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To Assess the Influence of Nanofilled and Nanoceramic Composite Restorative Systems on the Fracture Resistance of Maxillary Premolars with Class II Mesio-Occlusodistal Cavities

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ABSTRACT

Objective: To assess the influence of nanofilled, and nanoceramic, composite restorative systems on the fracture resistance of maxillary premolars with Class II mesio-occlusodistal (MOD) cavities.

Materials and Method: 30 sound maxillary human premolars were divided into 3 groups of 10 teeth each. Teeth in the first group were left intact and tested as unprepared positive controls. Teeth in the remaining two groups were prepared with MOD cavities and were restored with a nanofilled composite (Ice, SDI), a nanoceramic composite (CeramX mono®). The specimens were loaded occlusally in a universal testing machine using a metal sphere that contacted only the teeth on the cuspal inclines until fracture occurred. The results were analysed by Kruskal-Wallis and Mann-Whitney U tests. The level of significance was set at 0.05.

Results: No statistically significant difference in cuspal fracture resistance was found between the unprepared positive control teeth and those teeth restored with nano filled and nanoceramic composite ($P > .05$).

Conclusion: Under compressive load testing, teeth with nanofilled and nanoceramic filled composite restorations had similar cuspal fracture resistance which was not statistically different form intact unprepared teeth.

Keywords: Nano Composites, Fracture Resistance, Tooth preparation, Curing lights, compressive strength.

INTRODUCTION

With increasing public demand for esthetic restorations and the advent of adhesive cavity designs, composite resins are gaining popularity as posterior restorative materials[1]. In the last three decades, there has been a continuous evolution of composite resin materials and techniques. Due to this, the tooth can be ideally restored[2]. Dental restorations cause the loss of enamel continuity and increase fracture susceptibility of teeth[3]. Cusp fracture often occurs in teeth with restorations that cover more than one third of the intercuspal distance[4,5]. Optimizing tooth form has always been the "Holy Grail" of operative dentistry[6]. In recent years composite restorations have become a routine procedure for class I and class II lesions. Application of nanotechnology to composite resins has been one of the very important advances of the last few years in composite resin restorations. Nanotechnology is based on the production of functional materials and structures in the range of 100 nm using various physical and chemical methods. Composite resins which contain nano particles, have certain advantages, such as reduced polymerization shrinkage, increased mechanical properties, and diminished wear[7].

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From being the material of choice for anterior esthetic restorations, composites are now widely accepted as universal restorative materials for both anterior and posterior situations. Any preparation appears to decrease the tooth's resistance to fracture[8].

Some studies reported no significant differences in fracture strength of intact and directly or indirectly restored teeth[9,10]. However contrasting findings have been reported in other studies[11,12]. Opdam and roeters concluded that the choice of the restorative material is one of the major factors in the successful treatment of teeth[13].

There are very few reports showing that direct restorative materials reinforce the weakened tooth structure. This study aimed to assess the influence of nano filled and nano ceramic composites, on the fracture resistance of maxillary premolars with Class II mesio-occlusodistal (MOD) cavities.

The null hypothesis was that there would be no difference in the strength of fracture resistance of intact teeth and the teeth restored with composite materials.

MATERIALS AND METHODS

The restorative materials were used in accordance with the manufacturer's instructions and one operator performed all the restorative procedures. The shade taken was A2 enamel shade. The Light emitting Diode (LED) curing unit (Ledition, Ivoclar Vivadent®) was used for light polymerization. The wavelength of the unit was between 430 to 490nm.

Specimens and their preparation:-

Sound premolars extracted for orthodontic purpose were collected. After removal of soft tissue they were stored in 1% chloramine solution for 3 days. Of these 30 teeth were selected, all were free of cracks as determined by examination under Operating microscope (16X). The teeth had roots embedded in acrylic blocks(Rapid Repair, Dentsply®) up to 1 mm below the cement enamel junction (CEJ). They were then randomly divided into 3 groups (Group A,B and C). One group served as the intact group (group A). MOD cavities were prepared in the remaining two groups. For cavity preparation diamond straight fissure bur was used in high speed handpiece under copious air water cooling. Burs were replaced after five preparations to ensure high cutting efficiency.

