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Comparison of Fracture Resistance of Teeth with or without Cuspal Coverage Restored with Direct and Indirect Composite Restoration - An In Vitro Study

[1]Dr. Naveen Kumar Narayanappa, MDS, Reader, V.S.Dental College & Hospitals, Bangalore.

[2]Dr. Anitha Kumari Rangappa, MDS, Professor, V.S.Dental College & Hospitals, Bangalore.

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Corresponding Author: Dr. R. Anitha Kumari, Dept Of Conservative Dentistry, V.S. Dental College & Hospital, Kr Road, Vv Puram, Bangalore

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Abstract

Aim: The purpose of this study was to evaluate and compare the fracture resistance of Mesio-occluso-distal cavities restored with direct and indirect composite with and without Cuspal restoration.

Methods &Materials: Sixty sound maxillary premolar teeth were chosen and randomly divided into five groups each comprising twelve. Group A: MOD cavities with Cuspal coverage restored with direct composite (Filtek Z-350), Group B:MOD cavities without cuspal coverage restored with direct composite (Filtek Z-350), Group C:MOD cavities with cuspal coverage restored with indirect composite (Ceramage), Group D:MOD cavities without cuspal coverage restored with indirect composite (Ceramage) and Group E: intact teeth. The teeth were subjected to a compressive axial loading in a universal testing machine with 1 mm/min speed.

Statistical Analysis: Data were analyzed using one-way ANOVA and Tukey tests.

Results: The mean fracture strength recorded was group A: 879.83N, group B: 644.75N, group C: 980N, group D: 740.42, group E: 1018.50N. It was observed that Group B was statistically different from group C and group E ($p < 0.002^*$). Similarly a statistically significant difference was found between group C and group D ($p < 0.04^*$) and group D and group E ($p < 0.02^*$).

Conclusions: The fracture resistance of MOD cavities, with and without Cuspal coverage, restored with direct composite was not different, whereas in teeth restored with indirect composites, the fracture resistance of teeth

with Cuspal coverage was better than without cuspal coverage.

Summary: MOD cavities with and without Cuspal reduction were prepared in 60 premolar teeth and restored with direct (FiltekZ-350) and indirect composite (Ceramage). Fracture resistance of the teeth were tested and found that in direct composites, with and without cuspal coverage the results were the same, whereas in indirect composites the fracture resistance of teeth with cuspal coverage was better than without cuspal coverage

Keywords: Direct composites, indirect composites , cuspal coverage, Fracture Resistance.

Introduction

Composite restorations have revolutionized restorative dentistry since their introduction, because of their natural tooth like appearance and bonding ability.[1] Recently they have become more popular as posterior restorative material because of their improved strength. In addition as resins they have the ability to transmit and distribute functional stresses and thus reinforce the weakened tooth structure.[2] But there are disadvantages such as polymerization shrinkage, poor wear resistance, difficulty in re-creating the ideal contact and contour when doing posterior restoration.[3]

To overcome these challenges, indirect composite resin was developed. These are laboratory cured resins resulting in reduction of polymerization shrinkage, enhanced physical and mechanical properties and better reproduction of contact and contour.[4]

In mesio-occlusal-distal (MOD) cavity preparation, the removal of marginal ridges, occlusal enamel, cusps results in weakened tooth structure leading to decreased fracture resistance of the teeth.[5] Studies comparing restoration of MOD cavities with cusp capping and without cusp capping using direct and indirect composites are not reported in the literature.

Materials and Methods

A total of sixty maxillary premolar teeth were selected for the study. Each tooth was examined under light microscope (X10) to detect pre-existing crack or fracture. The teeth were stored in saline at room temperature. Teeth were randomly divided into five groups of 12 each based on the cavity design and material used for the study. Group A (n=12) : MOD cavity with cuspal coverage restored with direct composite **f**iltek Z350(3M ESPE), Group B (n=12) : MOD cavity without cuspal coverage restored with direct composite filtek Z350, Group C (n=12) : MOD cavity with cuspal coverage restored with indirect composite Ceramage (SHOFU INC), Group D (n=12) : MOD cavity without cuspal coverage restored with indirect composite Ceramage and Group E (n=12) : intact teeth (control group).

