Comparative evaluation of fracture resistance of teeth restored using fibrafill cube, polyethelene fiber and bulkfill composite in class I cavity - An invitro study

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ABSTRACT

Aim: To evaluate and compare the fracture resistance of teeth restored using fibrafill cube, polyethelene fiber and bulkfill composite in class I cavity.

Materials and methods: Forty-five intact, freshly extracted,caries-free human maxillary premolar teeth extracted for orthodontic purposes were selected. The teeth samples were embedded into acrylic resin up to 1 mm below CEJ. Standardized Class I cavities measuring 3mm in depth,3 mm in width while 4mm in length were prepared using diamond straight fissure bur. All the samples were etched using 37 % phosphoric acid and bonding agent was applied which was cured for 20 sec. The teeth were randomly divided into group of three containing 15 each. Group I was restored with fibrafill cube, Group II with polyethelene fiber and Group III with bulkfill composite. All the specimens were thermo-cycled for 500 cycles between 5°C and 55°C with 1 min in each cycle. Fracture resistance was recorded for all samples using a universal testing machine.

Statistical analysis: Data was analysed using One-way Anova Test and Post Hoc Tukey Test was used for intergroup comparison .

Results: The results were statistically significant. The fracture resistance was higher in group I (fibrafill cube) and least in group II (polyethelene fiber).

Conclusion: Within the limitations of the study it can be concluded that fibrafill cube showed higher fracture resistance.

Key words: Fibrafill cube, Polyethene fiber, Bulkfill composite, fracture strength, class I cavity.

INTRODUCTION

Resin composite materials are the primary choice for direct restorations in the posterior dentition.Numerous clinical studies have reported high clinical performance and durability.According to Behery et al due to increase in high patient demand for tooth-colored restorations that make a natural impression, the use of direct posterior composite resin restorations has widely increased for similar purposes.[1]Taha et al stated that in addition to the aesthetic considerations, a restoration must be able to restore the function, preserve the remaining tooth structure and prevent fracture of the tooth.

Composites have undergone constant evolution over past few years to enhance its esthetic, physical and mechanical properties.However, there are certain drawbacks. One of those is polymerization shrinkage. It occurs in the range of 2–5%.Polymerization shrinkage occurs as the distance between monomers decreases when the weak Van der Waals forces between monomers get converted into covalent bonds.[2]Polymerization shrinkage generates stress within resin composites at the interface between the composite restoration and the tooth substrate as well as within the tooth structure. This can lead to marginal gaps and micro-cracking of either the restorative material and tooth structure (or both).[3]

Damage in dental composites may result in matrix and/or filler degradation due to mechanical and/or environmental loads, interfacial debonding, microcracking and/or filler particle fracture. A continuous application of mechanical and environmental loads eventually causes progressive degradation and crack formation and growth which results in catastrophic failure of dental restorations.[4]De V Habekost et al stated that in accordance with both in vitro and clinical findings, showing that in general for both molar and premolar teeth, the greater the number of restored surfaces and the wider the isthmus of the restoration, or both, higher is the chance of cuspal fracture as the time progresses.[5]

Leakage or microleakage occurs in conjunction with all the dental restorations and has been defined as clinically undetectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative material placed into it. Debonding occurs at the interface of tooth and restoration when the shrinkage stress exceeds the bond strength. As a result a number of problems may arise, such as precipitating clinical and radiographic sequelae including hypersensitivity, secondary caries, pulp inflammation and finally removal of restoration. Reducing the amount of polymerization shrinkage is a major issue in the development of dental resin composites.[6]

Extensive work has been carried out in order to find out the alternative material with esthetic, durability, fluoride releasing properties, and better fracture resistance to overcome the restoration fracture, which is the most common cause of restoration failure in posterior teeth.[7]

Composite resins can be successfully utilized for reinforcement of weakened tooth structure. Mechanical and physical properties of direct composite resins such as fracture strength, hardness and polymerization shrinkage are variable.Thus, the properties of restorative materials should be taken into consideration prior to restoration of teeth.[8]

In the last 20 years, a leno woven ultra high molecular weight (LWUHMW) polyethylene fiber ribbon (byRibbond THM; Ribbond Inc., Seattle WA, USA)placed into a bed of flowable composite has been used in different direct restorative techniques. The purpose of the polyethylene fibers is multiple. Rudo and Karbhari used polyethelene fibers to form a stress-absorbing layer and reduce potential cracks and fractures while Belli et al used the fibers to internally splint the tooth and increase fracture resistance.[9,10]Polyethelene fiber (Ribbond) is colourless and pliable material which easily adapts to the tooth structure. Polyethene fibers are translucent and hence can be used in aesthetic restoration. The reinforced polyethylene fiber is also supposed to reduce the polymerization shrinkage and provide reinforcement in material while setting.[11]

