COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MAXILLARY PREMOLARS REINFORCED WITH THREE DIFFERENT TYPES OF FIBER POSTS IN TWO DIFFERENT WAYS: AN IN VITRO STUDY

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ABSTRACT

Background and objectives of the study
The present study aimed to evaluate the fracture resistance of endodontically treated maxillary premolars reinforced with three different types of fiber post in two different ways

Materials & Method
A total of 60 maxillary first premolars , which were extracted completely for periodontal reasons, were chosen. All extracted teeth were stored in a sterile solution until further use. MOD cavity was prepared and then access cavity preparation was done by using round bur followed by BMP was done untill 30-6% , obturation was done using AH-plus sealer and divided into 3 groups based on the type of fiber post used GROUP 1-Glass fiber post GROUP 2 - Carbon fiber post GROUP 3- Quartz fiber post and these again didvided into two subgroups SUBGROUP A denoting post space preparation keeping 5mm of gutta percha apically followed by composite restoration and SUBGROUP B denoting post space preparation with 3mm of coronal root space and buccopalatal flaring of remaining coronal fibers followed by composite restoration.All the restored teeth were thermocycled for for 500 cycles between 5°C and 55°C, dwell time 15 s followed by immersion in physiological saline, and incubation at 37°C for 15 day.After 15 days all the spicemen were sent to lab for comparing the fracture resistance and fracture pattren using universal testing machine

Results
The highest fracture resistance was seen in quartz fiber post followed by glass and carbon fiber post. The fracture reistance from highest to lowest followed as such 3B >1B >3A > 1A >2B >2A, All the fiber post showed favourable fracture patterns

Interpretation and Conclusion
This study concluded that, quartz fiber post showed highest fracture resistance due to its proprites followed by glass fiber post and carbon fiber post and Subgroup B showing highest fracture resistance because buccopalatal flaring can compromise the structural integrity of endodontically treated teeth.The distribution of fracture patterns among different groups showed a comparable trend. Favourable fracture pattern seen in highest propotion among all groups.Unfavourable fractures were relatively low across all groups
Keywords
Quartz fiber post, Glass fiber post, Carbon fiber post, Buccopalatal flaring

INTRODUCTION

During endodontic treatment, access preparation frequently causes significant coronal damage. [1] The endodontically treated teeth are unable to defend cuspal deflection brought on by masticatory loadings due to extensive dentin damage in the form of weakened marginal ridges and loss of the pulp chamber roof. [2] Until the final restoration is inserted, the root canal therapy is not complete. The gold standard is believed to be the placement of a crown after root canal therapy.[3]

The emphasis should be on strengthening both the remaining coronal and radicular tooth structure because there are numerous factors that contribute to tooth brittleness and susceptibility to fracture. To prevent fracture, teeth must be strengthened intracoronally, especially in the posterior teeth where stresses from occlusal forces might cause weakened cusps to break. [4]

Posts are frequently needed to stabilise the coronal and radical structures as it offers retention and resistance for a core material. [5-7] Since more than a century ago, posts have been used to restore endodontically treated teeth when more than half of the coronal tooth structure has been destroyed. [5,7,8]

Numerous prefabricated fiber posts with improved physical properties,are available like carbon, glass fibre reinforced, composite, quartz, cerapost, and zirconia posts [9,10]

Prefabricated posts like carbon, glass, quartz, and reinforced posts can boost retention and stress distribution while strengthening the tooth structure, but cast posts could not achieve this. [11]

Glass fibre reinforced and quartz fibre posts are made of Glass fibres inserted in an epoxy resin matrix that dissipates stress over a larger surface area, reducing root breakage and enhancing aesthetic results due to light transmission. [9,10]

Carbon fibre posts have the advantage of being fatigue resistant with good biocompatibility but the drawback of being dark in colour. They are made of pyramidal carbon fibres inserted in an epoxy resin matrix. [12]

