Fracture resistance of endodontically treated molars restored with resin composites

Sonam Asopa[1], Jyothi Mandava[2,*], Uma Chalasani[3], Anupreeta Anwarullah[4], Ravichandra Ravi[5]

[1,5]Senior Lecturer, [2]Professor & HOD, [3]Professor, [4]Reader, Dept. of Conservative Dentistry and Endodontics,

***Corresponding Author:**
Email: jyothi10mandava@yahoo.co.in

Abstract

Introduction: To conserve tooth structure, adhesive composite restorations that can provide intracoronal reinforcement are advocated to restore endodontically treated teeth.

Aim: The objective of the study was to compare the fracture resistance of endodontically treated molars restored with cuspal coverage restorations using different resin composites.

Materials and Method: Ninety extracted, maxillary molar teeth were randomly divided into two control groups and four test groups (n=15 each). In seventy five teeth, class II MOD cavities with mesio-palatal cusp cappings followed by root canal therapy and post endodontic restorations were done. Restorative materials tested were: nanohybrid composite (Filtek Z250 XT), bulk fill composite (Tetric Evoceram), fiber reinforced (Ribbond) composite and indirect composite (SR Adoro). After finishing and polishing of the restorations, teeth were subjected to thermocycling and then to compressive loading in a universal testing machine. The mean load necessary to fracture the teeth were recorded in Newtons and stress distribution in these restored molars were tested by finite element analysis(FEA). The mode of failure was observed using stereomicroscope. Statistical analysis was done using SPSS/PC version 20.0 software and the results were analyzed by one way ANOVA and Tukey's post hoc test.

Results: Post endodontic restorations using fiber reinforced composite and indirect composites exhibited fracture resistance similar to sound intact teeth ($p>0.05$). Significant difference in fracture resistance was observed for nanohybrid composite when compared with fiber reinforced and indirect composite groups($p<0.05$). Most of the restorable (favourable) fractures were observed in the nanohybrid composite group followed by the indirect composite group. Unrestorable fractures were seen mostly in the bulk fill composite group followed by the fiber reinforced composite group.

Conclusion: Restorations with fiber reinforced and indirect composites increased the fracture resistance of endodontically treated teeth. Resin composites with good bonding ability transmit and distribute functional stresses and hold the potential to reinforce the weakened tooth structure.

Keywords: Composite resins, Fracture resistance, Finite element analysis, Instron testing, Post endodontic restoration.

Introduction

The goal of endodontic treatment is to maintain the tooth as a functional unit within the dental arch. The objectives of restoring endodontically treated teeth are to replace the missing tooth structure, maintain function and esthetics, and to protect the tooth against fracture and reinfection.[(1)]The loss of marginal ridges due to caries, removal of the pulp chamber roof along with inner dentin during access cavity preparation, and loss of the protective feedback mechanism in non-vital teeth contribute to the high fracture susceptibility of endodontically treated teeth.[(2)] As the restorative modality is critical for the longterm success of endodontic treatment, the possible reconstruction materials and techniques are being debated.[(3)] The advancements in adhesive technology and the improved strength of newer composites have made it possible to create a conservative and esthetic post-endodontic restorations. The cusps of teeth restored with composite resin are mechanically splinted together reinforcing the teeth and thus, minimizes tooth fractures.[(4)]

Nanohybrid composites were introduced with lower shrinkage by replacing triethylene glycol dimethacrylate (TEGDMA) with polyeythlene glycol dimethacrylate (PEGDMA) relative to the conventional and microhybrid composites. They consist of agglomerated nano-sized particles and nanoclusters with a filler loading of 82% by weight and surface modified zirconia/silica exhibiting excellent esthetics, high compressive, diametral tensile and flexural strength.[(5)] Recently bulk fill composites were introduced as posterior restoratives that allows larger increments upto 4 mm to be polymerized.[(6)] Fiber reinforced composites were suggested to reduce polymerization shrinkage, increase toughness and impact strength, thereby enhancing fracture resistance of the restored teeth.[(2,4)] Based on recent reports, the use of short fiber-reinforced composite with retentive slots could be an alternative technique to prevent cuspal fracture of endodontically-treated teeth with mesio-occluso-distal (MOD) cavities.[(7)]

The major drawback of direct resin composite restoration is high polymerization shrinkage stress resulting in marginal gaps and microleakage, especially when the gingival margin is located subgingivally.[(8)] Indirect lab processed composite resin systems provide an esthetic alternative and reinforces the tooth structure with better mechanical performance and a significant reduction in polymerization shrinkage [(9,10)]