Modifying the restorative techniques may reduce the stress of polymerization shrinkage. To minimize the development of stresses, incremental placement technique is used in which the composite is cured in layer of thickness of 2mm.Incremental application is recommended in order to decrease polymerization shrinkage stress and achieve desirable mechanical properties.[12-14]This method is the gold standard for placement of composite resins.[13]However, it has certain drawbacks such as the possibility of void formation in between the increments, bond failure amongst the increments, difficult application in small cavities with limited access and also increased chairside time due to incremental application and separate polymerization of each layer.[15] In an attempt to overcome all these limitations, bulk-fill composites were introduced in to the market. They can be applied in the cavity as bulk with minimal polymerization shrinkage during curing. Bulk-fill composites do not require incremental application.[16-18] Therefore, they simplify the restorative procedure and also decrease the duration of treatment.[19]

Bulk-fill composites can be inserted as a single increment layer 4–5 mm in thickness have been proposed as an alternative to simplify the restorative procedure and decrease the polymerization shrinkage stress.[20]Ivoclar Vivadent Tetric N Ceram Bulk Fill has been used in this study.Tetric N Ceram bulkfill represents the medium viscosity type bulk fill. The curing depth of 4 mm is achieved mainly due to the patented photo-initiator Ivocerin, which is far more reactive than conventional initiators.[21]

The significant advantage of adhesive restorations is their ability to mimic the natural behaviour of enamel and dentine. The DEJ has been described as a prominent interphase connecting two bio-mechanically different tissue types, namely the rigid protective enamel and the more elastic supportive dentine, thus forming a mechanically extremely durable unit. The DEJ interphase also has function in the stress absorbing capability of the tooth. It provides crack tip shielding, which should be preserved or mimicked during restorative procedures. The rationale of mimicing DEJ is to prevent the crack propagation into the deeper layers of the restoration during a mechanical overload, thus minimizing the cantilever that acts to separate the restoration.[22]

Fibrafill cube by dentapreg is the most recent advancement and newer to restorative dentistry. It is the resin composite with integrated continuous membrane which distributes stress equally and mimics the function of dentinoenamel junction (DEJ). It has reduced risk of crack development and propagation through the interface between restorative material and remaining dental tissues.The system includes microhybrid light curable composite materials with integrated fiber reinforcement, intended for the fabrication of direct restorations as a substitute for the dentine layer.[23]

There hasn’t been any research conducted to date to assess the fracture strength of fibrafill cube, polyethelene fiber and bulkfill composite. Hence the goal of the study is to evaluate and compare the fracture strength of fibrafill cube, polyethelene fiber and bulkfill composite.

MATERIALS AND METHODS

1.Specimen preparation

A total of 45 sound human maxillary premolars, freshly extracted for orthodontic purpose were selected. The teeth with extensive wear, caries, cracks, fractures or previous restorations were excluded.The freshly extracted teeth were cleaned to remove any periodontal soft tissue or calculus from the root and crown by using a Gracey hand scaler (Hu-Friedy, Chicago, IL, USA) . All the teeth were disinfected by immersion in a 0.5% sodium hypochlorite solution for 15 min. Sterilized teeth were stored in distilled water until use. The teeth were embedded in the acrylic resin up to 1 mm below the cemento-enamel junction.

2. Cavity Preparation

Standardized Class I cavities were prepared using a diamond straight fissure bur (SF-11 Mani) and high-speed water-cooled hand piece. The dimensions of the cavity were such that the buccolingual width of the cavity was 3 mm, depth of the cavity was 3 mm while mesiodistal distance was 4 mm which was confirmed using a calibrated periodontal probe(Hu-Friedy, Chicago, IL, USA).All the specimens were etched with 37 % phosphoric acid (prime) rinsed and pat dried.Then the bonding agent (Coltene one coat bond SL) was applied to the teeth and cured for 20 sec. . All the specimens were randomly divided into group of three (n=15) as follows: -

1. GROUP I: RESTORED WITH FIBRAFILL CUBE

Fibrafill cube was placed into the cavity and cured for about 20 sec. 1 mm layer of packable composite (Filtek Z250 XT 3 M ESPE) was placed over it and was cured for 20 sec.

