Fracture resistance of teeth restored with different resin composite restorations(An in vitro study)

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ABSTRACT

Objectives: To evaluate the fracture resistance of maxillary premolar teeth with prepared MOD cavities and restored with bulk fill and incrementally placed resin composites.
Materials and methods: A total number of 40 MOD cavities were prepared in maxillary premolar teeth. Teeth were divided into 4 main groups according to the four restorative materials used: (I_1) Neo spectra ST (LV) (Dentsply), (I_2) Clearfil AP-X (Kurari Noritaki), (B_1) Sonic fill 3 (Kerr), and (B2) Palfique bulk flow (Tokoyama dental). Fracture resistance was tested using a universal testing machine.
Results: The readings revealed that the fracture resistance scores between the tested restorative materials were statistically insignificant, palfique bulk flow has the highest values while clearfil AP-X has the lowest values.
Conclusion: Bulk fill composites have comparable results to universal incrementally placed composites.
keywords: Fracture resistance, Maxillary premolars, MOD cavity, Bulk fill resin composites**.**

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1. Introduction

Resin composites are considered the materials of choice in restorative dentistry because of the increasing demand for high quality aesthetic and function results in everyday practice. Despite the continuous evolution of resin composites, problems such as polymerization shrinkage still occur [(1)].

Bulk-fill composites have been developed to reduce the shrinkage stress during polymerization and offer much greater depth of cure. This is achieved by the addition of fillers such as barium aluminum silicate filler, ytterbium trifluoride and mixed oxides. Furthermore, prepolymerized fillers have been added with silanes to reduce shrinkage stress [(2)].

Natural teeth perform flexion or bending during the mastication process. However, tooth fracture remains a major complication of posterior teeth especially if weakened with cavity preparations. Fracture resistance is one of the most important properties of dental materials depending on the material resistance to crack propagation internally and/or externally. These cracks can cause marginal or bulk fractures of the restoration [(3)].

2. Materials and methods

2.1 Study design:

This study was laboratory.

2.2 Study setting and population:

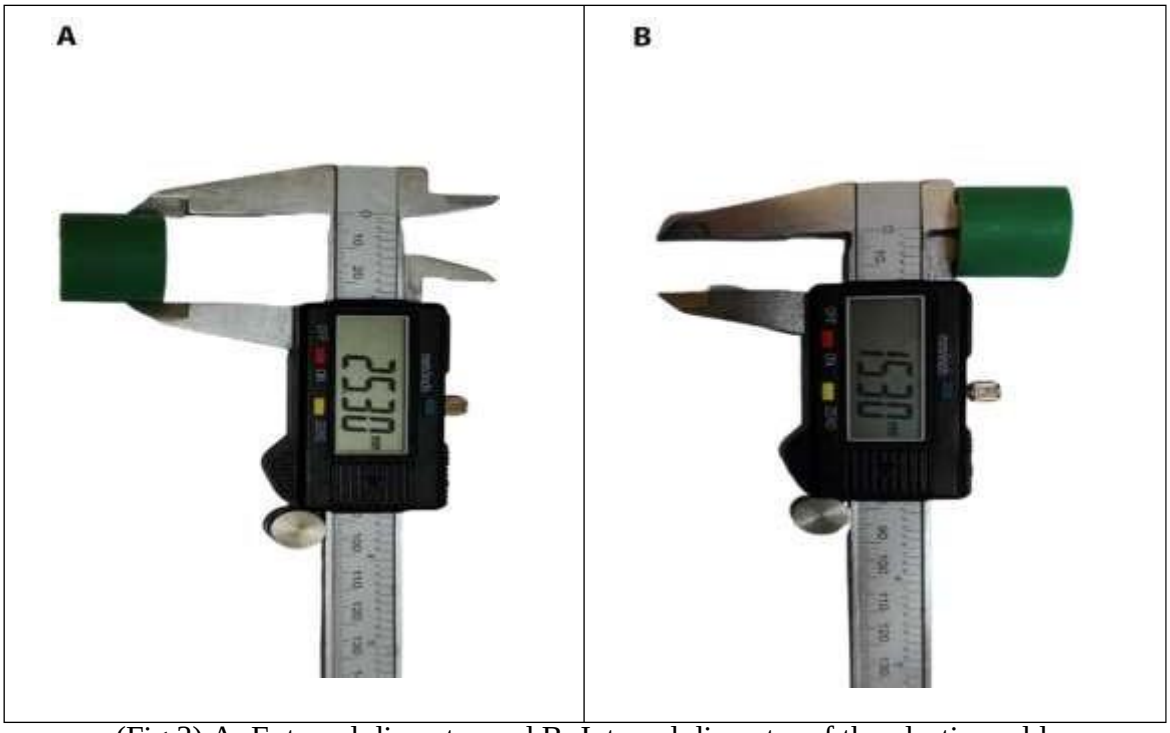
This study was carried out on extracted teeth. A total number of 40 Maxillary premolar teeth recently extracted for orthodontic reasons (Buccolingual width range (9 ± 0.8 mm) and mesiodistal width range (7 ± 0.8 mm), which were taken at the proximal cementoenamel junction (C.E.J) level using digital caliper) (Fig. 1,2), with prepared MOD cavities and restored with composite restorations to assess fracture resistance.