Evidence from prospective studies indicate that bulk fracture in composite fillings is the most common cause for failure of a restoration after 5 years.[(11)] A valuable and intensively used tool to characterize the fracture resistance of a material is the measurement of fracture toughness, describing an intrinsic characteristic of a material to resist fracture, or the amount of stress that is required to propagate through a pre-existing flaw.[12]Finite element analysis (FEA) is one of the popular numerical methods in stress analysis. The technique was developed to create mathematical models, in which the behavior of a physical system can be reproduced, i.e. a physical prototype can be studied through the creation of a mathematical model. In this method, a computer system is used to conjure up the physical properties of the structures in analysis, and through a great number of mathematical equations it determines the generated tension resulted from an applied force.[13]

Thus, the ***aim*** of this *in vitro* study was to compare the fracture resistance of endodontically treated molars with cuspal coverage restorations using different resin composite materials and to calculate the Von Misses stresses in maxillary molars using 3-dimensional (3-D) finite element model. The null hypothesis was that, there is no difference in the fracture resistance of endodontically treated molars restored either with direct or indirect composite restorations.

Materials and Method

Ninety extracted, human maxillary molar teeth with approximately similar bucco-lingual and mesio-distal dimensions were used in the study. Fully erupted teeth with mature apices, intact enamel and dentin without any carious lesions or restorations and without any developmental disturbances were included in the study. Teeth with open apices or resorptive defects, presence of cracks on the crown or root portion, hypoplastic teeth, and teeth with anatomical variations were excluded from the study. Fifteen teeth were kept intact without tooth preparation and served as negative controls. For 75 teeth samples, prior to cavity preparation and cusp reduction, an impression of the crown was taken with polyvinyl siloxane material (Adsil putty; Prime Dental Products; India) to act as a guide to obtain the original shape of the crown upon restoration. Mesio-occluso-distal (MOD) cavities were prepared with the initial occlusal depth of 1.5 mm crossing the oblique ridge to include the mesial and distal pit/fosssa. A proximal ditch was made with a axial wall depth of 0.8mm (0.3 into enamel and 0.5 into dentin), and the gingival seat was placed at the cemento-enamel junction (CEJ). After MOD cavity preparation, 3mm reduction of the mesio-palatal cusp was done using #271(SS white, Lakewood, US) tungsten carbide bur. The pulpal floor was kept flat and all the line angles were rounded.

Endodontic access cavities were then prepared in 75 teeth using a Endo Access Bur (Dentsply Maillefer, Switzerland).A size 10 Kfile (M access, Dentsply Maillefer, Switzerland) was introduced into each canal until it could be visualized at the apical foramen. The working length was determined by subtracting 1 mm from this length. Cleaning and shaping of the canals was completed in crown-down manner with Mtwo rotary files (VDW, Munich, Germany) upto #25 and #30 using 3%sodium hypochlorite irrigation. Subsequently, teeth were obturated usingAH Plus sealer(Dentsply De Trey, Konstanz, Germany) and 6% taper guttapercha cones and were divided into groups using a randomized stratified design.

Grouping method

Group 1: (n=15) Intact, sound maxillary molars without any tooth preparation (negative control).

Group 2:(n=15) Teeth received cleaning, shaping and obturation of the canals without post endodontic restoration (positive control).

Group 3: (n=15) restored with nanohybrid composite (Filtek Z 250 XT- 3M ESPE, St.Paul, MN, USA.).

Group 4: (n=15) restored with bulk fill composite. (Tetric Evoceram; IvoclarVivadent AG, Schaan, Liechenstein, Europe)

Group 5: (n=15) restored with fiber reinforced composite.(Ribbond ; RibbondInc, Seattle, Washington, USA and Filtek Z 350 XT)

Group 6: (n=15) restored with indirect composite.(SR Adoro System, IvoclarVivadent AG, Schaan, Liechenstein, Europe.) (Table 1)