2. GROUP II: RESTORED WITH POLYETHELENE FIBER

A thin layer of flowable composite (Filtek Z 350 3M ESPE) was applied in the cavity and left uncured. The polyethelene fibers (ribbond) were cut according to the dimensions of cavity (buccolingual width 3 mm and mesiodistal distance was 4mm) and soaked in bonding agent (Coltene one coat bond SL). The excessof the bonding agent was removed by gently tapping a dry microbrush on fiber,then the fibers were placed over the flowable composite which was placed in the cavity. A non-sticking plastic hand instrument was used to gently push the fibers so that they were laminated as closely as possible to the cavity floor and then cured for 20 sec. 1mm of conventional packable composite (Filtek Z250 XT 3M ESPE) was added over it and cured for 20 sec.

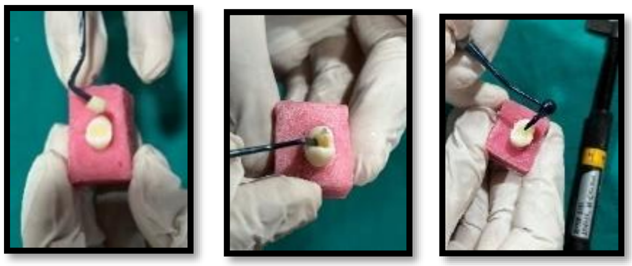
3. GROUP III: RESTORED WITH BULKFILL COMPOSITE.

3 mm increment of Bulk Fill (IvoclarVivadentTetric N Ceram) was placed in and cured for 20 sec.

To simulate the functioning in the oral cavity all the specimens were subjected to thermocycling for 500 cycles between 5°C and 55°C with 1 min in each cycle.

3.Evaluation of Fracture Resistance

All specimens were tested for the fracture resistance within 24 h after thermocycling.Fracture resistance was tested under compression using Universal Testing Machine (computerized, software-based Company: ACME Engineers, India Model: UNITEST 10 System Accuracy of the machine: +/- 1%). Each specimen was subjected to vertical compressive force with a 3 mm diameter stainless steel ball and a cross head speed of 0.5 mm/min. The force needed to fracture each tooth was recorded in Newtons.



GROUP I Fibrafill cube — GROUP II polyethelene fiber — GROUP III Bulkfill

STATISTICAL ANALYSIS

One-way analysis of variance (ANOVA) was used to compare the bond strength of the groups and followed by the post hoc test for intergroup comparison.

RESULTS

The maximum results obtained were for Group I Fibrafill cube with mean fracture strength value 1632.033 N followed by Group III bulkfill Composite with mean value of 1407.333 N. Least fracture resistance was found in Group II Polyethelene fiber with mean value of 861.200 N.The fracture strength value of three groups is presented Table 1.

Table 1 Descriptive statistics for Fracture resistance among three groups.

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Group I Fibrafill cube	15	1312.0	1851.5	1632.033	209.1962
Group II Polyethelene Fiber	15	743.0	949.0	861.200	79.0653
Group III Bulk Fill Composite	15	1168.0	1690.0	1407.333	159.8444

There was statistically significant difference among three groups for Fracture resistance with $p<0.001$

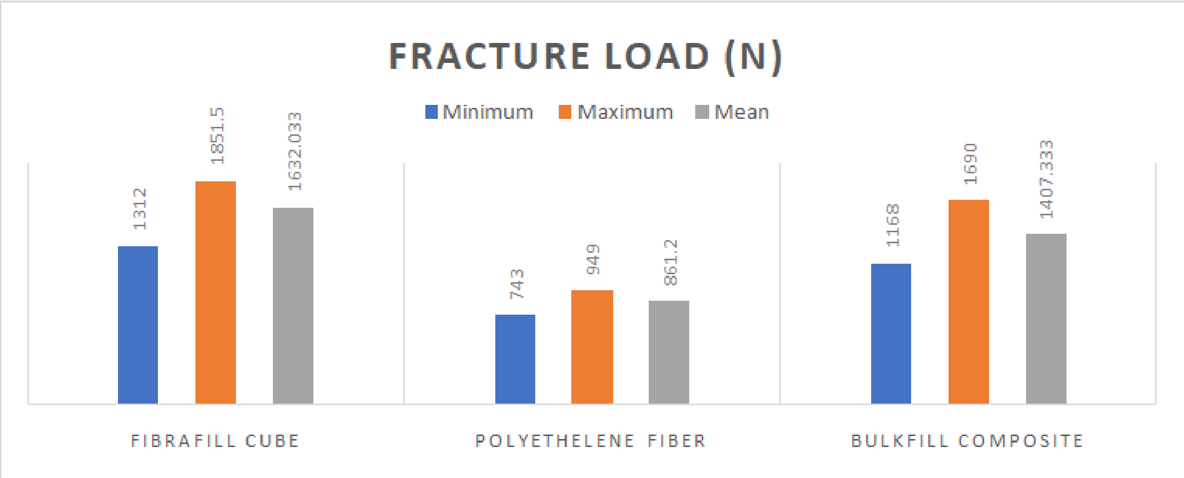
Intragroup comparison for mean fracture strength between Group I and II (Fibrafill Cube and Polyethelene Fiber) was statistically significant < 0.001.**Intragroup comparison**