Therefore the aim of this study is to compare the fracture resistance of endodontically treated maxillary premolars reinforced with carbon ,glass and quartz fiber post system in two different ways i e
1. compare & evaluate the fracture resistance of endodontically treated maxillary premolars by incoparating carbon ,glass and quartz fiber post with conventional post placement technique
2. compare & evaluate the fracture resistance of endodontically treated maxillary premolars by incoparating carbon ,glass and quartz fiber post with buccopalatal flaring of the coronal segment while preserving radicular dentin

MATERIALS AND METHODS

Sixty maxillary first premolars were chosen and kept in 0.1% thymol solution until the beginning of the experiment. All teeth measuring 21mm were selectwed for the test so that after keeping 5mm GP apically we could get a post length of 16mm for standardized preparation

For all the samples Standardized Mesio-occluso-distal [MOD] cavities were prepared width of the MOD cavities was kept one third of intercuspal distance from isthmus and width of the proximal boxes was one third of buccopalatal dimension . Access opening was done with endo round burs(BR-41) and working length was set at 0.5 mm short of the apical foramen

The biomechanical preparation was done using nickel titatnium rotary (HYFLEX C M COLTENE) files upto apical size thirty [30] with 6%taper . 17% Ethylenediaminetetra acid gel was used during bimoechanical preparation and prepared canals were irrigated with 0.9% saline solution,and 3% sodium hypochlorite

All the canals were dried using absorbent points and were obturated using gutta percha with

AH PLUS resin based sealer by single cone obturation technique

All the samples were randomly divided into three groups and reinforced with

GROUP 1-Glass fiber post
GROUP 2-Carbon fiber post
GROUP 3-Quartz fiber post

The specimen within each group were randomly divided into two subgroups

SUBGROUP A denotes MOD preparation followed with endodontic treatment of teeth and placement of fiber post keeping 5mm of gutta percha apically followed by composite restoration

SUBGROUP B denotes MOD preparation followed with endodontic treatment and placement of fiber post within 3mm of coronal root space and buccopalatal flaring of remaining coronal fibers followed by composite restoration

In subgroup A post space preparations were prepared using peeso reamers . All the post space were prepared to same depth in order to eliminate variables caused by difference in post length.Post space were prepared by keeping 5mm guttapercha apically,and post was compacted into the canal and luted with self adhesive dual cure resin cement(3M RELYX)

In subgroup B post space preparations were prepared using peeso reamers to same depth in order to eliminate variables caused by difference in post length.post space were prepared by removing the coronal 3mm gutta percha by using heated plugger and flattened.post was placed and compacted to obtain the shape of the prepared canal space and all the samples were followed by buccopalatal flaring of coronal fibers keeping the fibers 1 mm short of the occlusal cavosurface margin and luted with self-adhesive dual cure resin cement(3M RELYX)

Universal matrix band and retainer assembly was applied to all the prepared samples and the MOD cavities were bonded using self-etch dentin adhesive(3M ESPE) and light cured for 10 seconds, followed by restoration with light-cured composite resin and light curing for 30 s. All the restored teeth were finished and polished using flame shaped fine diamond bur

All the specimens were thermocycled between 5°C and 55°C, dwell time 15 s followed by immersion in physiological saline, and incubation at 37°C for 15 days.

After 15 days all the spicemen were sent to lab for comparing the fracture resistance using universal testing machine and observing fracture pattren. Each sample was loaded with a capacity of 1000 Newtons and the bar was placed to long axis of teeth and centered until bar is contacted to occlusal surface.according to the method described by Wu et al


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RESULTS

Null Hypothesis: There is no difference in the mean Fracture Resistance between 6 groups.
Alternative Hypothesis: There is a difference in the mean Fracture Resistance between 6 groups.