The occlusal preparation was 2mm deep with a width of 1/3rd intercuspal distance. The facial and lingual walls were prepared parallel to each other with a 90 degree cavosurface angle. The proximal boxes were one third the buccolingual distance and 1.5 mm deep axially. The cervical wall was 1mm coronal to CEJ.

Restoration Procedures

In group 2 MOD cavities were prepared but the teeth were restored with nano filled resin composite (Ice, SDI, Australia). The cavities were etched with 37% phosphoric acid gel for 15 seconds. The cavity was then thoroughly rinsed for 10 seconds and gently dried. The adhesive was applied twice, followed by agitation for 5 seconds and then light polymerization for 10 seconds.

In group 3 teeth were restored with nono ceramic composite (Ceram X mono, Dentsply DeTrey®). The cavities were etched with 36% phosphoric acid gel for 15 seconds. The cavities were then thoroughly rinsed for 10 seconds and gently dried. The adhesive was applied twice, followed by agitation for 5 seconds and then light polymerization for 10 seconds. Metal matrices were used to re-establish the proximal contour of the restoration. The filling of the cavities was made in three horizontal layers. Each increment was light cured from the occlusal aspect for 20 seconds for both groups. The proximal surfaces were cured after removal of the matrix and excess material was removed using scalpel blades. Polishing procedures were performed immediately using super snap discs (Super snap, Shofu, USA®).

Testing

The specimens were stored in distilled water at 37 °C for 24 hours. Axial compression was performed in a universal testing machine (Tinius Oleson, USA®) using a 8mm metal sphere in contact with the dental structure with a cross head speed of 0.5mm/min. Fracture resistance was recorded in kilograms (kg/f).

Table 1: Mean force producing fracture of the teeth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A	10	91.9460	15.15747	6.77862	73.1255	110.7665	68.69	108.12
B	10	80.0460	17.43106	7.79541	58.4025	101.6895	59.89	102.07
C	10	87.5240	18.78924	8.40280	64.1941	110.8539	65.81	105.84
Total	30	86.5053	16.70823	4.31405	77.2526	95.7580	59.89	108.12

Table 2: Results of ANOVA

	Sum of Squares	Mean Square	p value
Between Groups	361.808	180.904	**0.558**
Within Groups	3,546.504	295.542	
Total	3,908.311		

Table 3: Results of Tukey Test (Multiple Comparisons)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	**p value**	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	11.90000	10.87275	**0.535**	-17.1070	40.9070
A	C	4.42200	10.87275	**0.913**	-24.5850	33.4290
B	C	-7.47800	10.87275	**0.775**	-36.4850	21.5290

Statistical analysis

SPSS software was used for the statistical analysis. One way analysis of variant (ANOVA) was used to compare all 3 groups together, TUKEY test was used to compare two groups individually, all tests were done in SPSS statistical software.

Significance was set at $p<0.05$.

RESULTS

The mean force producing fracture of the teeth in each group and the standard deviation are presented in Table 1. There was no statistically significant difference between the three groups together, (p value 0.558, Table 2). And between two groups individually, with maximum difference between group A and B,(p value 0.535, Table 3). Both of which are statistically insignificant (p value <.05). The fracture patterns observed were mixed (showing adhesive, coshesive and enmesse fractures) in both the composite groups and hence not included in the results.

DISCUSSION

The null hypothesis was accepted ($p>0.05$). There was no significant difference between the intact teeth and the teeth restored with Composite materials. The structural integrity of a human tooth can be compromised by hard tissue loss caused by caries, abrasion, cracks or restoration failure. Most losses resulting from the decalcification physicochemical process require a restoration to approach the tooth's original strength[14].

Whenever there has been extensive loss of tooth structure, such as may be encountered with cuspal fracture of a premolar with a MOD restoration, the cavity design becomes more complicated. The balance between minimizing the risk of tooth fracture and maximizing the function of the repaired tooth must be carefully engineered[15-18]. Although not the primary cause for failure, tooth fracture may be most detrimental because it often results in extraction[19]. Therefore, the fracture of restored teeth is a significant problem, which warrants further study.

