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Dr. Kanduri Venkata Naga Vamseekrishna
Senior Lecturer MDS, Department of Conservative Dentistry and Endodontics, Care Dental College, Guntur, Andhra Pradesh, India

Dr. Jasika Ahuja
MDS, Department of Conservative Dentistry and Endodontics, Private Practitioner, Rajpura, Punjab, India

Dr. Aishwarya Arya
Senior Lecturer, Department of Conservative Dentistry and Endodontics, Awadh dental college and hospital, Jamshedpur Jharkhand, India

Dr. Bisma Jahangeer
MDS, Department of Conservative Dentistry and Endodontics, Private Practitioner- Kulgam, Jammu and Kashmir, India

Dr. Taniya Elsa Oommen
MDS, Department of Conservative Dentistry and Endodontics, Private Practitioner, Kerala, India

Dr. Divya Mishra
MDS- Dept of Conservative Dentistry and Endodontics Private Practitioner, Varanasi, Uttar Pradesh, India

Corresponding Author;
Dr. Kanduri Venkata Naga Vamseekrishna
Senior Lecturer MDS, Department of Conservative Dentistry and Endodontics, Care Dental College, Guntur, Andhra Pradesh, India

An *in vitro* study comparing fracture resistance of endodontically treated teeth using different restorative materials

Dr. Kanduri Venkata Naga Vamseekrishna, Dr. Jasika Ahuja, Dr. Aishwarya Arya, Dr. Bisma Jahangeer, Dr. Taniya Elsa Oommen and Dr. Divya Mishra

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Abstract
Aim: The aim of this *in vitro* study is to evaluate the fracture resistance of endodontically treated teeth restored with different restorative materials.
Materials and Methods: Fifty single rooted non-carious, non-restored, intact human premolars extracted for orthodontic purposes were considered. Access cavities were prepared and biomechanical preparations were done followed by obturation. Class II (MOD) cavities were prepared using a straight fissure bur and restored with different restorative materials. Samples were randomly divided in to 5 groups (n=10). Fracture resistance evaluated using a Universal Testing Machine (UTM) at a cross head speed of 1mm/min and the force required to fracture each tooth was recorded in newtons (N).
Results: There is a statistically significant difference in the mean values of the study parameter between the groups. Highest mean values were observed with Ribbond+ Packable+ Flowable followed by Ribbond +Packable.
Conclusion: Use of polyethylene ribbon fiber beneath the composite restorations considerably increased the fracture strength. Use of flowable composite beneath the packable restoration increased the fracture resistance.

Keyword: Fracture resistance, ribbond fibres, restoration, flowable composites

Introduction
Restoring the root canal treated tooth is one of the most difficult situations faced by an operative dentist. Root canal teeth are considered more susceptible to fractures post treatment due to numerous reasons like-

1. The normal functional stresses generated can lead to the fracture of undermined cusps of posterior teeth.
2. Root canal teeth might become weak due to the tooth structure loss caused by inappropriate access preparations, caries, very large cavity preparations, and instrumentation of the root canals [1].
3. dehydration of dentin has been listed by some researcher to be one of the prime reason for root canal treated teeth to fractures in comparison to natural teeth [2].

Wide mesio occluso distal (MOD) cavities when prepared have resulted in significant decrease in the strength as well as their fracture resistance of root canal treated teeth. Hence, the treatment of root canal procedure is only considered complete after the teeth are restored permanently with the restorative material [2].
For the long-term prognosis of success of endodontically treated teeth, the integrity as well as the durability of post endodontic restorations are considered prerequisite factors [3]. In order to gain this target and to avoid failure of the root canal treated tooth restorative material should have basic properties like easy manipulation, high strength, fast, direct, as well as should be cost effective for clinicians [2].