(fig. 1) Buccolingual dimensions of teeth.

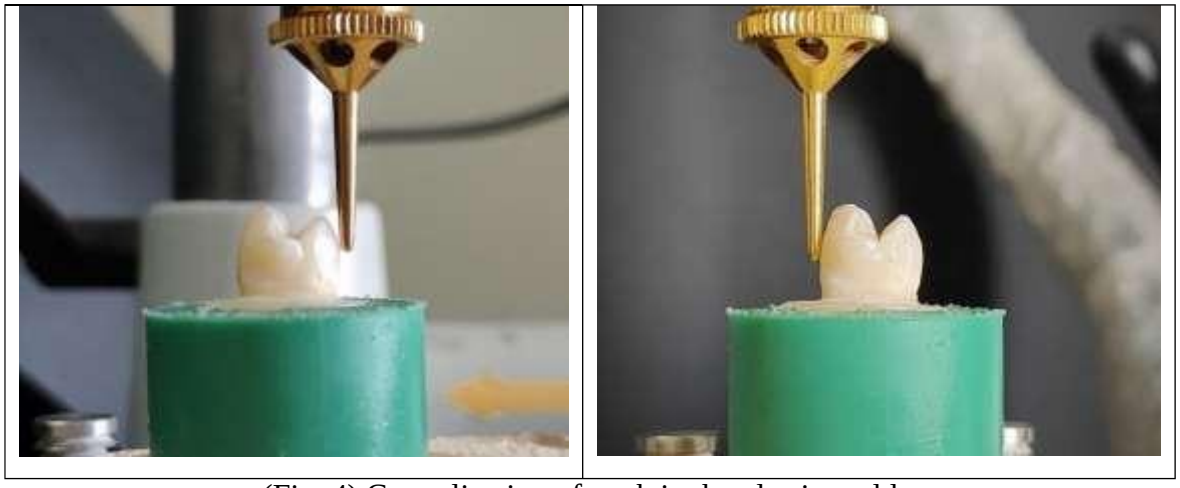
(Fig.2) Mesiodistal dimensions of teeth.

