endodontic restoration. Choosing the best technique and material according to functional requirements and determining the amount of remaining tooth structure for optimum strength against fracture are key to success. Based on these points, different materials and restorative techniques have been proposed in recent years to improve the therapeutic success of teeth with major and moderate structural loss. The ideal technique for restoring ETT is still a controversy. From a biomimetic viewpoint, the conservation and preservation of sound tooth structure is fundamental in maintaining the balance between mechanical, biological, adhesive, functional and esthetic requirements.

The availability of adhesive techniques has increased the clinician's repertoire in terms of restoring teeth in the recent times. Direct composite resin can be used to restore the ETT, structurally weakened teeth, with satisfactory long-term results. This alternative therapy is economical, easy to perform, less time consuming, doesn't require laboratory step and has no cement line-which can be the site for microleakage. (2) It has been stated that remaining tooth structure restored with adhesive restoration presents a higher fracture resistance. (20)

Tetric® N-Ceram Bulk Fill nanohybrid composite was chosen in this study for its many advantages, like not having to use a flowable material or apply an additional covering layer. Preparations with a depth of upto four millimetres can be filled in one step. The material does not require intermediate polymerization and is cured within ten seconds.

One of the studies have suggested that the model with 2.5 mm cusp reduction displayed the most-uniform stress distribution pattern. The pattern of tensile stress distribution is more perpendicular along the long axis of the tooth, in teeth with greater cuspal reduction. [21]. Also, resin composites with good bonding transmit and distribute functional stresses uniformly and have the potential to reinforce weakened dental structure.

The adhesive procedure was clearly not the only factor responsible for this resistance, and cusp protection that avoided the separation in consequence of the wedge effect caused by cusp elongation also plays a major role in this respect. [22] Therefore, composite restoration with cusp coverage reinforces unsupported or weakened dental walls and increases tooth resistance to fracture.

The trend in recent years has been "minimally invasive" dentistry, which means preserving as much tooth structure as possible whenever feasible. This inherently signifies moving away from procedures, such as crown placement, that require destruction of sound enamel and dentin if other, less invasive options are available and will be equally effective.

The protocol for placing restorations have changed due to greater advancements in optical and mechanical properties of dental ceramics [23], restorations fabrication techniques([4]) and adhesive systems [16]. So, removing only the pathology from a tooth and replacing the missing parts with an adhesive restoration should be a consideration.

One technique originally developed to veneer the facial surface of posterior teeth and combine an occlusal onlay was first published nearly 20 years ago. The technique used feldspathic porcelain and, according to Goldstein, it never caught on mainly because of fear of fracture in the posterior with the then-available materials and bonding techniques. [24]

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. This restorative option requires a much less invasive preparation than a full-coverage crown but provides the same structural benefits.[9] Simultaneously, with the components of an onlay and veneer, a vonlay enhances the strength and esthetics of the remaining tooth.[20] The term "vonlay", veneer + onlay was first used by Edward McLaren et al.

For patients presenting with wear, decay, enamel hypoplasia or occlusal problems in posterior teeth, this treatment option will be less invasive, more readily repairable, less technique-sensitive to attain adequate bonding, and will leave more - sound tooth structure remaining if further treatment is required in the future.

Direct veneers are fabricated using micro-hybrids and nanohybrids. Composite veneers can be fabricated directly or indirectly, depending on the indication. Direct veneering is accomplished by carefully layering and light-curing composites.

However, fabricating the restorations indirectly through heat pressing results in restorations that demonstrate exceptional characteristics, exhibiting wear resistance similar to enamel, wear compatibility with the opposing dentition, marginal integrity, good proximal contacts, excellent esthetics, and sufficient strength for the posterior portion of the mouth. However, they come with higher price and multiple appointments. So, an inexpensive and time-saving alternative was thought of, like the composites.

Composites are also commonly used in contemporary dentistry to form onlays, although this was once a contraindication for these materials. First-generation composites lacked adequate mechanical properties and wear resistance to be suitable for onlay restorations[22] demonstrating high rates of attrition, abrasion wear, marginal degradation, polymerization shrinkage, and poor adhesion. Newer-generation composites reflect the improved material science that overcame many of the problems of early composites, offering higher filler-to-matrix ratios that enhanced the mechanical properties.

With these references and some of the studies that have suggested direct composite onlays as a restorative option, we choose to go ahead with the vonlay design for the premolars.

These samples were later subjected to fracture testing using universal testing machine. According to the results obtained intact tooth & PFM groups exhibited significantly highest favourable fracture pattern as compared to Vonlay group at P=0.001 & P=0.003 respectively. However, no significant difference was observed between Intact Tooth & PFM groups and also between Onlay & Vonlay groups. The results of our study showed fracture resistance of vonlays less than that of composite onlay, however it was not clinically significant. The values were however clinically significant from that of intact tooth and PFM.

Nevertheless, for a definitive restoration a vonlay with a better material (Lithium disilicate, indirect composite……) would be a better choice due to the inherent excellent characteristics of the material. These materials themselves have exceptional characteristics, exhibiting wear resistance similar to enamel, wear compatibility with the opposing dentition, marginal integrity, good proximal contacts, excellent esthetics, and sufficient strength for the posterior portion of the mouth.

Within the limitations of this study, it can be concluded that direct vonlays can be option in cases of intermediate restorations as in case of intermediate post-endodontic restorations, teeth with questionable prognosis, economic constraints, and time constraints.

However, long term assessment with clinical studies with improved materials are necessary for advocating this procedure into routine clinical practice.

5. CONCLUSION

1. Fracture resistance of intact tooth was the highest.
2. This was followed by fracture resistance of endodontically treated premolars with MOD preparation and full crown restorations.
3. Fracture resistance of endodontically treated premolars with MOD restored with onlay design using direct bulk-fill composite resin was fairly good compared to that of intact tooth.
4. ETT premolars with MOD preparation restored with bulk-fill composite overlay restorations provided unfavourable fracture pattern as compared to full crown restorations and intact teeth.
5. Hence, even though full coverage restorations in the form of crowns are routinely advocated for ETT, direct composite cuspal coverage restorations didn't seem to affect the fracture resistance of ETT to a greater extent and can be thought as a suitable alternative.
6. The fracture resistance for vonlays was lesser than the onlay group. However, the difference was not statistically significant.
7. Hence, these direct Vonlay restorations can be used for:
    - Intermediate post-endodontic restorations.
    - - Teeth with questionable prognosis

- Economic constraints
- Time constraints

However, long term assessment with clinical studies with improved materials are necessary for advocating this procedure into routine clinical practice.

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