Due to advancement in technology, adhesive strategies is progressing at an alarming rate, making it easy to create direct bonding to the teeth which is highly conservative and esthetic simultaneously [2]. The characteristics of the restoration like its design and type of restorative materials play a significant role in determining the success as they not only restore but also seal the weakened tooth along with appropriate reinforcement. Resin composite restorative materials have become the preferred choice of many clinicians as well as patients for the coronal restorations due to their sufficient physical and mechanical properties along with retention and esthetic properties leading to maximum conservation of tooth structure [4].

When the resultant force exceeds the interfacial bond strength of composite restorative materials the adhesive failure negates the adhesive reinforcement of the weakened cusps resulting into polymerization shrinkage which is considered to be an inherent property of adhesive materials ultimately one of the significant causes of failure. Various incremental techniques have been suggested to overcome such problems though considered to be a time-consuming process [4]. Flowable composites act as an extendable and flexible intermediate layer possessing low modulus of elasticity are popularly used by most clinicians due to their better adaptability. Flowable resin composite are applied before the placement of restorative material in the form of an elastic liner having less filler (60%-70% by weight) content [2].

Bulk – Fill composite restorative materials were introduced in to the market recently and are considered superior to conventional ones especially in cases of extensive MOD cavities in terms of shrinkage stress and fracture resistance [4].

Due to its popularity, clinicians are able to perform adhesive restorations of root canal treated teeth using resin bonded composite properties. Fibers have the capability to reduce polymerization shrinkage, tolerate tensile stress, and prevent crack propagation in resin composite restorative materials [4].

Ribbond is a polyethylene fiber that has an ultrahigh elastic modulus [2] and the presence of polyethylene fiber with woven network allows an infusion of the resin into the fibers. Polyethylene fibers are considered to have a modifying impact on the interfacial stresses developed along the adhesive interface and allow efficient force transmission. Due to the presence of fiber network, higher modulus of elasticity, and lower flexural modulus act as stress relievers in restored teeth and may prevent unfavorable subgingival fracture of composite restorations and increase the reparability of fractured teeth [4]. Ease of manipulation and better adaptability to the contours of the teeth makes Ribbond fibres as a material of choice for root canal treated tooth. It also has the ability to distribute stresses and absorbs energy from repeated occlusal effects, reduces the stress concentrations via distributing forces over a larger area and hence preventing crack formation and propagation [2].

Materials and Methodology

This *in vitro* study was performed at Department of Conservative Dentistry & Endodontics at Maharishi Markandeshwar College of Dental Sciences & Research, Mullana. Seventy-five single rooted human premolars having no caries, abrasion, injury from forceps, fractures extracted for orthodontic and periodontic reasons were included for the present clinical study. Before proceeding all the teeth samples were cleaned of debris and soft tissue remnants and were placed in saline solution for a time period of 24 hours. Diamond burs at high speed were used to prepare endodontic access cavities and the pulp tissue was extirpated. The working length of each tooth sample was determined using #15 K – files and all the teeth were instrumented till 25 – 4% by using rotary endodontic system (Gen Endo, Coltene, Switzerland). 5.25% NaOCl irrigating solution was used, during the preparation, the root canals before introducing each file. Root canals were dried with absorbent paper points after the instrumentation and irrigation followed by obturation with gutta percha cones and ZOE based sealer. heated instruments were used to remove excessive coronal root canal filling materials. After this, Mesioocclusodistal (MOD) cavities were prepared in each tooth down to the canal orifices so that the thickness of buccal wall measured 2mm at the occlusal surfaces and 3mm at the CEJ.

Grouping

The samples were divided randomly into 5 groups (n = 15)-Fig. 1

Group 1: Control group – Not restored with any material.

Group 2: Cavities restored with flowable composite, ribbond, and packable composites. (R+B+F)

Group 3: Cavities restored with flowable composite and packable composites. (F+P)

Group 4: Cavities restored with packable composite alone.

