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Original Article

Comparative Evaluation of Fracture Resistance of Newer Restorative Materials with Conventional Amalgam in Class II Cavity Preparation

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Abstract

Introduction: Cavity preparation weakens the tooth structure and makes it susceptible to fracture. Thus, an ideal restoration in a tooth should be able to maintain the esthetics, function, preserve the remaining tooth structure, and prevent microleakage. Amalgam is very strong in bulk section, but its slow setting process, mercury content, and unpleasant color, has led to its decline in the recent years. Since then, many newer materials have been developed as an alternative.

Objectives: The objectives of the study were to evaluate and intercompare the fracture resistance of resin composite, fiber-reinforced composite, and dual-curing restorative material with conventional amalgam.

Study Design: The study was conducted in the department of pediatric and preventive dentistry in collaboration with mechanical engineering department on a sample size of 80 teeth. The samples included freshly extracted premolar teeth, free of caries, craze lines, fracture, or restoration.

Methodology: Standard Class II cavities were prepared in all the teeth which were divided into four equal groups. Samples of Group I, II, III, and IV were restored with amalgam, conventional composite, fiber-reinforced composite, and Cention N, respectively. Fracture resistance was calculated when the samples were subjected to a compressive load in a universal testing machine.

Results: The mean fracture resistance of Group 3 was the highest, followed by Group 4, Group 1, and Group 2 the least.

Conclusion: For Class II cavity preparation, among restorative materials studied, fiber-reinforced composite (Group 3) was found to be the best material as it exhibited the highest fracture resistance.

Key words: Fracture resistance, Amalgam, Ever X, Cention N

INTRODUCTION

One of the most prevalent oral diseases in modern civilization due to change in the lifestyle is dental caries. Its successful long-term treatment is the area of concern for dentists across the world.[1]

In posterior tooth restorations, physical and mechanical properties play a dynamic role as they are subjected to heavy occlusal loads. Due to the stress concentration at the axiopulpal line angle under masticatory load, restoration fracture mainly occurs at the isthmus of a Class II restored cavity. Hence, materials with high fracture resistance are highly recommended in cases where they are subjected to heavy load as seen in cases of Class II carious teeth.[2]

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Conventionally, amalgam has been used as the best core build-up material as it is strong in bulk section. Its slow setting process, mercury content, and unpleasant color are some of the reasons why alternative restorative materials were developed. The major drawback of amalgam, however, is its inability to bond to dental hard tissues which demands the use of macromechanical retentive features. This, in turn, causes further weakening of the remaining tooth structure.

At present, resin composites are the most widely used materials in restorative dentistry. It has micromechanical property that makes composite more suitable for filings even in small cavity. Synthetic resins evolved as a restorative material since they were insoluble, adhesive to the tooth structure, have tooth-like appearance, insensitive to dehydration, easy to manipulate, and reasonably inexpensive. The inherent drawback encountered while using composite resin was polymerization shrinkage and insufficient fracture resistance (Madley *et al.*, 1976).

To overcome this disadvantage, fibers were incorporated into the resin composite to enhance its mechanical adhesive and the flexural properties. Ever X flow is a fiber-reinforced composite designed to replace dentin and reinforce restorations. The short glass fibers of ever X flow material strength restorations and prevent them from cracking. Cention N (a dual cure restorative material) is another inventive restorative material for substituting lost tooth structure in posterior teeth. Cention N offers tooth-colored esthetics along with high flexural strength. The alkaline filler present balances the pH value during acid attacks by increasing the release of hydroxide ions. As a result, demineralization can be limited. Moreover, the release of substantial amount of fluoride and calcium ions assists in remineralization of dental enamel.

Since there is a paucity of information available on fracture resistance of these materials, this study was thus planned to compare and evaluate the fracture resistance of conventional composite, fiber-reinforced composite, and Cention N with amalgam in Class II cavity preparations.