Table 1: Restorative materials and procedure used in the study

Restorative Material	Composition	Liner	Bonding Agent	Restorative Procedure
Filtek Z 250 XT- 3M ESPE, St.Paul, MN, USA	Resin: BIS-GMA, UDMA, BIS-EMA, PEGDMA and TEGDMA Fillers: (82% by weight) Surface-modified zirconia/silica with a median particle size of approximately 3 microns or less Non-agglomerated/non-aggregated 20 nanometer surface-modified silica particles.	Filtek Z350 flowable composite (3M ESPE, St.Paul, MN, USA Bis-GMA, TEGDMA, Bis-EMA, silane-treated ceramic, silica, zirconium oxide – 55 vol% / 65 wt%	Adpersinglebond 2 (3M ESPE, St.Paul, MN, USA)- Ethanol, water, Bis-GMA, 5 nm silane treated colloidal silica, 2-hydroxyethyl methacrylate, glycerol 1, 3 dimethacrylate, methacrylate functional copolymer of polyacrylic and polyitaconic acids and diurethanedimethacrylates.	Etching of the cavity for 20 seconds followed by bonding for 10 seconds and then liner placement was done. Composite buildup was done using horizontal incremental layering technique and light cured for 40 seconds using Bluephase C8 LED light curing unit (IvoclarVivadent, Schaan, Liechtenstein, USA) with an intensity of 800 mW/cm^2
Tetric evoceram; IvoclarVivadent AG, Schaan, Liechenstein, Europe	Resin: (20–21% weight). Bis-GMA, Bis-EMA and UDMA Fillers: (79–81% weight): barium glass, ytterbium trifluoride, mixed oxide and prepolymer Additional contents: additives, catalysts, stabilizers and pigments (<1.0% weight). The particle size of the inorganic fillers is between 40 nm and 3,000 nm with a mean particle size of 550nm	Tetric N flow flowable composite (IvoclarVivadent, USA) Urethane dimethacrylate, Bis-GMA 27.8 Triethyleneglycoldimethacrylate - 7.3 Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide 63.8 Additives, stabilizers, catalysts, Pigments	Tetric N Bond Universal adhesive (IvoclarVivadent, USA) Methacrylates, ethanol, water, highly dispersed silicon dioxide, initiators and stabilizers.	Etching of the cavity was done for 20 seconds followed by bonding for 10 seconds. The cavity was lined and cured for 40 seconds and restored with TetricEvoceram Bulk fill composite as single increments of up to 4mm and light cured.
Ribbond (RibbondInc, Seattle, Washington, USA) and **Filtek Z 350 XT**	Filtek Z 350 XT- universal restorative Resin: bis-GMA, UDMA, TEGDMA, and bis-EMA. Fillers: a combination Of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-	Filtek Z350 flowable composite (3M ESPE, St.Paul, MN, USA Bis-GMA, TEGDMA, Bis-EMA, silane-treated ceramic, silica, zirconium oxide – 55 vol% / 65 wt%	Adpersinglebond 2 (3M ESPE, St.Paul, MN, USA)- Ethanol, water, Bis-GMA, 5 nm silane treated colloidal silica, 2-hydroxyethyl methacrylate, glycerol 1, 3 dimethacrylate, methacrylate functional copolymer of polyacrylic and polyitaconic acids and	Etching of the cavity was done for 20 seconds followed by bonding for 10 seconds .Access cavity surfaces were coated with flowable restorative composite.A piece of ribbond polyethylene fiber 3 mm in width and 6 mm in length was cut and coated with adhesive

	aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles)		diurethanedimethacrylates.	resin. The fiber was embedded inside the flowable composite extending buccolingually on the floor as well as circumferentially on the walls of the cavities. Remaining cavity was restored with Filtek Z-350 XT by incremental technique.
SR Adoro System, IvoclarVivadent AG, Schaan, Liechenstein, Europe	**composite SR Adoro layering materials :** Dimethacrylate (17–19 wt.%); copolymer and silicon dioxide (82–83 wt.%). Additional contents are catalysts, stabilizers and pigments (<1 wt%). The total content of inorganic fillers is 64–65 wt.%/46–47 vol.%. Particle size 10-100 nm. **SR Adoro liner**: Dimethacrylate (48 wt.%); barium glass filler and silicon dioxide (51 wt.%). Additional contents are catalysts, stabilizers and Pigments (<1 wt%). **SR Model Separator :**Polyglycol, polyethylene glycol in a water/alcohol solution **SR Gel:** Glycerine, silicon dioxide and aluminium oxide	Tetric N flow flowable composite (IvoclarVivadent, USA)Urethane dimethacrylate, Bis-GMA 27.8 Triethyleneglycoldimethacrylate - 7.3 Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide 63.8 Additives, stabilizers, catalysts, Pigments	Tetric N Bond Universal adhesive (IvoclarVivadent, USA)Methacrylates, ethanol, water, highly dispersed silicon dioxide, initiators and stabilizers.	Impressions of the prepared teeth were taken with a condensation silicon rubber base material and working dies were prepared. Indirect composite restorations were fabricated and polymerized for 20 seconds in a Polymat heat furnace (Ivoclar Vivadent, Schaan, Liechtenstein, USA). The restorations were luted with self adhesive universal resin cement, RELY X Unicem (3M ESPE, St.Paul, MN, USA.) according to the manufacturer's instructions.