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Table no. 1 Comparison of mean Fracture Resistance (in N) b/w 6 groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	p-value
Group 1A	10	457.75	19.04	429.4	487.5	<0.001*
Group 1B	10	654.62	59.32	577.0	778.9	
Group 2A	10	350.80	21.05	323.7	385.0	
Group 2B	10	401.72	19.94	371.4	439.6	
Group 3A	10	560.03	25.62	524.6	599.6	
Group 3B	10	782.90	34.61	737.4	846.8	

Statistically Significant

Note: Group 1A: Glass fiber post sub-group 1A; **Group 1B:** Glass fiber post sub-group 1B; **Group 2A:** Carbon fiber post sub-group 2A; **Group 2B:** Carbon fiber post sub-group 2B; **Group 3A:** Quartz fiber post sub-group 3A & **Group 3B:** Quartz fiber post sub-group 3B

The results indicated substantial differences in fracture resistance across the six groups. Group 1A exhibited mean fracture resistance at 457.75 ± 19.04 N, with individual values ranging from 429.4 N to 487.5 N. Group 1B displayed mean fracture resistance of 654.62 ±59.32 N, with values spanning between 577.0 N and 778.9 N. Group 2A recorded a mean fracture resistance of 350.80 ± 21.05 N, ranging from 323.7 N to 385.0 N. Group 2B demonstrated fracture resistance, exhibiting a mean of 401.72 ± 19.94 N, with values between 371.4 N and 439.6 N. Group 3A exhibited mean fracture resistance at 560.03 ±25.62 N, with values between 524.6 N and 599.6 N. Group 3B showed a mean fracture resistance of 782.90 ± 34.61 N, with values ranging from 737.4 N to 846.8 N. The statistical significance of these variations yielded a p-value of <0.001, indicating a highly significant difference among the groups. This suggests that the material composition or structural integrity in each group had a pronounced effect on fracture resistance. ***(Refer Graph no. 1)***

Table no. 2 Multiple comparison of mean difference in Fracture Resistance (in N) b/w groups using Tukey's post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		p-value
			Lower	Upper	
Group 1A	Group 1B	-196.87	-240.61	-153.13	<0.001*
	Group 2A	106.95	63.21	150.69	<0.001*
	Group 2B	56.03	12.29	99.77	0.005*
	Group 3A	-102.28	-146.02	-58.54	<0.001*
	Group 3B	-325.15	-368.90	-281.41	<0.001*
Group 1B	Group 2A	303.82	260.08	347.56	<0.001*
	Group 2B	252.90	209.16	296.64	<0.001*
	Group 3A	94.59	50.85	138.33	<0.001*
	Group 3B	-128.28	-172.03	-84.54	<0.001*
Group 2A	Group 2B	-50.92	-94.66	-7.18	0.01*
	Group 3A	-209.23	-252.97	-165.49	<0.001*
	Group 3B	-432.10	-475.85	-388.36	<0.001*
Group 2B	Group 3A	-158.31	-202.05	-114.57	<0.001*
	Group 3B	-381.18	-424.93	-337.44	<0.001*
Group 3A	Group 3B	-222.87	-266.62	-179.13	<0.001*

* - Statistically Significant

The test results provide insights into statistically significant contrasts, aiding in the identification of meaningful differences between experimental conditions. Group 1A exhibited significantly lower fracture resistance when compared to multiple groups. Specifically, the mean difference with Group 1B was -196.87 N (95% CI: -240.61 to -153.13, p < 0.001), confirming a notable contrast in mechanical strength. Conversely, when compared to Group 2A, the mean difference was 106.95 N (95% CI: 63.21 to 150.69, p < 0.001), indicating higher fracture resistance in Group 1A. Additionally, Group 1A demonstrated a statistically significant difference when compared to Group 2B (56.03 N, 95% CI: 12.29 to 99.77, p = 0.005). However, Group 1A exhibited lower resistance relative to Group 3A (-102.28 N, 95% CI: -146.02 to -58.54, p < 0.001) and Group 3B (-325.15

