Influence of post material and length on endodontically treated incisors: An in vitro and finite element study

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Statement of problem. Cast posts require sufficient length for prosthesis retention and root strength. For prefabricated metal and fiber posts, the effects of different post lengths on the strength and internal stress of the surrounding root need evaluation.

Purpose. The purpose of this study was to examine, using both experimental and finite element (FE) approaches, the influence of post material and length on the mechanical response of endodontically treated teeth.

Material and methods. Sixty extracted incisors were endodontically treated and then restored with 1 of 3 prefabricated posts: stainless steel (SS), carbon fiber (CF), and glass fiber (GF), with intraradicular lengths of either 5 or 10 mm (n=10). After composite resin core and crown restorations, these teeth were thermal cycled and then loaded to fracture in an oblique direction. Statistical analysis was performed for the effects of post material and length on failure loads using 2-way ANOVA (α=.05). In addition, corresponding FE models of an incisor restored with a post were developed to examine mechanical responses. The simulated tooth was loaded with a 100-N oblique force to analyze the stress in the root dentin.

Results. The SS/5 mm and all fiber post groups presented no statistical differences, with mean (SD) fracture loads of 1247 to 1339 (53 to 121) N. The SS/10 mm group exhibited a lower fracture load, 973 (115) N, and a higher incidence of unfavorable root fracture (P<.05). The FE analysis showed high stress around the apical end of the long SS post, while stress was concentrated around the crown margins in the fiber post groups.

Conclusions. Both long and short fiber posts provided root fracture resistance comparable to that of SS posts. For metal posts, extending the post length does not effectively prevent root fracture in restored teeth. (J Prosthet Dent 2010;104:379-388)

Clinical Implications

Post length is more critical to root fracture resistance in teeth restored with metal posts than in those restored with fiber posts, since long metal posts cause stress concentration in the apical root portion. Post material has more effect on the location of peak stress and the resultant fracture pattern than does post length.

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Endodontically treated teeth present a high risk of biomechanical failure due to the loss of tooth substance resulting from preexisting decay and endodontic therapy. In treating these teeth, intraradicular posts are recommended to aid in the retention of artificial crowns and support the teeth by distributing intraoral forces along the roots. However, structurally compromised teeth are not reinforced by post insertion with respect to sustained masticatory force.[1] The survival of these teeth depends on the condition of the tooth and restoration, and also on the design of the posts.[2,3] Post systems must be carefully considered to reduce the incidence of root fractures and to preserve the root if failure occurs.

Although cast posts and cores have been shown to prevent stress concentration in root dentin,[4] prefabricated posts have become popular due to their clinical convenience and promising results in in vitro root fracture resistance testing.[5,6] Metal and ceramic prefabricated posts exhibit higher elastic moduli than dentin. Investigations have shown that greater stress around the apices of these posts during loading may cause oblique and middle root fractures.[7] Recently, carbon fiber, glass fiber, and quartz fiber posts have been developed to bond with composite resin core materials to support restorations. Contemporary fiber posts are composed of unidirectional quartz fibers or glass embedded in a resin matrix made of epoxy resin or its derivatives. These posts are less rigid, with mechanical properties similar to dentin, and thus can form a homogeneous unit with the surrounding root.[8] Both carbon and glass fiber posts possess excellent bonding characteristics to resin cements and dentin and can more evenly distribute stress in compromised roots, as compared to metal posts.[9,10] Additionally, metal posts cemented in post spaces may come in contact with interstitial fluid and provoke potential electrochemical reactions. The electrolytic corrosion of metal posts is related to changes such as reduced post strength and root discoloration.[11,12] Use of nonmetal posts conceivably prevents this problem.

Early studies revealed that longer metal posts reduce stresses in the coronal third of restored roots compared to shorter posts. Accordingly, it has been suggested that post length be at least equal to the crown height or two thirds of the root length to facilitate even stress distribution and provide resistance to occlusal loads.[13-16] In contrast, the study by Giovani et al[17] disputed the necessity of increasing metal post length, since the differences in fracture resistance of teeth with posts of various lengths were not significant. In addition, increasing post length is usually accomplished with additional root wall enlargement, which could decrease the root strength.[18,19,20] As no consensus exists concerning the proper length for metal posts, the influence of post length on these nonrigid posts needs to be determined.

Some finite element studies showed that increased length of fiber posts provides more bonded areas to evenly distribute the stress and prevent root fractures.[21-23] In contrast, a recent study revealed that short fiber posts with the lowest crown/post length ratio tested (1:1) sustained an equivalent number of fatigue cycles as compared to longer posts.[24] Based on these conflicting findings, additional evidence is required to determine the proper length for fiber posts.

Finite element (FE) analysis works by dividing a problem domain into small elements and executing an element level computation to generate a piecewise solution. The derivate, stress or strain, is then obtained by averaging the element level solution. In investigations of complex biomechanical structures, FE analysis has been a powerful tool in measuring internal stress, which cannot be revealed by direct experimental approaches. FE analyses have been applied to stress distributions in endodontically treated roots,[21-23,25,26] since stress-induced root fractures are common failure patterns and may result in clinically unrestorable teeth.