In groups 3, 4, and 5, prior to post endodontic restoration, etching was done with 37% phosphoric acid (Eco-etch, Ivoclar Vivadent AG, Schaan, Liechenstein). All the restorations were finished, polished and stored in an incubator with 100% humidity at 37^0C for 1 week. Teeth were subjected to thermocycling at 5 to 55°C for 1000 cycles with a dwell time of 30 seconds and transfer time of 5 seconds. To simulate periodontal ligament (PDL), root surfaces were marked 2mm below the cemento- enamel-junction (CEJ) and covered with a silicone layer of 0.25 mm thickness around the surface of the root. Each tooth was then mounted vertically in a polystyrene resin block to a depth of 2mm below CEJ.

Fracture resistance testing: Resistance offered by all the samples against vertical fracture was tested using universal testing machine (Instron, Canton, MA, USA). A vertical compressive force was applied with a 3-mm diameter stainless steel sphere near the interface between the buccal and lingual cuspal slopes of the teeth at a crosshead speed of 0.5 mm/min until the samples fractured. The amount of force required for vertical fracture was recorded in Newtons (N).

Finite element model and testing: To evaluate the stress distribution in the tooth, six teeth (n=1 for each group) were taken and FEA analysis was done using the ANSYS 14.5 workbench software. All the samples were scanned with a multilayer spiral computerized tomography (CT) machine (Phillips Brilliance 64 CT scanner system) at 1 mm intervals in both the coronal and sagittal axes. The designing of the samples was done by using CAD/CAM software CATIA (V5R20). A set of digital models were established for each of the six experimental groups and the material properties were assigned in (Table 2). Mesh convergence test was carried out, and it was determined that the ideal element size was 0.1 mm. Null displacement was defined for each model simulating the maxillary bone, whereby nodes at the top of the maxilla in each model were fixed so that posterior and superior direction movement was restricted.[14]

Table 2: Material Properties

	Modulus of elasticity(Gpa)	Poisson's ratio	Manufacturer
Enamel	84.1 (Magne 2010)[15]	0.30 (Magne 2010)[15]	-
Dentin	18.6 (Magne 2010)[15]	0.31 (Magne 2010)[15]	
Periodontium	0.05 (Magne 2010)[15]	0.45 (Magne 2010)[15]	
Guttapercha	0.186 (Magne 2010)[15]	0.49 (Magne 2010)[15]	DENTSPLY, malliefer, USA
Nanohybrid composite	17.2	0.24	Filtek Z 250 XT (3M ESPE, St. Paul, MN, USA)
Bulkfill composite	8.5	0.30	Tetric Evoceram Bulk fill (Ivoclar Vivadent, Schaan, Liechtenstein, USA)
Fiber reinforced (fiber+bondingagent+composite)	23.6	0.32	Ribbond (RibbondInc, Seattle, Washington, USA)
Indirect composite	7.5	0.30	SR ADORO system (Ivoclar Vivadent, Schaan, Liechtenstein, USA)
Luting cement	4.9	0.4	Rely X U 200 (3M ESPE, St. Paul, MN, USA)

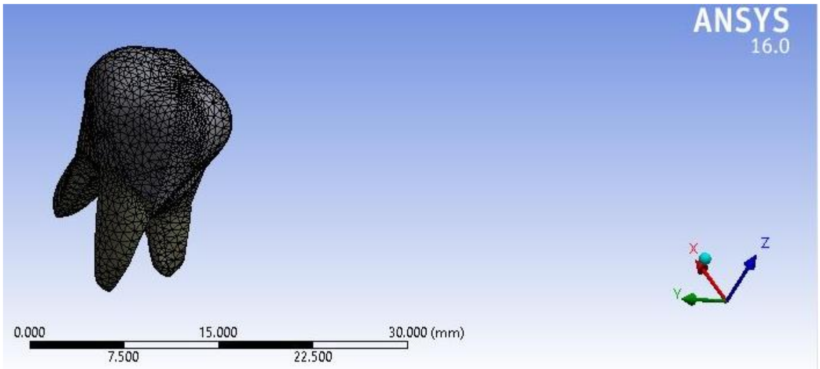

Fig. 1: Mesh developed for analysis

A compressive load similar to the maximum load applied on the teeth samples was delivered at occlusal central pit area at 90˚ to the radicular axis, in the vestibular direction. Stress distribution analysis was qualitatively performed using the von Misses stress criteria.