MATERIALS AND METHODS

The study sample comprised 80 human premolar teeth with intact root, extracted for orthodontic purposes. All the teeth (80 premolars) were cleaned of debris and soft-tissue remnants and were stored in formalin until used. Before the teeth were used, they were washed with tap water to eliminate formalin. To simulate periodontium, root surfaces of the selected teeth were first dipped into melted wax to a depth of 2 mm below the cement-enamel junction to produce a thin layer and then vertically embedded in polyvinyl cylinders with self-cure acrylic (to simulate the alveolar bone). The wax spacer was later substituted with light body addition silicone (to simulate the periodontal ligament).

Class II cavity preparation (mesio-occlusal) was done on all the mounted teeth using high-speed bur and water spray. The cavities were prepared with gingival margin located 1.0 mm above the cementoenamel junction, 2 ± 0.2 mm pulpal width, 2 ± 0.2 mm gingival width, and 3 ± 0.2 mm buccolingual width and were verified using periodontal probe. The facial and lingual walls of the occlusal segment were prepared parallel to each other. All the teeth after cavity preparation were randomly divided into four groups for 20 teeth each. Teeth in Group 1 were restored with amalgam, in Groups II, III, and IV were restored with conventional composite (3M, Ivoclar), Ever X flow, and Cention N, respectively. All the restorations were done according to the manufacturer instructions.

After restoration, the samples were thermocycled for 500 times at 5°C and 55°C with each cycle corresponding to a 15 s bath at each temperature. Fracture resistance was tested when samples subjected to a compressive load with cross-head speed of 1 mm/min in a Universal Testing Machine. The force was applied in the center of the restoration contacting only the buccal and lingual cusp inclines of each tooth and parallel to the long axis of the tooth [Figure 1]. Peak load to fracture was recorded in Newtons (N) for each specimen and the data collected were sent for statistical analysis.

RESULTS

Data were summarized in Mean ± SE (standard error of the mean). Groups were compared by one factor analysis of variance (ANOVA) and the significance of mean difference between (inter) the groups was done by Tukey's HSD (honestly significant difference) *post hoc* test after ascertaining normality by Shapiro–Wilk test and homogeneity of variance between groups by Levene's test. A two-tailed ($\alpha = 2$) $P < 0.05$ was considered statistically significant. Analysis was performed on SPSS software (Windows version 22.0).

The fracture resistance of four groups (Group 1, Group 2, Group 3, and Group 4) is summarized in Table 1 and also depicted in Figure 2. The fracture resistance of Group 1, Group 2, Group 3, and Group 4 ranged from 1305 to 1660, 1300 to 1645, 1855 to 2260, and 1770 to 2010 Newton, respectively, with mean (± SE) 1530.75 ± 22.26, 1489.45 ± 22.63, 2044.50 ± 30.06, and 1893.50 ± 16.96 Newton,