Cavity Preparation

In Group A, Class II MOD cavities were prepared using a 245 bur under high speed, water cooled handpiece. The occlusal width of the cavity was one-third of the intercuspal distance, 2mm deep pulpally, proximal boxes was one-third of the proximal buccolingual width of the tooth, axial wall 1.5mm in height and gingival seat 2mm wide with the palatal cusp reduction of 2mm was done with round ended tapered diamond burSSW-TR13C (SS White). Bur was replaced for every 5 cavity preparations. Bur was replaced for every 5 cavity preparations.

The cavity dimensions were standardized for all the groups with the digital caliper. In Group B, the cavity preparation was similar to group A without palatal cusp reduction. In group C, Class II MOD cavities of occlusal depth of 2mm, mesial and distal proximal boxes of 1/3rd width of the buccolingual extent of the proximal surface with axial wall height of 1.5mm and gingival seat width

of 2mm and 10^0-12^0 tapered walls gingivo-occlusally were prepared using composite inlay bur TPS2 kit(Brasseler –Komet), followed by 2mm of palatal cusp reduction with round ended tapered diamond bur. In group D, cavity preparation was similar to group C without palatal cusp reduction.

Restorative Procedure

In Group A & B, Two layers of self etched adhesive (single bond universal) was applied and gently dried & light cured for 10 second. The composite (Filtek z 350) was placed using incremental technique and each layer was cured for 40 second according to manufacturer's instructions. The restorations were finished and polished. And stored in water at room temperture for 24 hours. In Group C & D, Impressions of the prepared teeth were taken with a condensation silicon rubber based material. Working dies were prepared. Ceramage spacer was applied on the working dies except the margins. And ceramage separator was applied to the inner surfaces and around the cavity. Indirect composite was placed using incremental technique. Before curing the final layer oxy- barrier is applied to avoid air contact. Curing is done in ceramage oven according to manufacturer's instructions. Each restoration was checked for marginal fitness on both die and tooth. Restorations with unacceptable fit, marginal opening were excluded. Indirect composite restorations were cemented with Rely X U200 resin cement, following the manufacturer's instructions. The specimens were then stored in distilled water at 37°C for 24 hours. The samples were then subjected to thermocycling treatment that comprised 500 cycles between 5°C (± 2°C) and 55°C (± 2°C), with a dwell time of 20 seconds and transfer time of 5 seconds.

Testing

The teeth were mounted up to cervical, 1mm below the cemento-enamel junction, in self curing acrylic resin cylinder with 20 mm height &15mm diameter and were subjected to a compressive axial loading using a 6mm diameter rod in the Universal testing machine with 1mm/min speed.

Mode of Failure

Fracture modes were recorded, based on the degree of tooth structure and restoration damage, according to the following criteria,

Mode I – simple fracture: crack or small fractured pieces of tooth structure or restoration

Mode II – moderate fracture: complete fracture of one cusp

Mode III – catastrophic fracture: longitudinal fracture, running towards the dental root.

Fracture mode I- II are represented restorable but mode III are not restorable.

Statistical Analysis

SPSS vs. 22 for windows was used for statistical analysis of data using One-way ANOVA test followed by Tukey's HSD post hoc Analysis. Results with p value less than 0.05 were considered statistically significant.

Result and Discussion

Fig 1 shows the mean fracture resistance of different groups, highest fracture resistance was seen in group E and lowest resistance was seen in group B. Table 1 shows mean values for the different groups using one way ANOVA test. It was found that there is a statistically significant difference ($p<0.001$*) among the 5 study groups. Table 2 shows the groups which are significantly different from each other by Tukey's HSD Post hoc Analysis. It was observed that Group C had higher fracture resistance than group B and was statistically significant <0.002*). Similarly group C had

higher fracture resistance and was statistically significant than group D ($p<0.04$*).

A large number of samples in group A and C showed type III fracture pattern whereas fracture pattern of teeth in group B that were restored with direct composite without cusp coverage showed mode I and II.