2.3 Sample grouping: The Maxillary premolars were divided into 4 main groups (n = 10), composed of (I_1) Neo spectra ST LV (Dentsply), (I_2) Clearfil AP-X (Kurari Noritaki), (B_1) Sonic fill 3 (Kerr), and (B2) Palfique bulk flow (Tokoyama dental)**.**

2.4 Preparation of mold and mounting of teeth: Root surfaces were marked 2 mm below the crown margin to simulate the biologic width and to mimic the alveolar bone support in healthy tooth [(4)]. Teeth then were dipped in melted set up wax (Tenatex Pink) up to marketed point to form a uniform coat of about 0.2 - 0.3 mm around root surface. Specimens were then imbedded in auto-polymerizing acrylic resin (Charm temp, auto mix cartilage, temporary crown material). teeth embedded up to 2mm apical to cemento-enamel junction surrounded by a cylindrical-shaped plastic mold (internal diameter 15.30 mm, external diameter 25.30, Hight 20 mm) (fig.3 A, B), with the long axis of the tooth parallel to the plane of the plastic mold. Accurate centralization of the teeth in the acrylic resin was done using dental surveyor. (Fig. 4)
After acrylic setting, the block was removed from the mold and checked carefully. Then the teeth were removed from the casted acrylic block, wax spacer was removed then light body poly-vinyle siloxane material (Speedex) was injected in the space mold and then teeth were re-inserted in the mold. Thus, the periodontal ligament was simulated to some extent. The specimens were stored in distilled water at room temperature for 24 hours before testing.



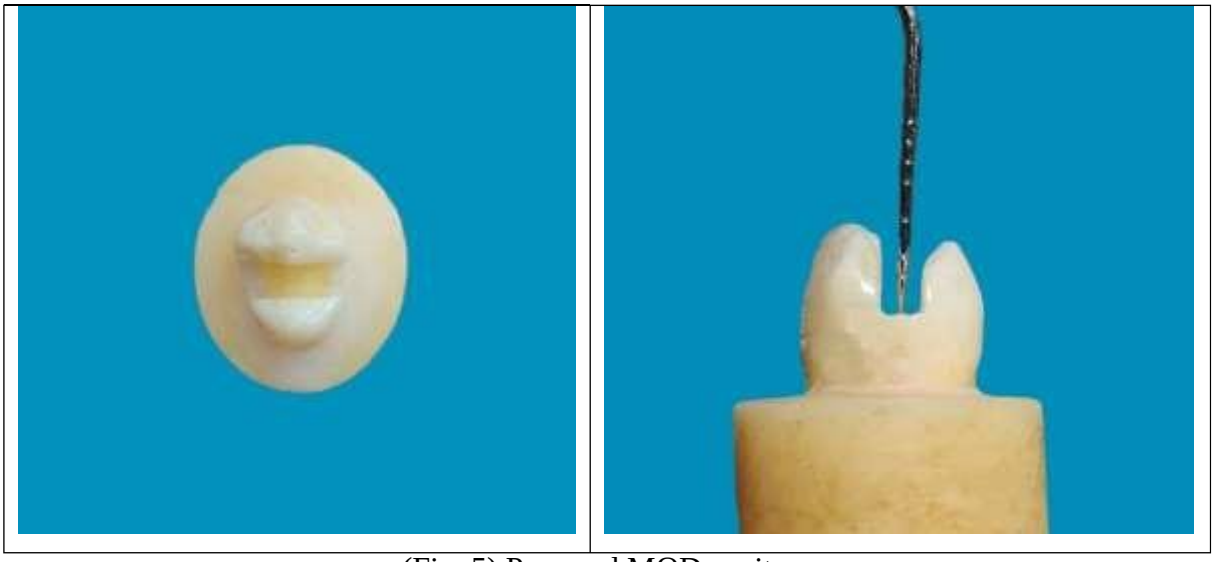
(Fig 3) A: External diameter and B: Internal diameter of the plastic mold.



(Fig. 4) Centralization of teeth in the plastic mold.

2.5 Cavity preparation:

Standardized MOD cavities were prepared with a parallel sided carbide fissure burs in a high-speed hand piece under water coolant, with each bur being replaced after every four preparations [(5)].
MOD cavity preparation was centred between buccal and palatal cusps to preserve the maximum dentinal support for both cusps. For centralization, A line was drawn at cementoenamel junction on the two proximal surfaces of each tooth by a waterproof marker, then 2 lines were drawn from cusp tips to cementoenamel junction to represent inter-cuspal distance. Cavity dimensions were then measured using periodontal prope and the cavity outline was drawn centred in the inter-cuspal distance formally measured. (Fig. 5)



(Fig. 5) Prepared MOD cavity

2.6 Restorative procedures:

Cavities were encircled with a metallic matrix band held firmly by matrix retainer (Tofflemire, USA) against the proximal aspects on the teeth being restored to simulate the clinical conditions [6,7] The bands were changed for each restoration.