Statistical Analysis: The data obtained was tabulated and subjected to statistical analysis using SPSS/PC software version 20.0. Statistical significance was set at 95%. A one-way analysis of variance (ANOVA) was used to determine whether there are any significant differences between the means of the groups. Comparisons among the six groups were performed by using Tukey's multiple post hoc test.

Results

The mean critical breaking force for the intact teeth was 1962 N, while treated but unrestored teeth was 762 N. Intergroup multiple comparisons with Tukey's *post hoc* test [Table 3] revealed highly significant difference ($p<0.05$) between sound teeth and unrestored teeth, and between nanohybrid and bulk fill groups. No statistical difference was observed between intact teeth and fiber reinforced group and indirect composite groups($p>0.05$). No significant difference in fracture resistance was observed between nanohybrid and bulk fill group, but significant difference was observed for nanohybrid composite group ($p<0.01$) when compared to fiber reinforced and indirect composite groups.

Table 3: Tukey's posthoc multiple comparisons

Groups		Mean fracture resistance in Newtons (N)	P-value
Group 1	Group 2	762.76	0.01*
	Group 3	1228.51	0.01*
	Group 4	1401.44	0.01*
	Group 5	1598.50	0.75
	Group 6	1586.11	0.06
Group 2	Group 3	1228.51	0.01*
	Group 4	1401.44	0.01*
	Group 5	1598.50	0.01*
	Group 6	1586.11	0.01*
Group 3	Group 4	1401.44	0.68
	Group 5	1598.50	0.05*
	Group 6	1586.11	0.05*
Group 4	Group 5	1598.50	0.55
	Group 6	1586.11	0.62
Group 5	Group 6	1586.11	0.99

*p=<0.05

Modes of failures were included in restorable if fracture line is extending above or 1mm below CEJ or un-restorable i.e. fractures extending more than 1mm below CEJ(Table 4). Restorable fractures were observed mostly in nanohybrid composite group followed by the indirect composite group. Unrestorable fractures (catastrophic failures) are seen mostly in the bulk fill composite group followed by the fiber reinforced composite group.

Table 4: Mode of failures

Group	Restorable		Un-restorable	
	N	%	N	%
Nanohybrid	12	80.0	3	20.0
Bulkfill	8	53.3	7	46.7
Fiber reinforced	9	60.0	6	40.0
Indirect	10	66.7	5	33.3