When MOD cavities are subjected to the occlusal forces, deflection of a weakened cusp or fracture of the cusp may occur. Favorable clinical outcomes have encouraged many clinicians to use resin composites for the restoration of posterior teeth, even when restoring relatively large cavities. It is accepted that the demands of patients who expect tooth colored restorations in posterior teeth are influenced in selecting restorative materials.[6]

In the present study, direct and indirect resin composite resin were used to restore class II MOD cavity preparations with and without cusp capping in extracted teeth and were then evaluated for fracture resistance. Maxillary premolars were selected because studies have shown that these teeth are more prone to fracture and it showed least anatomic variations. The greater susceptibility to fracture could be because of the anatomical shape, the steep cuspal inclines of maxillary premolars.[7, 8] MOD cavity preparations tend to increase the tooth's susceptibility to vertical fracture. Thus, the restorative material used should replace the lost tooth structure and increase the fracture resistance of the tooth and promote effective marginal sealing.[9]

The application of nanotechnology to composite resins is one of the most important advances in the last few years. Nanotechnology is based on the production of functional materials and structures in the range of 100 nm using various physical and chemical methods, which have its own advantages like counteracting polymerization shrinkage, better fracture resistance, better gloss retention and diminished wear, when compared to a conventional micro hybrid composite resin.[10] Filtek Z 350 is a nano filled composite with a filler particle size 5-20nm and combination of nanomer sized particles to the nano cluster formulations. This formulation reduces the interstitial spacing of the filler particles providing increased filler loading, enhanced physical properties when compared to composites, which contain only nanoclusters.[11] A spherical shape filler particle is known to have many advantages such as to allow an increased filler load in composites which increases their fracture strength since mechanical stresses tend to concentrate on the angles and protuberances of the filler particles.[11]

Ceramage is an indirect composite with micro ceramic system from Shofu. It is filled with more than 73% micro-fine ceramic PFS filling materials, (Progressive Fine Structured Filler), supported by an organic polymer matrix, UDMA, (Urethane dimethacrylate) and filler zirconium silicate which increases the homogeneous structure and gives Ceramage, properties similar to those of porcelain.[12] The light polymerization was done with Solidilite system, equipped with 4 halogen lamps for fast curing with a curing time of 1- 5 minutes at a wavelength of 420-480 nm and temperature of 55 °C.[13,14]This study used thermocycling for aging to simulate degradation of bond over a period of time due to changes of temperature in oral cavity.

The present study showed highest fracture strength in group E (1018.50N), followed by group C (980N), group A (879.83N), group D(740.42N), and group B (644.75N). In the present study, group C (ceramage with cuspal coverage) showed higher fracture resistance than group B (filtek z 350 without cuspal coverage). It was believed that a more extensive preparation, such as MOD cavity with cuspal coverage, would present lower

values because of the greater amount of dental structure removed when compared to MOD preparations .One of the possible reason could be direct composite have lower modulus of elasticity which promote a greater distribution of stress than the enamel which has high elastic modulus and friability. The compressive load, generating stresses is concentrated and initiate crack formation and propagation, resulting in lower fracture resistance.[15]

The difference in composition between the two materials is filtek Z-350 does not contain "ceramic fillers" which might have some effect on the fracture resistance of the material. And also the indirect heat and light polymerization process increased the degree of conversion of the composite resins, improving their cohesive strength.[15]

Comparison between intra group, showed group C indirect composite with palatal cusp coverage resisted fracture better than group D without palatal coverage and the difference was highly significant. This is in agreement with study conducted by Burke et al.[16], Casselli et al.[15] yamanel et al.[17], ElAyouti et al.[18] ,who found that coverage of the at-risk palatal cusp may provide sufficient protection from fracture. This can be explained by, composite resin characterized by lower modulus of elasticity that promoted a greater distribution of stress than the enamel. In contrast, the enamel has high elastic modulus, low strain capacity and friability, so the stress generated during the compressive load is concentrated and could initiate crack resulting in lower fracture resistance. Stress concentration areas located at palatal cusp tip, for cavities without cusp reduction, were wider than for teeth with cusp coverage, further, cusp reduction relocated stress concentration areas from the remaining tooth structures to the restoration. [19]

Studies by Burke ,1994[16] and Trope,1991[20] confirmed increased cuspal fracture resistance in teeth bonded to resin restorations. On the other hand, Ruyter,1992[21] reported that direct composite restorations had a better bonding with tooth compared to indirect restorations since more free radicals are present in direct restorations to react with cement[22]. In the present study indirect composite were luted with Rely X U200 resin cement which has high bond strength in comparison to other self-adhesive resin cements.