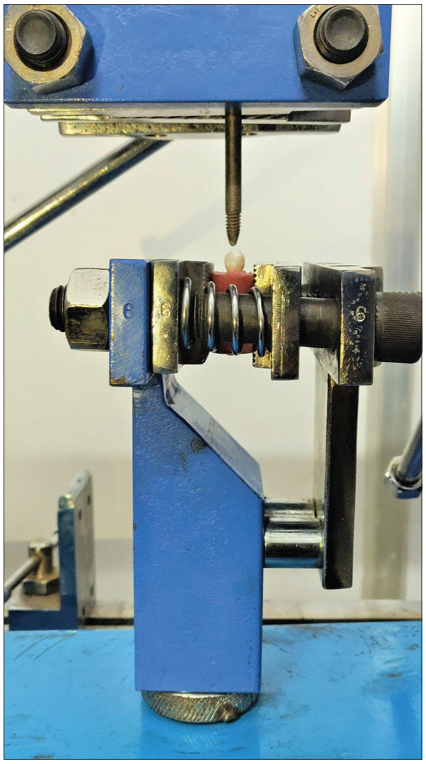

Figure 1: Sample subjected to compressive load in a universal testing machine

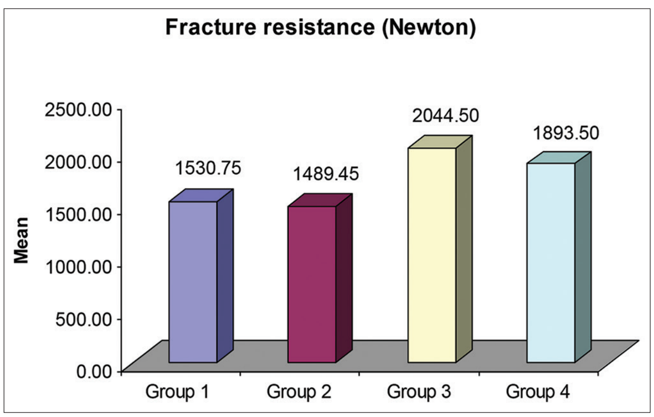

Figure 2: Bar graphs showing mean fracture resistance of four groups

Table 1: Fracture resistance (Newton) of four groups

Group	*n*	Mean±SE	F value	*P* value
Group 1	20	1530.75±22.26	135.20	< 0.001
Group 2	20	1489.45±22.63		
Group 3	20	2044.50±30.06		
Group 4	20	1893.50±16.96		

The fracture resistance of four groups was summarized in Mean±SE and compared by ANOVA (F value)

respectively, and median 1548, 1493, 2045, and 1893 Newton, respectively. The mean fracture resistance of Group 3 was the highest, followed by Group 4, Group 1, and Group 2 the least (Group 2 <Group 1 <Group 4 <Group 3).

Comparing the mean fracture resistance of four groups, ANOVA showed significantly different fracture resistance among the groups (F = 135.20, $P < 0.001$) [Table 2].

Further, comparing the difference in mean fracture resistance of Group 1 with other groups (Group 2, Group 3, and Group 4), Tukey test showed significantly different and higher fracture resistance of both Group 3 (25.1%) (1530.75 ± 22.26 vs. 2044.50 ± 30.06, mean difference = 513.75, q = 21.91, $P < 0.001$) and Group 4 (19.2%) (1530.75 ± 22.26 vs. 1893.50 ± 16.96, mean difference = 362.75, q = 15.47, $P < 0.001$) as compared to Group 1 but not differ between Group 1 and Group 2 (1530.75 ± 22.26 vs. 1489.45 ± 22.63, mean difference = 41.30, q = 1.76, $P > 0.05$) though it was found 2.7% higher in Group 1 as compared to Group 2

Similarly, comparing the difference in mean fracture resistance of Group 2 with other groups (Group 3 and Group 4), Tukey test showed significantly different and higher fracture resistance of both Group 3 (27.1%) (1489.45 ± 22.63 vs. 2044.50 ± 30.06, mean difference = 555.05, q = 23.68, $P < 0.001$) and Group 4 (21.3%) (1489.45 ± 22.63 vs. 1893.50 ± 16.96, mean difference = 404.05, q = 17.24, $P < 0.001$) as compared to Group 2

Similarly, comparing the difference in mean fracture resistance between Group 3 and Group 4, Tukey test showed significantly different and higher (7.4%) fracture resistance of Group 3 as compared to Group 4 (2044.50 ± 30.06 vs. 1893.50 ± 16.96, mean difference = 151.00, q = 6.44, $P < 0.001$).

DISCUSSION

Fracture resistance is the inherent property of a material by virtue of which it resists plastic deformation under a particular load. Masticatory forces tend to deflect the cusps under stress, whether the tooth is restored or unrestored. It is, therefore, important that any restorative material that is used to repair a missing tooth structure should also reinforce the tooth and minimize the risk of fracture of its cusp.[2]

In dentistry, silver amalgam is the utmost common and time tested material being used for the restoration of posterior teeth.[3] In the hands of an experienced clinician, even today, it is still the cheapest, easy to use, most durable, and satisfactory material.[4] However, the discoloration exhibited by this material has shown to be a major disadvantage. Lack of adhesion to the tooth structure involves removal of the sound tooth structure, thus reducing the strength of the tooth is another disadvantage of using amalgam as a restorative material.