for mean fracture strength between Group I and III (Fibrafill Cube and Bulkfill composite) was statistically significant 0.001.**Intragroup comparison for mean fracture strength between Group II and III (Polyethelene Fiber and Bulkfill composite)** was statistically significant < 0.001.Intragroup comparison for mean fracture resistance between three groups are depicted in Table 2

Table 2 Various Intragroup comparison of Fracture resistance between three groups (post hoc test)

Multiple Comparisons						
(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig. p value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group I Fibrafill cube	Group II Polyethelene Fiber	-770.8333*	57.9519	<0.001*	-911.627	-630.039
Group I Fibrafill cube	Group III Bulk Filled Composite	-224.7000*	57.9519	.001*	-365.494	-83.906
Group II Polyethelene Fiber	Group III Bulk Filled Composite	546.1333*	57.9519	<0.001*	405.339	686.927
*. The mean difference is significant at the 0.05 level.						

Graph 1. Fracture Resistance of Fibrafill cube, polyethelene fiber and bulkfill composite.



DISCUSSION

Removal of tooth structure during cavity preparation has been shown to weaken teeth and increase the chances of fracture.[24]Fracture is a complete or incomplete break in a material which results from the application of heavy forces. Fracture resistance is directly related to the cessation of the crack propagation. Masticatory forces have a tendency to deflect cusps, and composites tend to decrease the deformation of the cusps under masticatory load. [25] The mechanical and physical properties of direct restorative materials, such as fracture toughness, modulus of elasticity, creep, hardness and polymerization shrinkage should be taken into consideration before restoration.

Plotina et al and Taha et al stated that polymerization shrinkage is a serious problem for large direct composite restorations, resulting in cuspal strains with subsequent stress or disruption of the bond, microleakage and recurrent caries or even enamel cracking. Polymerization shrinkage stress which may result in various clinical problems such as fractures is affected by the composition and filler content of resin composites.[26,27]

Deliperi et al mentioned that the other characteristic problem of composite materials is their inadequate fracture toughness, which was shown to be significantly lower than that of dentin. [28]Lassila et al and Demarco et al mentioned that fracture within the body (bulk) and margins of restorations and secondary caries are major problems which lead to the failure of posterior composites. [29,30]As modern composite resin materials are rigid, they do not lack strength, but they lack toughness .[28] As described by Lassilla et al., fracture toughness is a mechanical property that describes the resistance of brittle materials to the catastrophic propagation of flaws under an applied load.[29] Thus, it describes damage tolerance of the material and can be considered as a measure of fatigue resistance which predicts the structural performance. According to Braga et al the problem of lack of toughness is especially well seen in extensive direct restorations as the volume of the material increases in suchcases.[31]

In this study Group I Fibrafill cube showed higher fracture strength followed by Group III Bulkfill composite. Least fracture strength was found in Group II polyethelene fiber. The manufacturers claim that fibrafill cube is the only resin composite with integrated continuous membrane which distributes stress and mimics the function of dentinoenamel junction (DEJ). It extends possibilities for large restorations and build-ups of endodontically treated teeth with severe loss of hard dental tissues.

The material is available in the form of discrete application blocks with integrated membrane reinforcement and is made of surface-treated continual glass fibers. The fibrafill cube is made of special glass. Advanced technologies such as Fiber Membrane Integration and Monomer Embedded Fibers ensure reliable function and longetivity. The material's consistency has been optimized for easy manipulation and condensability. A unique system of packaging eliminates the risk of cross contamination due to separate packaging of individual units. Fibrafill cube represents a unique biomimetic solution for hard tissue restoration. It is a complex system based on reinforcing effect of a continual fiber reinforcement and short dispersed fibers making it ideal for dentin replacement in large posterior applications (pre-endodontic and postendodontic build-ups and fillings).