N, 95% CI: -368.90 to -281.41, p < 0.001), reinforcing significant structural differences. Group 1B demonstrated significantly higher fracture resistance compared to several groups. When compared to Group 2A, it showed a mean difference of 303.82 N (95% CI: 260.08 to 347.56, p < 0.001), confirming its superior mechanical properties. Similarly, the difference between Group 1B and Group 2B was notable (252.90 N, 95% CI: 209.16 to 296.64, p < 0.001), reinforcing its greater strength. Group 1B also exhibited higher resistance than Group 3A, with a mean difference of 94.59 N (95% CI: 50.85 to 138.33, p < 0.001), further confirming significant variations in fracture resistance. However, its comparison with Group 3B yielded a negative mean difference of -128.28 N (95% CI: -172.03 to -84.54, p < 0.001), suggesting lower resistance in Group 1B relative to Group 3B.

Group 2A exhibited significantly lower fracture resistance compared to multiple groups. When compared to Group 2B, it showed a mean difference of -50.92 N (95% CI: -94.66 to - 7.18, p = 0.01), confirming statistically significant variability. Similarly, Group 2A demonstrated lower resistance than Group 3A (-209.23 N, 95% CI: -252.97 to -165.49, p < 0.001) and an even greater decline compared to Group 3B (-432.10 N, 95% CI: -475.85 to - 388.36, p < 0.001), reinforcing considerable differences in mechanical integrity.

Group 2B demonstrated lower fracture resistance when compared to Group 3A (-158.31 N, 95% CI: -202.05 to -114.57, p < 0.001) and even greater reduction compared to Group 3B (- 381.18 N, 95% CI: -424.93 to -337.44, p < 0.001), highlighting its relative weakness in mechanical performance.

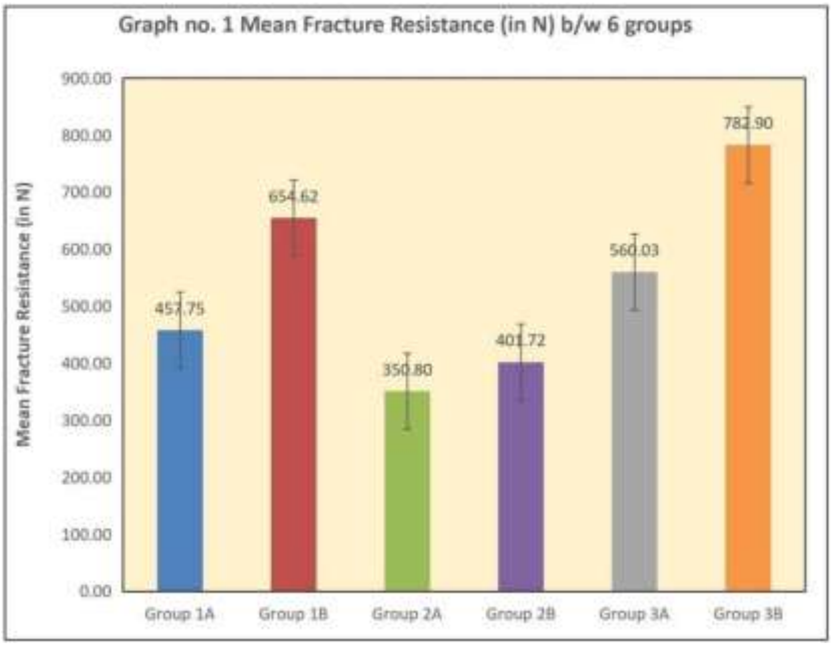
Group 3A exhibited significantly lower fracture resistance than Group 3B, with a mean difference of -222.87 N (95% CI: -266.62 to -179.13, p < 0.001), confirming substantial differences between the two groups.