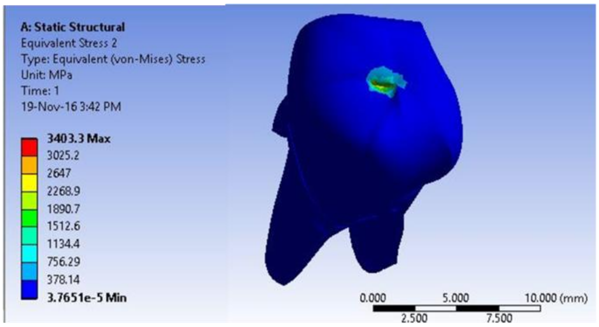

Fig. 2: intact maxillary molar

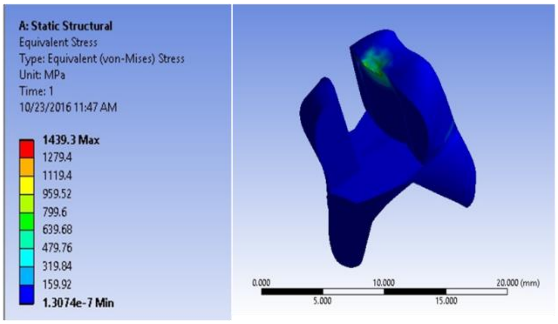

Fig. 2 a: unrestored molar

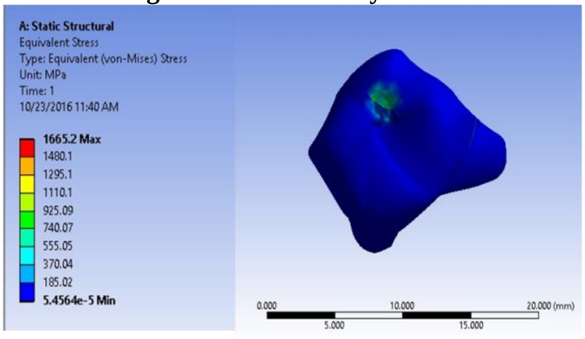

Fig. 2c: Nanohybrid composite restored molar

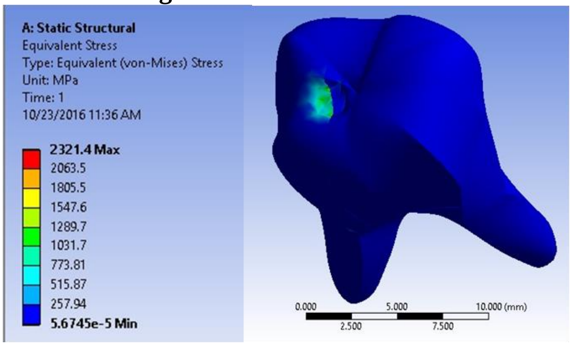

Fig. 2d: Bulkfill composite restored molar

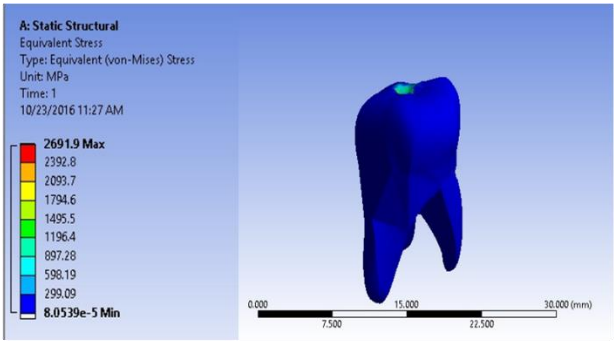

Fig. 2e: Fiber reinforced composite restored molar

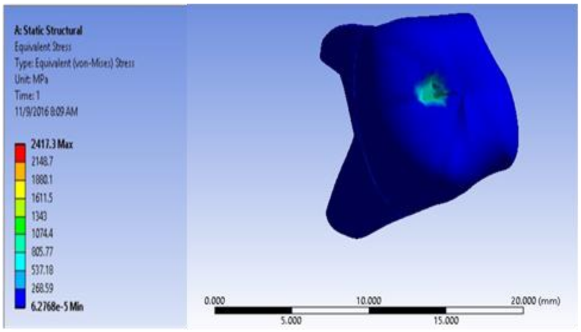

Fig. 2f: Indirect composite restored molar

Fig. 2: Distribution of Von Misses stresses generated corresponding to failure indices

The finite element simulation revealed that the risk of fracture was mostly at the palatal cervical area due to the loss of the mesiopalatal cusp. In the nanohybrid composite group most of the stress concentration was within the composite. In the bulkfill composite and fiber reinforced composite the stresses were transferred from the composite to the root surfaces. The indirect composite showed maximum stress concentration at the interface between composite and the tooth i.e. where the luting agent was present. (Fig. 2)

Discussion

In clinical practice, the remaining coronal tooth structure and functional requirements are important for the clinician to determine the optimum type of restoration. To conserve more tooth structure, Mannocci et al. suggested using direct composite restorations to restore teeth following root filling.(16) The adhesive property of composite resin restoration allows minimal cavity preparation and provides intra-coronal reinforcement.(2,16) Nevertheless, in large cavities, cusp coverage with direct or indirect composite restoration seems to be a more secure option. This was supported by Plotino et al. who found similar fracture resistance of root filled teeth with direct or indirect composite restorations.(17) Resin composite restorative procedures takes the restorative margins to the axial surfaces, protecting the adhesive interface from early marginal discrepancies under loading.(18)

Most of the documented fracture resistance studies are done on premolars or mandibular molars. Maxillary molars were selected for the study as these are the second most common teeth affected by caries and are the main teeth responsible for chewing action. Mesio-occluso-distal (MOD) cavities were prepared to simulate a situation that is often found clinically and has been extensively reproduced in other clinical studies.(2,4) The general effect of MOD cavity preparation is the loss of excessive tooth structure, necessitating the replacement of the tooth structure with a restoration that provides effective marginal seal and increases the fracture resistance of residual tooth.(18) Capping of the mesiopalatal cusp was done as this is the functional cusp that intercuspates during occlusion.