2.6.a. Application of adhesive protocol:

The adhesive protocol used was selective etching of enamel and placing one-bottle adhesive for both enamel and dentin.

2.6.a.1. Application of acid etchant:

Selective etching of enamel was done by application of the etchant gel (DE Trey conditioner 36, Etching gel) only on enamel for 15 seconds. Then rinsed with water for 10 seconds using triple-way syringe to completely remove the acid from the tooth surface then gently dried **by blotting with cotton pellet.**

2.6.a.2. Application of adhesive agent:

Adhesive systems were used according to each material used. The adhesives were applied as one step to the prepared cavities and rubbed on enamel and dentin surfaces using disposable brushes and then cured by LED light curing unit (Elipar Deep Cure-L. 3M ESPE) according to manufacturer's instructions.

2.6.b. Application of composite material:

The composite was applied and built up according to the manufacturer instructions by using a gold packing instrument.

I_1 (Incremental filling): after curing of the adhesive (Prime and Bond Universal**),** the cavities were restored with Neo spectra ST(LV) composite which packed in two horizontal increments, 2mm thickness each (measured by periodontal probe) and each increment was individually light cured with light curing unit as mentioned before.

I_2 (Incremental filling): after curing of the adhesive (Clearfill S3 bond), the cavities were restored with Clearfil AP-X composite which packed in two horizontal increments, 2mm thickness each (measured by periodontal probe) and each increment was individually light cured light curing unit as mentioned before.

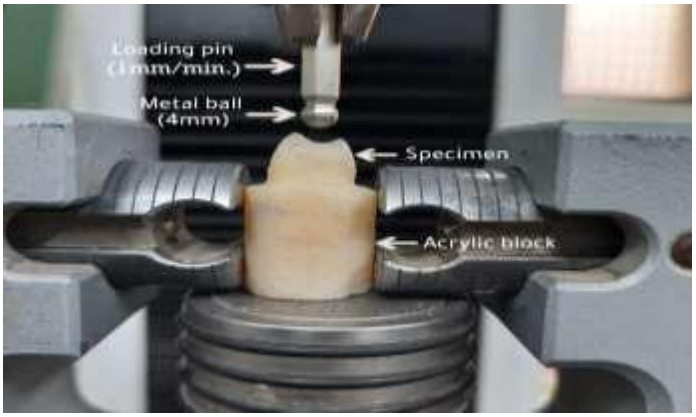
B_1 (Bulk filling): after curing of the adhesive (OptiBond Universal, Kerr), the cavities were restored with SonicFill 3 bulk fill composite. Mounting of the Sonicfill handpiece to the high-speed aerator was done (air pressure between 2-3 Bar), followed by placing the composite compule into the tip of the device. Then, the speed of composite ejection from the SonicFill handpiece was adjusted to speed 3 (where No.1 is the slowest, No.5 is the fastest). Upon activation of the handpiece, resin composite flowed into the cavity in one increment.
The tip of the compule was always at a lower level than the ejected composite material inside, after turning off the hand piece, composite was packed using ball burnisher and the excess material was removed before curing, then curing was done according to the manufacturer's instructions with the same light curing unit as mentioned before.

B_2 (Bulk filling): after application and curing of the adhesive (Palfique bond, Tokayama dental), the cavities were restored with PALFIQUE bulk flow composite which applied as one increment of 4 mm thickness and then cured for 20 seconds according to the manufacturer instructions as mentioned before. The light curing tip was placed as close as to the cavity surface (0 mm).
In all groups, buccal and lingual post-curing was done for 40 seconds after removing the matrix band. Finally, all restorations were finished using yellow coded finishing burs and polished using spiral polishing wheels (3M ESPE).