Group 5: Cavities restored with Ribbond and Packable Composites. (R+P)

Self – curing polymethyl methacrylate resin were used to mount all the samples at a level 1 to 1.5 mm below the CEJ using a metal mold cylinder (30 mm length, 20 mm width) keeping the long axis of the tooth parallel to that of the mold. These samples were tested for fracture resistance under Universal Testing Machine- UTM (fig. 2 & 3). A modified stainless-steel ball measuring 6mm in diameter was placed parallel to the long axis to measure the compressive force was applied and centered over the teeth until the ball contacted the internal surface of buccal functional cusps and the small part of the restoration. A crosshead speed at 0.5 mm/min was applied as the Compressive loading force on the teeth. The mean loads required to fracture the tooth samples were recorded in terms of Newtons (N). The results were sent to statistical analysis.

Fig 1: Grouping of samples

Fig 2: UTM MACHINE

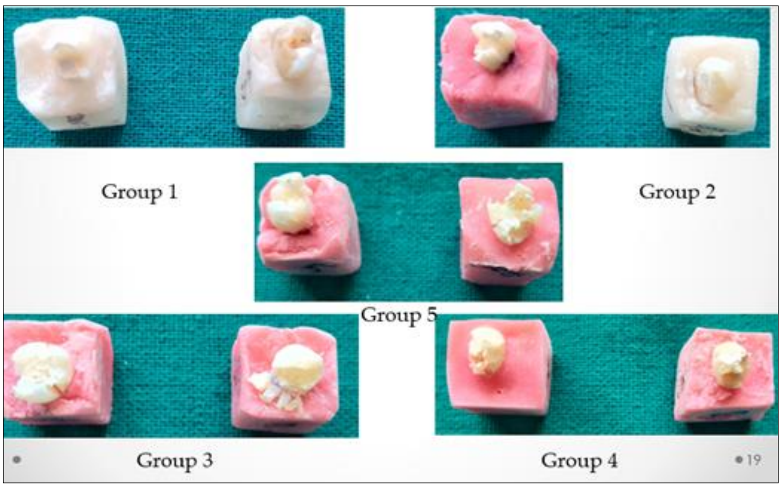

Fig 3: Samples after testing

Results

Table 1: Descriptive statistics

Metric		Positive control	Ribbond + Packable + Flowable	Packable + Flowable	Packable	Ribbond +Packable
Mean (N)		965.954000	1280.234000	793.099333	725.486000	1262.962000
95% Confidence Interval for Mean		785.128153	901.286747	550.073287	582.390193	1016.013711
		1146.779847	1659.181253	1036.125380	868.581807	1509.910289
5% Trimmed Mean		952.491111	1240.658333	778.633148	710.092778	1245.330000
Median		927.710000	966.720000	637.500000	612.350000	1313.100000
Variance		106621.322	468253.006	192587.765	66769.307	198854.348
Std. Deviation		326.5292053	684.2901474	438.8482253	258.3975746	445.9308779
Minimum		519.8700	550.1500	271.6400	495.3500	553.1000
Maximum		1654.3700	2722.6800	1574.9500	1232.7000	2290.2000
Range		1134.5000	2172.5300	1303.3100	737.3500	1737.1000
Interquartile Range		399.7000	1338.7800	679.5700	432.4800	644.0500
Skewness		.776	.858	.649	.835	.516
Kurtosis		.050	-.536	-.840	-.690	.593

Table 2: Comparison between the groups

Group	N	Mean (N)	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F value	P value
					Lower Bound	Upper Bound		
Positive control	15	965.954	326.5292	84.3094	785.128	1146.779	4.843	0.002*
Ribbond + Packable + Flowable	15	1280.234	684.2901	176.6823	901.286	1659.183		
Packable + Flowable	15	793.099	438.8482	113.31015	550.073	1036.12		
Packable	15	725.486	258.3975	66.7179	582.39	868.581		
Ribbond + Packable	15	1262.962	445.9308	115.1388	1016.013	1509.91		

One way analysis of variance; p≤0.05 considered statistically significant; * denotes statistical significance