It has been reported that the use of flowable composite as a cavity liner reduces cuspal flexure.(19,20) Due to their lower elastic modulus, flowable composites act as flexible intermediate layer and might relieve stresses developed during polymerization of the large composite restoration.(21) Ribbond is a leno-woven ultrahigh molecular weight polyethylene (UHMWPE) ribbon. These fibers have high tensile strength, modulus of elasticity, and fracture toughness, and conform well to the contours of the teeth. Fibers were placed in buccolingual direction over the base of the access cavity and circumferentially along the walls so as to adapt to the walls and strengthen the tooth.(22)

Intact teeth presented the highest mean fracture load due to the presence of the palatal and buccal cusps with intact mesial and distal marginal ridges which form a continuous circle of dental structure, reinforcing the tooth.(23) It was stated that high filler loading reduces volumetric shrinkage and minimizes the development of shrinkage stresses in resin based composites,(24) and in the present study Filtek Z250 XT with high filler loading (81.86 wt%, 67.8 vol%) has shown increased fracture resistance compared to unrestored teeth.

Teeth restored with bulk fill composites (Tetric Evocerambulkfill) exhibited increased fracture resistance when compared to nanofilled composites (Filtek Z250 XT). Tetric Evoceram bulkfill contains ivocerin which is more reactive than conventional initiators and allows larger increments upto 4 mm to be polymerized in just 10 seconds.(25) These polymerization boosters fills the gaps between the traditional initiators and the glass fillers which relieves shrinkage strain. Due to its lower elastic modulus of 71 GPa, glass filler is flexible like a microscopic spring and thus reduces the shrinkage stresses developed.(25)

In accordance with other studies,(26,27) teeth restored with fiber reinforced composite has exhibited highest mean fracture resistance with no significant difference from intact sound teeth. The higher modulus of elasticity and lower flexural modulus of the polyethylene fibers are believed to have a modifying effect on the interfacial stresses developed along the etched enamel/resin boundary. Fiber placement in occlusal and circumferential direction might also protect the cusps by shortening their heights, avoiding the separation of cusps with wedging effect. For this reason, in the present study, the fibers were placed in occlusal and circumferential direction.

The null hypothesis was partially rejected as the teeth restored with indirect composites showed mean fracture resistance nearing to fiber reinforced composites, with no significant difference from intact sound teeth. It is postulated that fracture resistance of MOD restorations with cuspal coverage are influenced by mechanical properties of resin composite used rather than the type of curing. The higher fracture resistance of composite inlays might be attributable to toughening of the polymer matrix, resulting from the greater degree of conversion and cross-link density of the polymer. In addition, secondary curing can relieve stresses generated during the initial curing.(8)

The FEA was applied for the better simulation of restored endodontically treated teeth and to describe the stresses created during loading. A major advantage of FEA is its ability to solve complex biomechanical problems and is an effective tool in evaluating and comparing the experimental data.(28) However, in the FEA, assumptions related to the material properties of simulated structures (such as isotropy, homogeneity, and linear elasticity) are not usually absolute representations of the structure.(29) Therefore, FEA must ideally be used as an aid for planning further laboratory tests and clinical studies to reduce the inaccuracies inherent in FEA. The results obtained in the experimental and FE simulation showed a good correlation with ideal matching at the fracture points.

With careful attention to diagnosis and treatment planning, the *fiber reinforced composite resin restorations* without crown coverage might be considered as an economical, practical and tooth saving alternative than the more expensive and extensive crown coverage methods.

Conclusion

Within the limitations of this in vitro study, it can be concluded that, both fiber reinforced composites and indirect composites, increased the fracture resistance of endodontically treated teeth. Hence, both materials can be considered for restoring endodontically treated teeth alternative to full coverage restorations.