2.7 Storage of teeth: Restored teeth were stored in normal saline which changed weekly until the time of evaluation at room temperature.

2.8 Thermocycling:
All specimens were subjected to thermocycling between 5C° to 55C° in water bath (30 seconds each) for a total of 10000 cycle (equivalent to aging of about 12 months) [8] with 10 seconds dwell time at each bath using thermocycling device (SD Mechanotronicthermocycler, Germany).

2.9 Fracture resistance testing
The specimens were individually mounted on a computer-controlled materials testing machine (Instron universal testing machine; Model 3345) with a load cell of 5 kN and data were recorded using computer software (Instron Bluehill universal, Instron, England). The specimens were mounted and secured on the lower fixed compartment of the testing machine by tightening screws, to ensure that the loading steel rod with spherical tip of 4 mm diameter was positioned on the central occlusal surface of the restoration in such way the load applicator tip only touched the inclined planes of buccal and lingual cusps, The loading steel rod with spherical tip was attached to the upper movable compartment of the machine traveling at cross head speed of 1mm/min. (fig. 6). A layer of tin foil (1mm thickness) was placed between the loading tip and the occlusal surface of the restoration to achieve an even stress distribution and to minimize the transmission of local force peaks. (Fig. 7).



(Fig. 6) specimen secured at the testing machine.

(Fig. 7) Tin foil between the loading tip and the occlusal surface of the restoration

2.10 Statistical analysis:

Data were collected, tabulated, and statistically analyzed using a commercially available software program (SPSS Chicago, IL, USA). Numerical data were described as mean and standard deviation or as median and range as appropriate according to the normality of the data using tests of normality (Shapiro-Wilk test). Qualitative data were presented as frequencies (n) and percentages (%). The Chi-square test was used to compare the two groups. Numerical data were described as mean and standard deviation. F-test (ANOVA) was used for normally distributed quantitative variables, to compare more than two groups. The level of significance was set at $p < 0.05$. All tests were two-tailed.

3. RESULTS

One-way ANOVA test results revealed that the difference between the averages of all groups is not big enough to be statistically significant. (Table 1)

The results revealed that group B_2 had a higher mean ± SD fracture resistance value of (1425.80± 455.39) followed by group I_1 with a fracture resistance value of (1291.8 ± 389.87), and group B_1 with a fracture resistance value of (1254.75± 373.28). The lower mean ± SD fracture resistance value was recorded with group I_2 (1075.43± 321.42). (Table 2)

For intergroup comparison, the results of the Tukey HSD test showed a non-statistically significant difference among the different tested groups ($p>0.05$). (Table 3)

Table (1): ANOVA table for fracture resistance comparison

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	3	751021.2825	250340.4275	1.663	0.1887
Error (within groups)	44	6622469.143	150510.6623		
Total	47	7373490.425	156882.775		

DF; degree of freedom.

Table (2): Comparison of fracture resistance of different groups.