Table 2: Comparison of difference in mean fracture resistance (Newton) between groups by Tukey test

Comparison	Mean diff.	Mean diff. (%)	q value	*P* value	95% CI of diff.
Group 1 versus Group 2	41.30	2.7	1.76	*P*>0.05	45.98–128.60
Group 1 versus Group 3	513.75	25.1	21.91	*P*<0.001	426.50–601.00
Group 1 versus Group 4	362.75	19.2	15.47	*P*<0.001	275.50–450.00
Group 2 versus Group 3	555.05	27.1	23.68	*P*<0.001	467.80–642.30
Group 2 versus Group 4	404.05	21.3	17.24	*P*<0.001	316.80–491.30
Group 3 versus Group 4	151.00	7.4	6.44	*P*<0.001	63.72–238.30

Diff: Difference, CI: Confidence interval, q value: Tukey test value

This led to the evolution of adhesive restorations which included resin composite and glass ionomer cement. Later, fibers were incorporated into the resin composite to enhance its mechanical properties. Another recent material which provides conservative tooth preparation as well as fluoride release is Cention N.

Solomon *et al*.[3] in their study had shown that bulk composite resin placed in horizontal increments showed lesser fracture resistance than silver amalgam. Pretronjevic *et al*.[5] found no significant difference in the fracture resistance of premolars restored with resin composite and amalgam

In the present study, standard Class 2 cavities were outlined and prepared on all the samples to decrease the potential effect of amount of tooth structure loss on the strength of those teeth. Precautions were taken to minimize the variabilities.

Stresses induced due to the variations in the elements of the Class 2 cavity preparation design (depth of the cavity, width of the isthmus, and thickness of the remnant interaxial dentin) have been discussed.[6] Granath and Svensson found that the extent of width of cavity and depth was directly related to cusp displacement, that is, an increase in width of cavity and depth means an increase in cuspal displacement during loading and vice versa. It has been observed clinically that after some years of Class 2 restoration of premolar teeth, cuspal failures are quite common. After periodontal disease and caries, tooth loss from fracture ranks third and is especially common in people over 40 years of age.[7]

In the present study, fracture resistance of amalgam was compared with resin composite, fiber-reinforced composite, and Cention-N. Fracture resistance of fiber-reinforced composite (2044.50 ± 30.06) was found to be highest followed by Cention N (1893.50 ± 16.96), amalgam (1530.75 ± 22.26), and then conventional composites (1489.45 ± 22.63). The increased fracture resistance of fiber-reinforced composites restored in Class II cavity can be attributed to large filler particle which strengthens physical properties (Magne *et al*., 2009). Other factor besides filler size which can be responsible for low fracture resistance is filler loading and stress transfer from resin matrices to filler particles (Magne, 2009; Magne *et al*., 2008; Zhao *et al*., 1997; Ferracane *et al*., 1998; Kim *et al*., 2000; Bonilla *et al*., 2001, and Kim, 2002).

Fracture resistance of Cention N was found to be higher than amalgam and conventional composite. This may be attributed to the fact that Cention N releases a large number of fluoride and calcium ions which form a sound basis for remineralization of the dental enamel the highly cross-linked polymer structure is responsible for the high flexure strength (Chowdhury *et al*., 2018).

Kumar *et al*.[1] evaluated the fracture resistance of fiber-reinforced composite, core build up material, and flowable composite and reported that fiber-reinforced composite showed maximum mean fracture toughness. This was statistically significant when compared to other tested restorative materials. A study of Garoushi *et al*.[8] showed that short fiber fillers could stop the crack propagation and provided increase in fracture resistance of composite resin.

Jayashankara *et al*.[9] and Chowdhury *et al*.[2] compared Cention-N and nanocomposite Filtek Z350 for resistance to fracture in Class II cavities. They found that Cention-N and Filtek Z350 materials have higher resistance to fracture in Class II cavity restoration and dental amalgam showed comparatively inferior results.

CONCLUSION

For Class II cavity preparation, among restorative materials studied, this study found fiber-reinforced composite (Group 3), the best material as it exhibited the highest fracture resistance. However, findings of this study may be further validated on larger sample size and comparisons with other different restorative materials.

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