References

1. Vârlan C, Dimitriu B, vârlan V, Bodnar D, Suciu I. Current opinions concerning the restoration of endodontically treated teeth: basic principles. J Med Life. 2009;2(2):165-172.
2. Soares PV, Santos-Filho PC, Martins LR, Soares CJ. Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part I: fracture resistance and fracture mode.J Prostho Dent 2008:99(1):30–7.
3. Ree M, Schwartz RS. The endo-restorative inteface; current concepts. Dent Clin North Ame 2010;54(2);345-374.
4. Mondelli RF, Ishikiriama SK, de Oliveira Filho O, Mondelli J. Fracture resistance of weakened teeth restored with condensable resin with and without cusp coverage. J App Oral Sci; 2009:17(1):161–5.
5. Jayanthi N, Vinod V. Comparative evaluation of compressive strength and flexural strength of conventional core materials with nanohybrid composite resin core material an in vitro Study. J Ind Prosthodont Soc 2013;13(3):281-9.
6. N Ilie, S Bucuta, M Draenert. Bulk-fill Resin-based composites: An in vitro assessment of their mechanical performance. Oper Dent 201338:6, 618-25.
7. Yasa B, Arslan H, Yasa E, Akcay M, Hatirli H. Effect of novel restorative materials and retention slots on fracture resistance of endodontically-treated teeth. Acta Odont Scand 2016;74(2):96-102.
8. Torabzadeh H, Ghasemi A, Dabestani A, Razmavar S. Fracture resistance of teeth restored with direct and indirect composite restorations. J Dent 2013;10(5):417-25.
9. Shafiei F, Memarpour M, Karimi F. Fracture resistance of cuspal coverage of endodontically treated maxillary premolars with combined composite-amalgam compared to other techniques. Oper Dent 2011;36(4):439-4.
10. Belli S, Erdemir A, Yildirim C. Reinforcement effect of polyethylene fibre in root-filled teeth: comparison of two restoration techniques. Int Endod J 2006;39(2):136-42.
11. Creugers NH, Mentink AG, Fokkinga WA, Kreulen CM. 5-year follow-up of a prospective clinical study on various types of core restoration Int J Prosthodont. 2005 ;18(1):34-9.
12. Ilie N, Hickel R, Valceanu A, Huth K. Fracture toughness of dental restorative materials. Clin Oral Inves 2012;16(2):489-98.
13. Kumar P, Rao RN. Three-dimensional finite element analysis of stress distribution in a tooth restored with metal and fiber posts of varying diameters: An in-vitro study.J Conserv Dent. 2015;18(2):100-104.
14. Xiong Y, Huang SH, Shinno Y, Furuya Y, Imazato S, Fok A, Hayashi M. The use of a fiber sleeve to improve fracture strength of pulpless teeth with flared root canals. Dent Mater. 2015;31(12):1427-34.
15. Magne P. Virtual prototyping of adhesively restored endodontically treated molars. J Prosthet Dent 2010, 103; 343-51.
16. Mannocci F, Bertelli E, Sherriff M, Watson TF, Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. J Prosthet Dent 2002;88(2): 297–301.
17. Plotino G, Buono L, Grande NM, Lamorgese V, Somma F. Fracture resistance of endodontically treated molars restored with extensive composite resin restorations. J ProsthetDent 2008;99(2): 225–3.
18. Xie KX, Wang XY, Gao XJ, Yuan CY, Li JX, Chu CH. Fracture resistance of root filled premolar teeth restored with direct composite resin with or without cusp coverage. Int Endod J 2012;45(6):524-9.
19. Reddy SN, Jayashankar D, Nainan M, Shivanna V. The effect of flowable composite lining thickness with various curing techniques on microleakage in class II composite restorations: an in vitro study. J Contemp Dent Pract 2013;14:56–60.
20. Radhika M, Sajjan GS, Kumaraswamy BN, Mittal N. Effect of different placement techniques on marginal

microleakage of deep class-II cavities restored with two composite resin formulations. J Conserv Dent 2010;13:9–15.
21. Akbarian G, Ameri H, Chasteen J, Ghavamnasiri M. Fracture resistance of premolar teeth restored with silorane-based or dimethacrylate-based composite resins. J Esthet Rest Dent 2014;26(3):200-7.
22. Akman S, Akman M, Eskitascioglu G, Belli S. Influence of several fiber-reinforced composite restoration techniques on cusp movement and fracture strength of molar teeth. Int Endod J 2011;44(5):407-15.
23. Casselli DSM, Silva ALF, Casselli H, Martins LRM. Effect of cavity preparation design on the fracture resistance of directly and indirectly restored premolars. Braz J Oral Sci 2008;7(22):1636-40.
24. Hamouda IM, Shehata SH. Fracture resistance of posterior teeth restored with modern restorative materials. J Biomed Res 2011;25(6):418-24.
25. Alrahlah, N. Silikas,D.C. Watts Post-cure depth of cure of bulk fill dental resin-composites. Dent Mater 2014;2(30):149–54.
26. Sulthan Ibrahim Raja K, Ramachandran A, Mohanavelu D, KumarappanSenthil K. Effect of two different types of fibers on the fracture resistance of endodontically treated molars restored with composite resin. J Adhe Dent 2013;15(2):167-71.
27. Belli S, Erdemir A, Ozcopur M, Eskitascioglu G. The effect of fiber insertion on fracture resistance of root filled molar teeth with MOD preparations restored with composite. Int Endod J 2005;38(2):73-80.
28. Ersoz E. Evaluation of stresses caused by dentin pin with finite elementsstress analysis method. J Oral Rehabil 2000;27:769-73.
29. Asmussen E, Peutzfeldt A, Sahafi A. Finite element analysis of stresses in endodontically treated, dowel restored teeth. J Prosthet Dent 2005;94: 321-9.