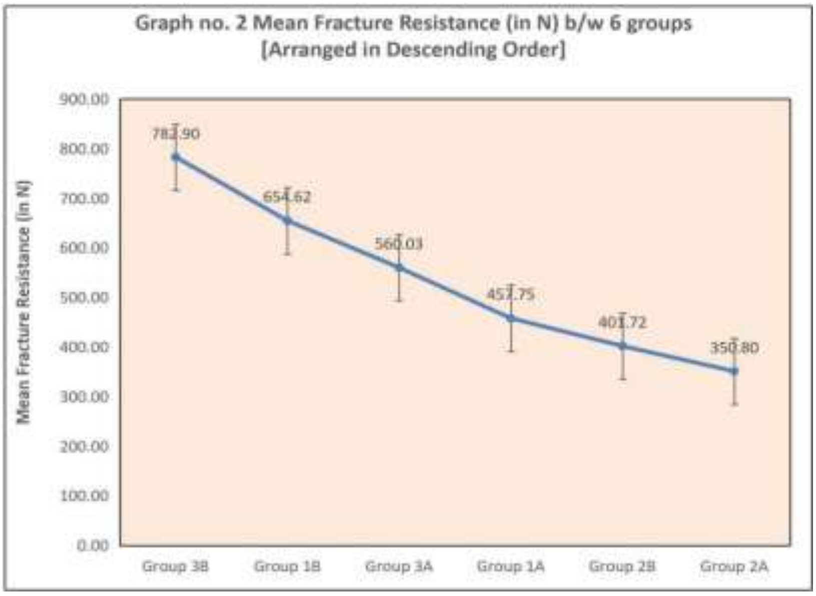
Inference: Group 1B exhibited the highest fracture resistance, followed by Group 3B. Group 1A and Group 3A demonstrated moderate resistance, whereas Group 2B and Group 2A exhibited lower values, with Group 2A showing the least resistance among all groups. ***(Refer Graph no. 2)***

Table no. 3 Comparison of Fracture Pattern between different groups using Chi Square Test

Variable	Groups	Favourable		Unfavourable		p-value
		n	%	n	%	
Fracture Pattern	Group 1A	9	90%	1	10%	0.97
	Group 1B	8	80%	2	20%	
	Group 2A	8	80%	2	20%	
	Group 2B	8	80%	2	20%	
	Group 3A	8	80%	2	20%	
	Group 3B	9	90%	1	10%	

The distribution of fracture patterns among different groups showed a comparable trend. Group 1A and Group 3B had the highest proportion of favorable fractures, with 90% (n=9) in each, while the remaining groups exhibited a slightly lower percentage at 80% (n=8). Unfavourable fractures were relatively low across all groups, ranging from 10% (n=1) in Groups 1A and 3B to 20% (n=2) in the other groups. The p-value of 0.97 indicated that there was no statistically significant difference in fracture pattern distribution among the groups.


Graph no. 1 Mean Fracture Resistance (in N) b/w 6 groups
Mean Fracture Resistance (in N)
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
457.75
654.62
350.80
401.72
560.03
782.90
Group 1A
Group 1B
Group 2A
Group 2B
Group 3A
Group 3B


Graph no. 2 Mean Fracture Resistance (in N) b/w 6 groups
[Arranged in Descending Order]
Mean Fracture Resistance (in N)
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
782.90
654.62
560.03
457.75
401.72
350.80
Group 3B
Group 1B
Group 3A
Group 1A
Group 2B
Group 2A