Fibrafill cube minimizes the development of cracks and their propagation through the interface between restorative material and remaining dental tissues. There is also reduced risk of severe failure of remaining hard dental tissues which in turn increases the longetivity. There is increased fracture toughness of the filling or build-up. Manufacturers claim that fibrafill cube reduces the effect of stress concentration in critical areas in large fillings and restoration. The presence of membrane reinforcement has the effect of distributing tension over a large area, thus mimicking the function of DEJ. It reduces the shear stress in the adhesion area, securing the marginal integrity.[23]

Fibrafill cube minimizes the polymerization stress due to the composition and presence of reinforcing fibers. Reinforcing fibers increase adhesion between individual layers of the composite on the principle of micromechanical retention. It minimises the risk of fatal failure and extending the service life of a restoration due to overall reinforcement and increased toughness. Fibrafill cube is available in universal dentin shade. The dimensions of cube are around 3mm in width, 4mm in length and 3mm in height.[23]

Fibrafill cube contains silane treated glass <80 % wt, Isopropylidenediphenol PEG-2 Dimethacrylate (Bis-EMA) <10 % wt, Silane treated silica <5 % wt, Bisphenol A Glycidyl Methacrylate (Bis-GMA) <5 % wt,Urethane Dimethacrylate (UDMA)<5 % wt,Triethylene glycol dimethacrylate (TEGDMA)<5 % wt, 2-hydroxyethyl methacrylate (HEMA)<2 %

wt,Camphorquinone (CQ)<1 % wt, 2-(dimethylamino)ethyl methacrylate (DMAEMA)<1 % wt, 3,5-di-tert-4-butylhydroxytoluene (BHT)<1 % wt.[32]Fibrafill cube has wide range of applications.They are used for class I cavity, class II cavity, class V cavity including large combined cavities in the posterior area, deep cavities in endodontically treated teeth,pre-endodontic and post endodontic restorations,core restorations etc.

Tetric N Ceram Bulk Fill represents the medium viscosity type bulk fill. The curing depth of 4 mm is achieved mainly due to the patented photo-initiator, Ivocerin, which is far more reactive than conventional initiators.[8]Manufacturers claim that opposed to conventional composites, bulk-fill composites generate a lower polymerization shrinkage stress and have higher light transmission properties due to reduction of light scattering at the filler–matrix interface by either decreasing the filler amount or increasing the filler size.[33]

The monomer matrix of bulkfill composite is composed of dimethacrylates (19–21% weight). The total content of inorganic fillers is 75–77% weight or 53-55% volume. The fillers consist of barium glass, prepolymer, ytterbium trifluoride and mixed oxide. Additives, catalysts, stabilizers and pigments are additional contents (< 1.0% weight). The particle size of the inorganic fillers is between 0.04 and 3 µm. The mean particle size is 0.6 µm.

'Ivocerin' is a patented photoinitiator which is responsible for ensuring complete cure of the restoration. A conditioned shrinkage stress reliever has been added in order to reduce shrinkage and stress caused by it. According to Kumar and Sarthaj filler content plays a significant role in the depth of cure with the bulk-fill composites.[34] The increase in the filler content leads to greater depth of cure. An increase in the filler content decreases the volume of the resin matrix for polymerization and also increases hardness.

The main advantages of bulk-fill composites are number of voids are reduced, since all of it is placed at one time. Application studies have depicted that the bulk filling technique saves 55% on time compared with the conventional layering technique. This highly photoreactive initiator causes theTetric N cream bulkfill composites to be slightly higher in opacity when compared with other bulk-fill materials. As a result this bulk fill composite has an enamel like translucency of around 15%, which allows the material to blend in smoothly with the surrounding dental tissue on unstained dentin.The bulkfill composites can be used in restoration of deciduous teeth, Class I and II restorations in the posterior area including the replacement of individual cusps , class V restorations,reconstructive build-up and extended fissure sealing in molars and premolars.