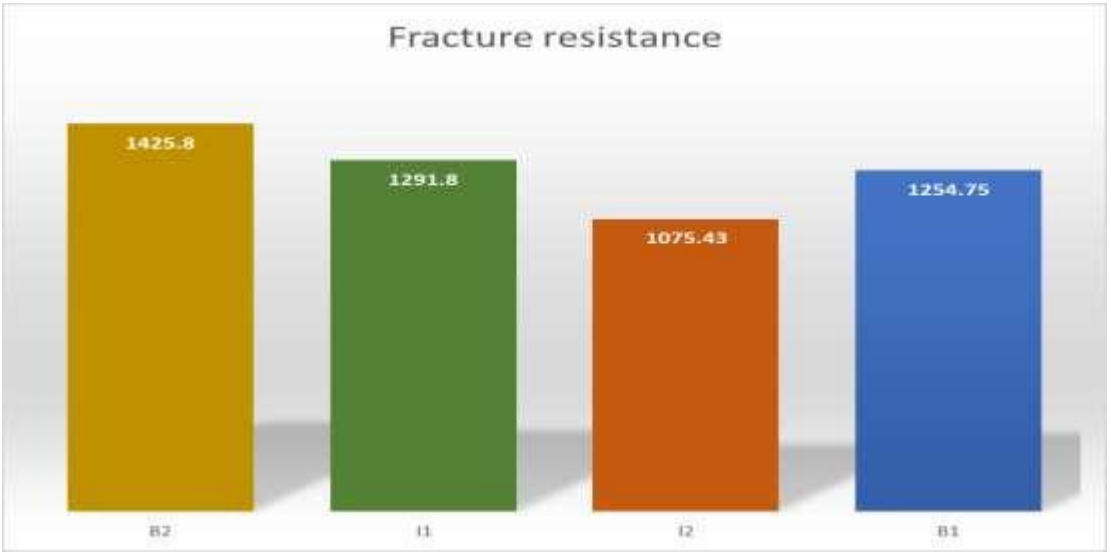
Variable	Mean± SD	f-ratio	p-value
Group B_2	1425.80± 455.39	1.663	0.1887 ns
Group I_1	1291.8 ± 389.87		
Group I_2	1075.43± 321.42		
Group B_1	1254.75± 373.28		

*; Significant at p<0.05. ns; non-significant.

Table (3): Tukey HSD for intergroup comparison

Pair	SE	Lower CI	Upper CI	p-value
B_2-I_1	111.9935	-288.9593	556.8066	0.8324
B_2-I_2	111.9935	-72.5099	773.256	0.1358
B_2-B_1	111.9935	-251.8327	593.9332	0.7034
I_1-I_2	111.9935	-206.4335	639.3324	0.5266
I_1-B_1	111.9935	-385.7563	460.0096	0.9954
I_2-B_1	111.9935	-243.5602	602.2058	0.6719

SE; standard error. CI; confidence interval.



(Fig. 8): Comparison of fracture resistance of different groups

4. Discussion

Fracture has been reported of the most common reasons for replacement of posterior composite restorations, MOD cavity preparation causes a drastic reduction in tooth strength because of the loss of marginal ridges [9]. Fracture resistance is considered one of the standard suggested tests for evaluating the fragility of a restored tooth as it dictates the maximum load that a restorative material and a tooth can withstand before any damage takes place [10]. This study examined the fracture resistance of maxillary premolars, the anatomic shape of which creates a tendency for separation of their cusps during mastication [11, 12]. The general effect of MOD cavity preparation is the creation of long cusps in order to simulate the worst clinical situation [13]. This study evaluated the Fracture resistance (resistance to compression) of four experimental groups (two universal and two bulk fill composites) which include: Neo spectra ST, Clear fill AP-X, Sonicfill 3 and PALFIQUE bulk flow. Clinically, the oral environment represents a challenge to durability of composite restorations due to temperature changes. Therefore, in the present study before testing the specimens, thermal cycling regime was conducted to simulate intra-oral temperature changes (thermal changes caused by drinking, eating, and breathing) on the tested specimens during service for 10000 cycles which is equal to about one year of clinical service [8]. The results of this study showed that bulk fill flowable composite PALFIQUE bulk flow (PBF) has the highest fracture resistance in comparison to other tested groups with no significant difference. This could be attributed to their unique filler composition, highly cross-linked resin matrix and resiliency which provide ability to withstand higher stress prior to fracture. These favorable results for PBF may be explained by generating less polymerization shrinkage stress, possibly as a result of increasing the translucency and containing a RAP technology, which enhance light-curing efficiency of dental composites by increasing the free radicals produced from each activated camphoroquinone (CQ) molecule, hence increase depth of cure (DOC) and degree of conversion (DC) of composite material [14]. Another explanation for the higher fracture resistance of the composite resin group would be the lower elastic modulus of the composite that resulted in lower stresses in the composite restorations [15]. Moreover, PBF composites are typically nano-filled with spherical silica-zirconia fillers which improve their mechanical properties [16]. These results are in line with the results of Abdelwahed G. et al. (2022) who compared the depth of cure of PBF composite to other dental composites and found that PBF had higher curing depth. The researchers attributed this to the fact that PBF uses a proprietary resin matrix that leading to better mechanical properties [17]. Another study by Natsir N. et al 2022 tested the tensile strength and fracture pattern of PBF and concluded that it can be used as an effective base material for the complex restoration of the posterior tooth. This finding may be attributed to a low modulus flowable composite that increase the flexibility by allowing it to act as a stress breaker [18]. On contrast to the results of our study, EL-Safty (2012) observed lower mechanical properties with bulkfill flowable composite resin than conventional nanohybrid composite [19]. This may be due to differences in materials and methods used.