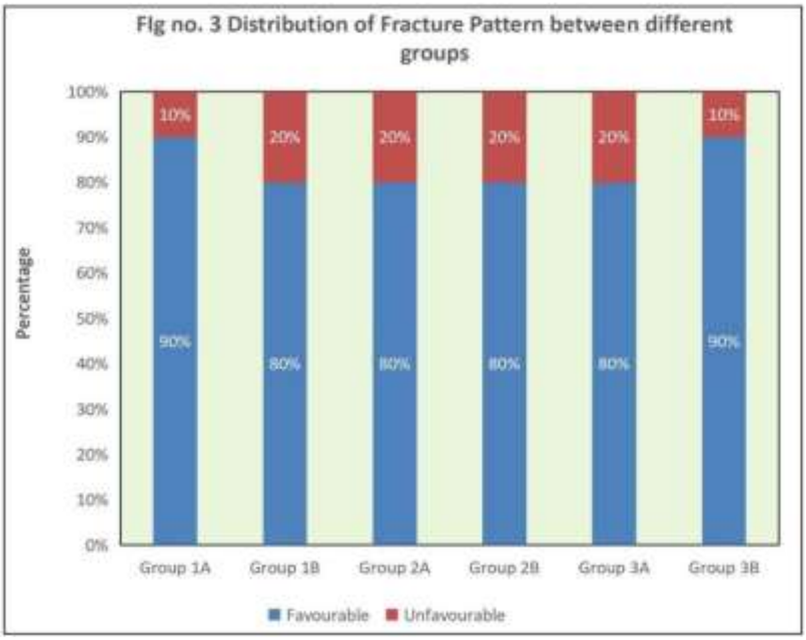


Fig no. 3 Distribution of Fracture Pattern between different groups
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
10%
20%
20%
20%
20%
10%
90%
80%
80%
80%
80%
90%
Group 1A
Group 1B
Group 2A
Group 2B
Group 3A
Group 3B
Favourable
Unfavourable

DISCUSSION

This study was aimed to evaluate fracture resistance of endodontically treated maxillary premolar reinforced with three different fiber post systems in different ways

Effective endodontic therapy relies on three-dimensional obturation and keeping the tooth in a functional and nonpathological state[13] .The loss of tooth structure has a direct impact on the fracture resistance and strain values of the teeth that remain after endodontic treatment.[15] Over time, Endodontically treated teeth get drier and their dentin experiences modifications in the cross-linking of collagen. Thus, compared to non Endodontically treated teeth, it has been proposed that endodontically treated teeth are more brittle and susceptible to breakage[14].

The second most common reason why endodontically treated teeth fail is root weakening during treatment. Posts have been utilized to reduce root weakening.[14].The main purpose of a post is to retain the final restoration in place and distribute occlusal forces throughout the tooth structure; its efficacy is determined by a number of variables, including post length, diameter, remaining dentin thickness,around the post and post adaption.[16] .To prevent overly weakening the root during post space preparation, the post should be positioned in the widest and straightest canal [14]

In this study Maxillary premolars were chosen because, in contrast to molars, they are frequently subjected to lateral stresses that are harmful, unfavorable crown/root proportion, and concurrent handling of shear and compressive pressures and their anatomical shape these are more likely to fracture[17].Complex MOD preparations are extremely prone to fracture since the residual tooth walls also affect cusp fracture and tooth strength is atleast reduced by 60%[18]

Fiber posts are designed with micro-retentive surfaces, often achieved through surface treatments like sandblasting or silanization, which enhance their adhesion to resin cements and core materials. This micromechanical interlocking ensures a more durable bond between the post and the root canal dentin [19] . One of the most significant advantages of fiber posts is that they require minimal tooth preparation. Their insertion often preserves more of the remaining tooth structure compared to metal posts, aligning with the principle of minimally invasive dentistry This structural preservation contributes to better long-term outcomes. Fiber posts are also aesthetic [20]

In this present study three different post materials are used to check the fracture resistance of endodontically treated premolar.namely quartz fiber post, glass fiber post and carbon fiber post

In this IN-VITRO study the quartz fiber post with 3mm of coronal root space and buccopalatal flaring showed highest fracture resistance (782.90) followed by glass fiber post(654.62) (refer graph no 1) , The subgroup 1A and 3Ashowed less fracture resistance compared to subgroup 1B and 3B (refer graph no 2) because of the buccopalatal flaring and minimal radicular extension can compromise the structural integrity of endodontically treated teeth. The coronal portion's fibers are flared to improve their bond with the core. This post's special method allows it to be used in canals that are wide, oval, or even curved. Additionally, by strengthening the root, it increases resistance to fractures [16].However, appropriate post selection and restorative techniques, such as anatomical posts and reinforcement with composite resin or accessory posts, can significantly enhance fracture resistance in these compromised teeth.[17,18].Chhabra, Naveen et al concluded that The buccopalatal flaring of glass fiber post and minimal radicular extension showed the highest fracture resistance