Polyethylene fibers have shown greater fracture resistance in past studies. [38]Ribbond is a spectrum of 215 fibers which has very high molecular weight. It was first introduced to the market in the year 1992.Ribbond comprises of bondable,pliable,reinforced ultra-high-strength polyethylene fibers.[36] Fibers have high elasticity coefficient of 117 GPa. This makes them highly resistant to stretch and distortion. Also they have high resistance to traction which is around 3 GPa. This helps them to easily adapt to tooth morphology and dental-arch contours.[35] Ribbond fibers are exposed to gas plasma treatment. Due to this fibers can easily absorb water. This treatment reduces the superficial tension of fibers which ensures a good chemical bond to composite materials. Ribbond fibers are biocompatible, esthetic, translucent, practically colorless and disappears within the composite or acrylic without show-through.[35-38] They are also characterized by an impact strength which is five times greater than that of iron.[37]Ribbond fibers have variety of uses. They can be utilized in stabilizing traumatized teeth, restoring fractured teeth and creating a fixed partial denture and for direct-bonded endodontic posts and cores, orthodontic fixed lingual retainers and space maintainers.[35-38]

According to the manufacturer original RibbondÔ fibers are woven utilizing the lock-stitch leno weave which prevents slipping of fibers within resin matrix. This prevents micro-cracks and also formation of larger cracks. Ribbond fibers also reinforces the restoration in multiple directions. Beli *et al* found that insertion of polyethylene fiber in the occlusal third of a composite restoration increased the fracture resistance of endodotically treated teeth when compared to teeth restored with composite resin alone.[39]

Polyethylene fibers consist of a dense concentration of fixed nodal intersections that help in maintaining the integrity of the matrix. According to Akman et al polyethelene fibers enables the stresses in the bulk of the material to be transferred from one area to another more effectively because of the well-defined load paths. As shown by Eskitascioglu et al., using polyethylene fiber ribbon in combination with bonding agent and flowable composite under composite restoration may act as a stress absorber .This might be due to its lower elastic modulus.[40,41]

However Luthria *et al.*, evaluated the fracture resistance of endodontically treated teeth with wide MOD cavities which were restored with particulate filler composite resin reinforced by different types of fiber reinforced composite (glass and polyethylene). The results showed that the fracture resistance of composite restorations reinforced with glass FRCs (Interlig) was higher (600.5 N) than polyethylene FRCs (Ribbond).[42]

In the present study also placing polyethelene fibers into the class I cavity didn't increase the fracture resistance. When compared with fibrafill cube and bulkfill composite, polyethelene fiber showed the least fracture strength.

The causes for lower fracture resistance of Group III(polyethelene fiber) may include the following:Non uniform wetting of fiber with unfilled resin. Manual wetting of polyethelene fibers with unfilled adhesive was performed as suggested by the manufacturer which may lead to areas of non-uniform wetting in the fiber in turn affecting the adhesion of fiber to resin matrix. This may cause several problems in the future of the restoration. The poorly impregnated regions can cause increased water sorption, hence leading to deterioration of mechanical properties of the composite. The polyethylene fiber is treated with cold gas plasma in order to convert the material from hydrophobic to hydrophilic. This treatment is meant to make the fiber surface more receptive to bonding with the resin however; it makes the fiber very technique sensitive. Any contamination to the fiber surface may affect its adhesive properties. The polyethylene fibers were tougher to handle in this present study. The fibers frayed on cutting and became very stiff once the wetting procedure was done.[42]

An additional reason for its poor performance might be its lower tensile strength, density and elongation when compared to glass fibers. Kolbeck et al reported that the reinforcing effect of glass fibers is higher than that of polyethylene fibers.[43]Geerts *et al.*, also concluded thatglass fiber reinforcement seems to be the most appropriate over polyethelenefiber when fracture strength is taken into consideration.[44]Hence the fibrafill cube containing glass fibers proved to be superior than the polyethelene fibers in this in vitro study.

1mm layer of Filtek Z250 XT 3M ESPE packable composite was added over fibrafill cube and polyethelene fiber. Filtek Z250 also has shown high fracture strength. This high fracture toughness can be contributed to large filler particles (3.5m) that may improve "crack pinning" and "crack deflection" effects.[45]

Despite of this the obtained fracture resistance values in all the three experimental groups were much higher than the average normal biting force of human maxillary premolars (100-300N).[46] Many differences exist between fractures which occur clinically and those induced by a machine. Forces generated intraorally during function differ in magnitude, direction and speed of application whereas the forces applied to the teeth in this study were at a constant direction and speed and they increased continuously until the fracture of tooth occurred. Further in vivo studies should be carried out to test the reinforcement effect of these restorative materials in clinical situations.

CONCLUSION

It is possible to draw the conclusion under the constraints of this in vitro investigation that fibrafill cube showed higher fracture strength followed by bulkfill composite. Least fracture strength was found in polyethelene fiber.

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