Table 3: Multiple pairwise comparisons of the study parameter between the groups

Reference Group (I)	Comparison Group (J)	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Positive control	Ribbond + Packable + Flowable	-314.2800000	.330	-779.045954	150.485954
	Packable + Flowable	172.8546667	.835	-291.911288	637.620621
	Packable	240.4680000	.599	-224.297954	705.233954
	Ribbond + Packable	-297.0080000	.388	-761.773954	167.757954
Ribbond + Packable + Flowable	Packable + Flowable	487.1346667*	.035	22.368712	951.900621
	Packable	554.7480000*	.011	89.982046	1019.513954
	Ribbond + Packable	17.2720000	1.000	-447.493954	482.037954
Packable + Flowable	Packable	67.6133333	.994	-397.152621	532.379288
	Ribbond + Packable	-469.8626667*	.046	-934.628621	-5.096712
Packable	Ribbond + Packable	-537.4760000*	.015	-1002.241954	-72.710046

Tukey's post hoc tests; * denotes statistical significance

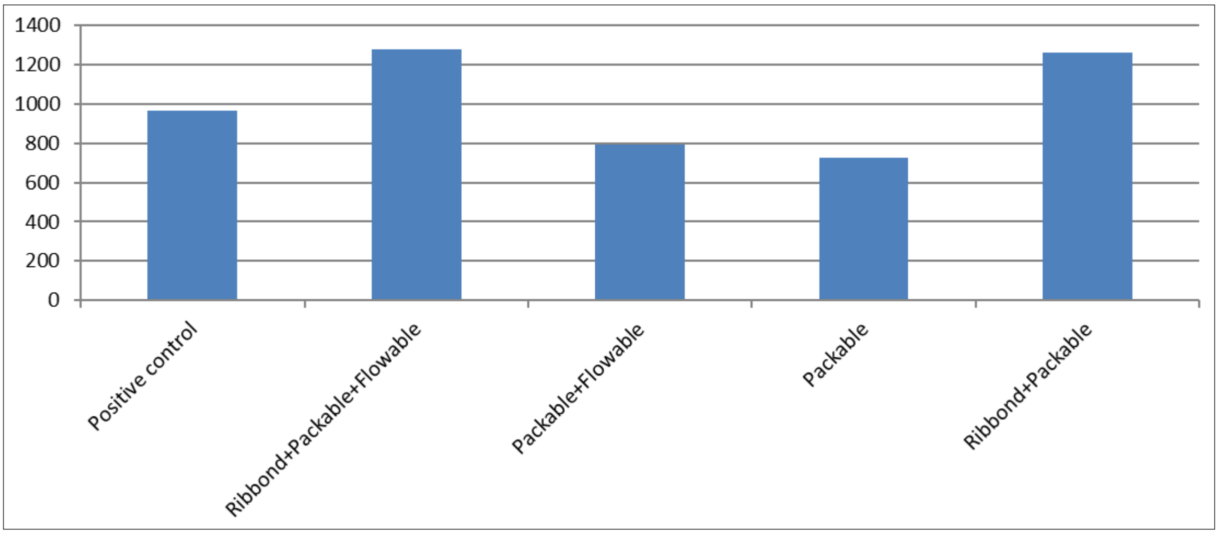

Fig 1: Comparison of study parameter between the groups

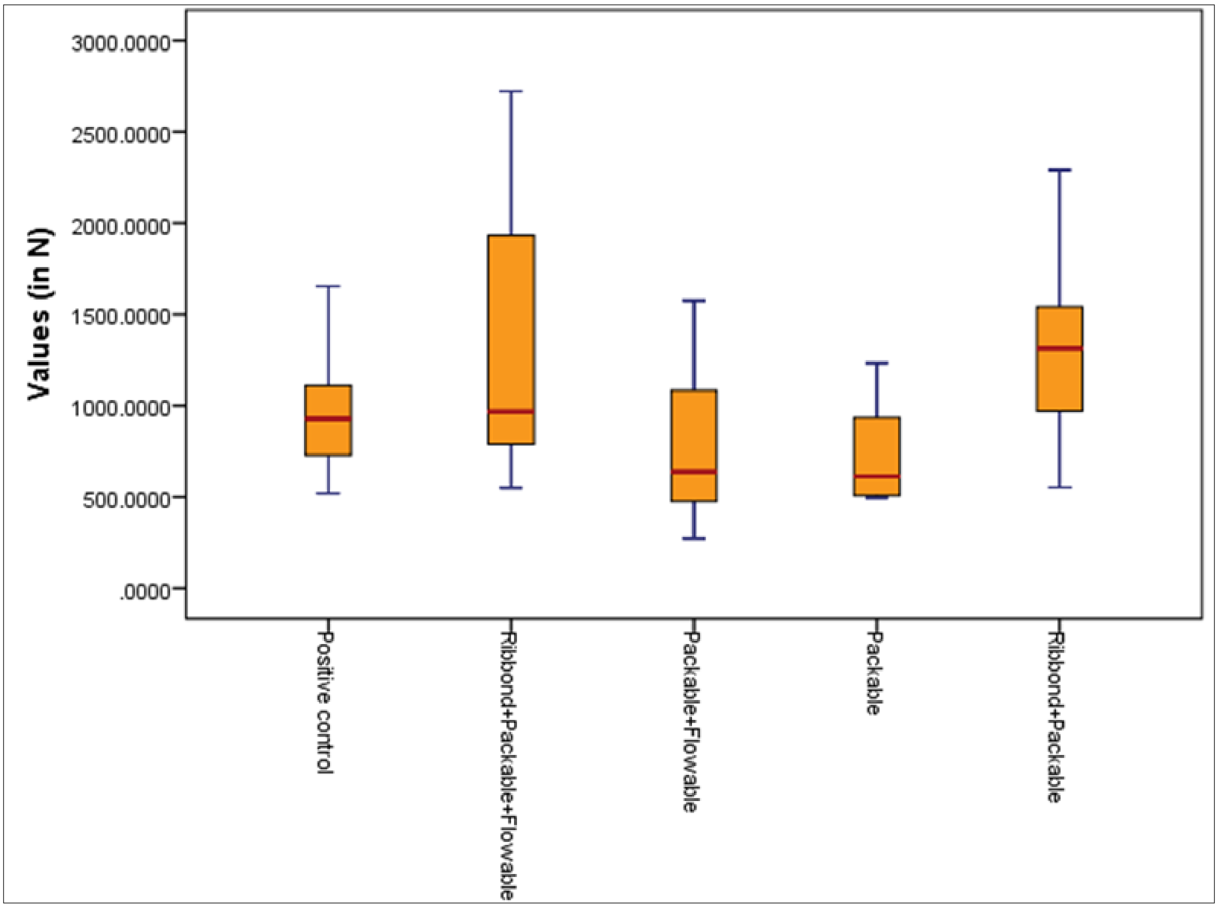

Fig 2: Box and whisker plot showing the comparison of study parameter between the groups

Statistical analysis

Data were analyzed using IBM SPSS version 20 software (IBM SPSS, IBM Corp., Armonk, NY, USA). Descriptive statistics, one-way analysis of variance with Tukey's post hoc tests were done to analyze the study data. Bar chart and box plot were used for data presentation.

Inference

- There is a statistically significant difference in the mean values of the study parameter between the groups. Highest mean values were observed with Ribbond+ Packable+ Flowable followed by Ribbond+ Packable. Least mean values were demonstrated with packable composite.
- In multiple pairwise comparisons, it was concluded that there was no significant difference between the four types of restorative materials with the positive control with higher mean values than positive control for 'Ribbond +Packable+ Flowable' and the 'Ribbond+Packable' composites. The mean values recorded in the 'packable+Flowable' and Packable groups were lesser than those observed in the positive control group.
- 'Ribbond+Packable+Flowable' and the 'Ribbond+Packable' composites showed significantly higher mean values compared to 'packable+Flowable' and Packable composites.
- There was no significant difference reported between 'Ribbond+Packable+Flowable' and the 'Ribbond+Packable' composites.
- Similarly, there was no significant difference between 'packable+Flowable' and Packable composites.