The nanohybrid RBC (neo spectra ST) and bulk fill RBC (Sonicfill 3) acted similarly in terms of fracture resistance with higher values for nano hybid RBC than bulk fill RBC with no significant difference. This may be due to the rheological similarity that is based upon methacrylate matrix consisting of BisGMA,TEGDMA and the inorganic silica nanofillers. The difference is in viscosity and photo-initiator system that is modified in bulk fill RBC to enable it to be cured in 4mm thickness. The photo-initiator apparently succeeded in its claimed role with efficient degree of conversion [20]. This is emphasized by the approximate results found when comparing it with incrementally packed nanohybrid RBC. Under cured RBC leads to a drop in mechanical and physical properties of composites which did not happen with the bulk fill RBC [21]. These results are consistent with a study by Abdul vahid N. and Manjunath K, 2016 [22] , Fahad and Majeed, 2014 [23], Atiyah and Baban, 2014 [24] and Toz et al, 2015 [25], They all concluded that, bulk fill composites act similar to nanohybrid RBC in terms of load bearing capacity when used in MOD cavities and can be used reliably as nanohybrid RBCs. On the other hand, it was reported by Hada Y.S.et al, 2019 [26] that nanohybrid composite was statistically significantly higher than bulk fill composite, which was in disagreement with the present study where bulk fill and nanohybrid composites acted

similarly in terms of fracture resistance with no statistically significant difference. Hada Y S. et al. justified their results by difference in the chemical compositions of the materials matrix, filler content, filler size, and distribution.

Finally, the results of the current study showed that micro hybrid composite (Clearfill AP-X) showed the lowest fracture resistance in comparison to all groups with no significant difference with other groups. Larger filler particles have less surface contact area which results in a lower surface energy of the filler-matrix interface and leads to a lower fracture toughness. this is attributed to the smaller surface contact area of large fillers compared to smaller filler particles which provide better filler-matrix interface bonding [(27)]. Another explanation for this is the distribution and orientation of the filler particles. In Clearfil AP-X, due to presence of different sizes of filler particles, it is possible to be not evenly distributed, and some areas may have a higher concentration of filler particles than others. This can result in areas of the composite that are weaker and more prone to fracture [(28)]. These results were in accordance with the results of Taha et al. 2011[(29)], Margarit et al, 2021[(30)], Mohan et al, 2019 [(31)] and Ata, 2017 [(32)] , who observed that improved fracture resistance was found in the nanohybrid group that showed higher fracture resistance while micro hybrid group revealed lower fracture resistance in comparison to all restored groups, that was also statistically insignificant. In contrast, the present study was in disagreement with another study conducted by Bonilla et al. 2020 [(33)] and Lohbauer et al. 2013[(34)], who reported that micro hybrid composite showed the highest fracture resistance compared to nanohybrid. This can be attributed to the organic matrix composition that is responsible for polymerization shrinkage and considered the weak link of the composite system.

5. Conclusion

BPF (B_2) showed higher mean fracture resistance values followed by Neo spectra ST (I_1), Sonic fill 3 (B_1) while clearfil AP-X (I_1) showed lower values than other groups with no significant difference between all groups.

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