Quartz fiber posts exhibit the highest fracture resistance[refer graph 2] among fiber post systems due to their high tensile strength, excellent bonding with resin matrices, and an elastic modulus similar to dentin. These properties enable efficient stress distribution and reduce the risk of catastrophic root fractures. Quartz fibers also demonstrate superior fatigue resistance and are less brittle than glass fibers. While carbon fiber posts are strong, their stiffness increases stress transmission to the root and results in less favorable fracture patterns. Glass fiber posts, though esthetic and compatible with dentin, generally show slightly lower fracture resistance than quartz due to variations in fiber purity and bonding strength. Owing to their mechanical advantages and translucency, quartz fiber posts are preferred in high-load and esthetically critical areas.[22] Akkayan et al. also reported higher fracture resistance in the quartz fiber group compared to glass fiber posts[23]

Group 2 demonstrated lower fracture resistance (refer to Graph 2) compared to other groups, likely due to the unfavorable mechanical properties of carbon fiber posts. Although carbon posts are rigid and strong, their modulus of elasticity—ranging from 9 to 50 GPa—is significantly higher than that of dentin, which impairs stress distribution at the post-dentin interface and increases the risk of root fracture [27]. Their stiffness and brittleness resemble that of metal posts, and their modulus is approximately ten times greater than dentin [25], contributing to less favorable biomechanical behavior. Charu Dayal et al. (2014) compared the fracture resistance of zirconia, glass, and carbon fiber posts, reporting the highest values with zirconia, followed by glass and then carbon fiber posts [27]. Similarly, Sharma et al. found that quartz fiber posts offered superior fracture resistance compared to both glass and carbon posts [11].

Glass fiber posts derive their strength from unidirectional glass fibers embedded in a resin matrix, providing good mechanical performance without significantly altering their modulus of elasticity. This compatibility with dentin allows for better stress distribution, thereby reducing the risk of root fracture compared to carbon fiber posts (refer to Graph 2) [9]. Their translucency and ability to form a monoblock through adhesive bonding enhance intra-radicular reinforcement and transverse strength [30].Akkayan et al., revealed that quartz fiber post protects the root from fracture more than the glass fiber post because quartz is made up of refined glass particles offereing better mechanical and chemical properties[27]. Shweta Sharma et al observed higher fracture resistance in quartz followed by glass and carbon fiber post as observed in the present study[22]

The fracture pattern is critical in assessing the restorability of fractured teeth. Visual inspection was used to determine the type, location, and direction of failure. Fractures were classified as favorable if they occurred at or above the simulated bone level, and unfavorable if they occurred below it [26]. In this study, the MOD cavity design—with minimal remaining tooth structure at the cervical margin—may have influenced the fracture pattern. Additionally, the low elastic modulus of composite resin may have allowed force transmission to adjacent dental tissues, focusing stress on the thin cervical dentin and contributing to favorable fracture patterns [31].Fiber posts demonstrated a higher rate of favorable fractures in our in-vitro study. As shown in Table 3, Groups 1A and 3B recorded the highest proportion of favorable fractures (90%, n=9), while the remaining groups showed 80% (n=8). Unfavorable fractures were relatively low, ranging from 10% (n=1) in Groups 1A and 3B to 20% (n=2) in others. The p-value of 0.97 (refer to Graph 3) indicates no statistically significant difference in fracture pattern distribution among groups.These findings align with those of Akkayan et al., who also observed a predominance of favorable fracture patterns in teeth restored with fiber posts [32]. The use of resin cement likely contributes to improved fracture resistance by enhancing marginal adaptation, retention—particularly in short posts—and promoting more restorable (favorable) failure modes.

CONCLUSION

Under the limitations of this in-vitro study, it can be concluded that: Fracture resistance of maxillary first premolars with quartz fiber post showed higher fracture resitance among three different fiber post which is glass fiber post,carbon fiber post and quartz fiber post .All the fiber post showed favourable fracture pattern and didn't have much significant difference among all groups

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