Although the highest fracture resistance obtained with Group C restorations made with ceramage, these restorations presented more severe failure modes when compared to other restorations. This could be because of less homogeneous stress distribution and also the restoration involved only one cusp, and the other one remained almost intact , This non-homogeneous stress distribution added to more stress absorption by composite resin restoration which resulted in a high fracture resistance and predominance of catastrophic failure This observation is more important than the fracture strength values because these fractured restorations cannot be repaired.[15]

Limitations of study being the forces created intraorally during mastication vary in magnitude, speed and direction while forces applied to the teeth in the study were constant in speed and direction and increased continuously until the fractured occurred.[9] Further clinical studies with these materials add more knowledge to this in vitro studies.

Fig-1 mean fracture resistance of different groups.

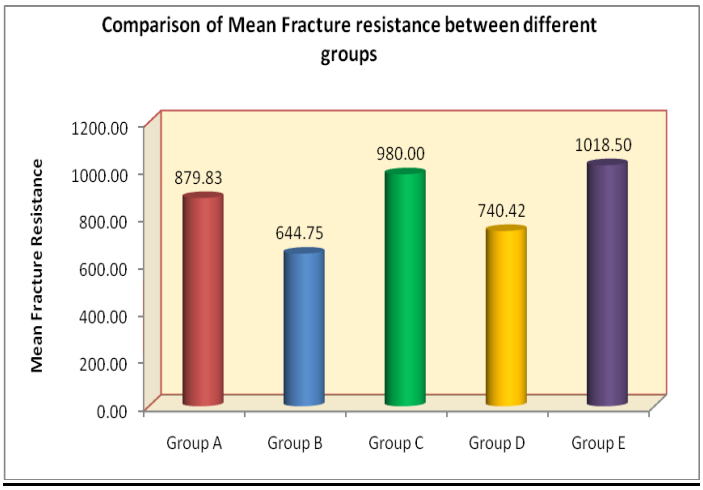

Table1: Mean values for the different groups using one way ANOVA test

Comparison of Mean Fracture resistance between different groups using one-way ANOVA test followed by Tukey's HSD post hoc Analysis

Groups	N	Mean	SD	Std. Error	Min	Max	F	P-Value
Group A	12	879.83	171.58	49.53	655	1286		
Group B	12	644.75	114.56	33.07	445	895		
Group C	12	980.00	221.15	63.84	683	1461	6.973	<0.001*
Group D	12	740.42	183.05	52.84	455	989		
Group E	12	1018.50	301.24	86.96	756	1865		

Table 2: Multiple comparison of mean difference between groups using Tukey's HSD Post hoc Analysis

Multiple comparison of mean difference between groups using Tukey's HSD Post hoc Analysis

Group (i)	Group (j)	Mean Diff	95% CI of the Diff		P-Value
			Lower	Upper	
Group A	Group B	235.08	-4.08	474.24	0.06
	Group C	-100.17	-339.33	138.99	0.76
	Group D	139.42	-99.74	378.58	0.48
	Group E	-138.67	-377.83	100.49	0.48
Group B	Group C	-335.25	-574.41	-96.09	0.002*
	Group D	-95.67	-334.83	143.49	0.79
	Group E	-373.75	-612.91	-134.59	<0.001*
Group C	Group D	239.58	0.42	478.74	0.04*
	Group E	-38.50	-277.66	200.66	0.99
Group D	Group E	-278.08	-517.24	-38.92	0.02*

Conclusions

Within the limitations of this study, it can be concluded that, the fracture resistance of MOD cavities with and without cuspal coverage, restored with direct composite was not different, whereas in teeth restored with indirect composites, the fracture resistance of teeth with cuspal coverage was better than without cuspal coverage. The fracture resistance of MOD cavities without cuspal coverage was lesser than the norma

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