Discussions

Treatment interventions often lead to immense loss of hard tissue structure as well as large cavity preparations which are considered to be inevitable reasons for the fracture of endodontically treated. MOD cavities having extensive preparation might lead to cuspal fracture of the tooth due to improper restorative techniques in a root-filled tooth. Fennis reported that the data collected from over 46,000 patients among 28 dental practices resulted in 20.5 cusp fracture with an incident rate per 1000 person-year, 21% included premolar teeth.[2] Premolars were evaluated in the present study due to their ease of availability and also posterior teeth are regarded to be prone to more compressive loads in comparison to anterior teeth as they possess narrow mesiodistal root width which might lead to root fractures. Size of the cavity could be considered another significant factor to cause alteration in the strengthening of the teeth.

In the present study, 2 mm was considered to be the width of the the floor of the MOD cavity approximately. In order to simulate the forces of centric occlusion axial forces were applied on the functional cusps, parallel to the long axis of the teeth. Most of the studies have utilised a universal testing machine – UTM with the aim of producing a compressive load on to the sample with the help of various metallic load devices like steel spheres, steel cylinders as well as wedge-shaped devices with a straight and cast metal antagonist tooth. In the present study, the teeth samples were subjected to vertical compressive loading using a 6-mm-diameter, stainless-steel sphere. All of the teeth specimen were stored in saline solution for a day before the tests were performed. To eliminate the post mortal changes of the tooth structure longer times of storage in solution were avoided. Also, only intact teeth were used as control group in order to compare the biomechanical properties of healthy teeth with that of endodontically treated teeth restored with different techniques [2].

Several studies have concluded that the adhesive restorations have more advanced properties in order to transmit forces and distribute functional stress. Fracture strength could be increased by using flowable composite under the restorations but the present study witnessed no statistically significant difference between these groups.

Ribbond fiber materials is a leno-woven, ultra–high-molecular weight polyethylene fiber with an ultrahigh elastic modulus property. The unique intrinsic fabric architecture has an interwoven structure which is formed due to the unique orientation of fibers in various directions helping in dispersing the forces over broader area, hence reducing the stress altitudes. It is required for the Ribbond needs to be soaked with wetting resin before being placed in the flowable composite resin. An unique united structure is formed due to the leno design which improves the impregnation of the wetting resin, thus increasing the chemical bonding of the fiber with flowable resin [2]. In our present study, fiber insertion (Ribbond) procedure showed a positive influence on stress distribution.

Limitations

It was an *In vitro* study, hence the forces applied were at a constant speed and direction which is not in simulation with oral cavity where dynamic forces are experienced.

Periodontal simulation was not considered for the present study.

Conclusion

Within the limitations of this study, it can be concluded that:

- The fracture strength is increased on using polyethylene ribbon fiber beneath the composite restorations.
- Use of flowable composite beneath the packable restoration increased the fracture resistance of restorations and helps in distributing stress over wide extensive cavities.
- Ribbond could be considered to be more reliable restorative techniques in comparison to others.

Clinical Significance

Usage of Ribbond as an adjunct under the packable composite restorative material improves the fracture resistance of the restoration, thus prolonging the longevity of treatment. as the fibers of ribbond have the capability to reduce polymerization shrinkage, it helps in adequate stress distribution and reducing post operative sensitivity. In addition to this, restoring endodontically treated tooth with ribbond is very beneficial for the patients economically in comparison with the prosthetic treatment. So, this should be considered quite an essential material not only for an operator but also to the patients.

Conflict of Interest

Not available

Financial Support

Not available

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