Occlusal and MOD preparations tend to increase the tooth's susceptibility to vertical fracture, MOD cavity preparation decreases the strength of the tooth up to 1/3 of the intact strength[4]. Burke et al[19] concluded that the best method for measuring the resistance of premolars to fracture is the use of a cylinder of a defined diameter. In this experiment, the authors used a steel sphere with a diameter of 8 mm because it contacted the cusps in positions close to those found clinically[20].

The limitations of this study must be recognized. The continually increasing load applied to the teeth in this investigation is not typical of the type of loading that occurs clinically. During static loading, the force was applied slowly with a crosshead speed of 0.5 mm/min. This corresponds to the load in a parafunctional situation rather than to an occlusal type load or an impact type load. Ideally, more relevant test methods should be developed in which the behaviour of the in vitro tests would more closely mimic the clinical condition. Performing in vitro experiments that aim to analyse the fracture resistance of restored posterior teeth, characterized by the fracture of either the restorative material or dental structure, is an important method for improving restorative procedures[21,22].

Mechanical fracture tests are performed to numerically quantify the influence of restorative material types[23] and preparation characteristics[24] on fracture resistance when submitted to a concentrated and increasing load. These tests usually produce failure loads that exceed the load limit exerted by normal stomatognathic system movements[25]. In spite of this, higher loading situations in which the individual grinds a solid body of small dimensions and the force that would be distributed over the occlusal surfaces of posterior teeth is concentrated over a single tooth. If this tooth is structurally defective or prepared with an inadequate cavity design, the result may be fracture of the tooth, restoration or both[26].

Adhesive restorations could partially or completely restore reduced fracture resistance[22,24]. Based on the results of this study, improved fracture resistance with nearly similar values to the positive control group was noted with the nanoceramic group.

One of the most important advances of the last few years is the application of nanotechnology to composite resins. 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 polymerisation shrinkage, better fracture resistance, better gloss retention, and diminished wear, when compared to a conventional micro hybrid composite resin[30]. The Nano Ceramic filled material is one which is having ceramic particles in Nano sizes to be used as a filler. The organically modified, ceramic- based, Nano ceramic composite was also developed using the same technology. It contains methacrylate-modified, silicon dioxide–containing Nano filler and resin matrix that is replaced by a matrix full of highly dispersed methacrylate-modified polysiloxane particles while the Nano hybrid materials don't contain these "ceramic fillers" Which might have some effect on the fracture resistance of the material[31].

Our study has shown no difference statistically in the three groups, these shows that both the materials have been able to restore the tooth up to the fracture resistance comparable to the strength of the natural tooth (the positive controls) which is in agreement with previous studies. Kahler et al[27] showed that composite resins have mechanical properties comparable to that of intact sound teeth. However, polymerization shrinkage of composite resins is a major clinical concern, since residual stresses are incorporated into the restored tooth. These stresses have the potential to deform cusps, propagate enamel fractures and introduce microleakage[5,6].

Difference was observed in the means of the Nano filled and Nano Ceramic filled material fracture resistance, out of which the Nano ceramic filled composite was having a higher value which is closer to the 'intact' tooth, but not different statistically as the p value is >0.05. This signifies that even the nano hybrid material which is having better flow and lustre than the nano ceramic filled material is also having a comparable fracture resistance to the nano ceramic filled material and hence the difference which can be pointed out based on the mean value but not different statistically.

Previous studies[27,28] showed that the nanoceramic composite restorative material showed reduced shrinkage and the best modulus and hardness values compared to other materials, this could explain the comparable results in the group of teeth restored with nanoceramic material and the positive control group.

Concerning the nanofilled group, it achieved the highest mean fracture resistance loads comparable to the nanoceramic group. This may be attributed to the nanocluster structure of the nanofilled composite material. Curtis et al reported that the nanoclusters provided a distinct reinforcing mechanism compared with the microhybrid, nanofilled or nanohybrid composite resins resulting in significant improvements to the strength and reliability[29].

Our study is in agreement with other studies showing better results after restoration with the nano filled and nano ceramic filled composite resins, encouraging their wide clinical use[27]. In this study, on the basis of the static occlusal loading applied, teeth restored with nano ceramic composite showed comparable fracture resistance to that of intact teeth. The potential clinical relevance of these findings is that restoring MOD cavities with a nano ceramic composite could provide fracture resistance comparable to intact teeth. The findings of this in vitro study need to be confirmed in clinical trials.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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