Although a 3-dimensional (3-D) FE model may present configurations similar to real conditions, 2-dimensional (2-D) models have been widely used. Pegoretti et al[27] used a 2-D plane strain analysis, including the orthotropic elastic properties of fiber posts, to assess the mechanical responses of tooth models with different post-and-core systems. The authors presented an acceptable interpretation of the stress field and peak stress locations in the tooth models. Although simplifications inherent in the 2-D FE models may reduce the accuracy of peak stress value predictions, the findings with respect to the stress states were similar to those obtained from 3-D models.[28,29]

Various designs for the restoration of endodontically treated teeth have been proposed. Improper post placement may jeopardize rather than enhance the clinical performance of restored teeth, and increase the risk of root fracture. The purpose of this study was to investigate the mechanical response of devitalized teeth restored with posts of different materials and lengths, using an approach that combined a mechanical test and finite element (FE) analysis. The null hypothesis was that neither the post material nor length would be found to have an effect on the fracture strength and stress distribution of endodontically treated teeth.

MATERIAL AND METHODS

Sixty intact extracted human maxillary anterior teeth of similar size and shape were selected. The study was determined to be exempt from the University of Michigan Medical School Institutional Review Board due to the use of teeth from disassociated subjects. No formal power analysis was performed to determine adequate sample size. Considering limitations in collecting teeth, the sample size was set at 10; thus, the total number for 6 experimental groups was 60. Previous studies have yielded adequate power to detect clinically important differences using a sample size of 10.[10,15,17]

The crowns of the test teeth were removed by horizontal sectioning 2 mm above the cemento-enamel junction (CEJ). Mean root length for these teeth was 16.37 mm, and the mean mesiodistal diameter at the CEJ was 6.14 mm. The root canal of each tooth was instrumented using nickel titanium rotary instruments (ProFile; Dentsply Tulsa, Tulsa City, Okla) to a final file size of no. 40 and shaped with a conventional step-back technique. Each canal was then filled using a thermoplastic gutta-percha technique (Obtura II obturation system; Obtura Spartan, Fenton, Mo).

A parallel post was selected, as this had a consistent size and diameter at each length tested. Three post systems of similar shape and from the same manufacturer (J. Morita, Osaka, Japan) were chosen: a stainless steel (SS) post (SB post; 1.44 mm in diameter); a carbon fiber (CF) post (CF post; 1.40 mm in diameter); and a glass fiber (GF) post (GF post; 1.40 mm in diameter) (Fig. 1).

After completion of the endodontic treatments, the teeth were distributed into 6 groups with different combinations of post systems and lengths: group SS/10, an SB post with a 10-mm insertion length; group SS/5, an SB post with a 5-mm insertion length; group CF/10, a CF post with a 10-mm insertion length; group CF/5, a CF post with a 5-mm insertion length; group GF/10, a GF post with a 10-mm insertion length; group GF/5, a GF post with a 5-mm insertion length.

In groups SS/10, CF/10, and GF/10, 10 mm of gutta-percha was removed from the root canals with a heat carrier. In the other 3 groups, 5 mm of gutta-percha was removed. The teeth were prepared with the corresponding spiral reamers (L3 reamer; J. Morita USA, Irvine, Calif). The posts were shortened to the designated length, leaving an additional 5 mm coronal to the CEJ. The post spaces were rinsed with water, dried, and treated with 2 consecutive coats of self-etching primer (Bistite II DC; Tokuyama Dental Corp, Tokyo, Japan). Subsequently, the posts were cemented with a resin cement (Bistite II DC; Tokuyama Dental Corp) and light polymerized (Optilux 501; Kerr Corp, Orange, Calif) using an output intensity of 850 mW/cm^2 for 2 minutes. The cement was allowed to polymerize for another 10 minutes. A custom-made translucent silicone (Coping Material; Keystone Industries, Cherry Hill, NJ) matrix was used to fabricate a core of standardized shape and size. The composite resin core material (Rebilda DC; VOCO GmbH, Cuxhaven, Germany) was mixed with a spiral dispenser and injected into the matrix and onto the root. The composite resin was light-polymerized through the core matrix for 60 seconds. After removal of the matrix, the teeth were prepared with a ferrule collar of 1.5 mm on the cervical portion and with a shoulder margin.

1 Prefabricated posts used. From right to left: SS post, CF post, and GF post.

Impressions of the teeth were made with a vinyl polysiloxane material (Aquasil Ultra LV; Dentsply DeTrey GmbH, Konstanz, Germany), and metal ceramic crowns were fabricated using Ni-Cr alloy (Wiron 99; BEGO, Bremen, Germany) and porcelain (VITA VMK 68; VITA Zahnfabrik, Bad Säckingen, Germany). The crowns were designed with a small palatal rest 1 mm wide and 2 mm cervical to the incisal edge, with the metal/ceramic junction located 1 mm from the palatal rest. The crowns were cemented with resin cement (Bistite II DC; Tokuyama Dental Corp). After removal of excess cement, the teeth were stored in 100% humidity for 24 hours and then thermal cycled for 1500 cycles between 5°C and 60°C, with a 20-second dwell time.

After thermal cycling, the teeth were separately mounted in epoxy resin (Epoxy adhesive; Nan Pao Resins Chemical Co, Changhua, Taiwan); the roots were embedded 2 mm apical to the crown margins. Each jig was secured in a custom-made holding device at a 45-degree angle, with the palatal side facing up. A universal testing machine (Instron 5565; Instron Corp, Norwood, Mass) was used to test these specimens. A custom-made knife-edged chisel was used to apply a load at a constant crosshead speed of 0.5 mm/min until failure occurred (Fig. 2). Failure was defined as the point at which the loading force showed a dramatic reduction of applied load as either fracture of the root/post/crown or debonding of the post occurred.

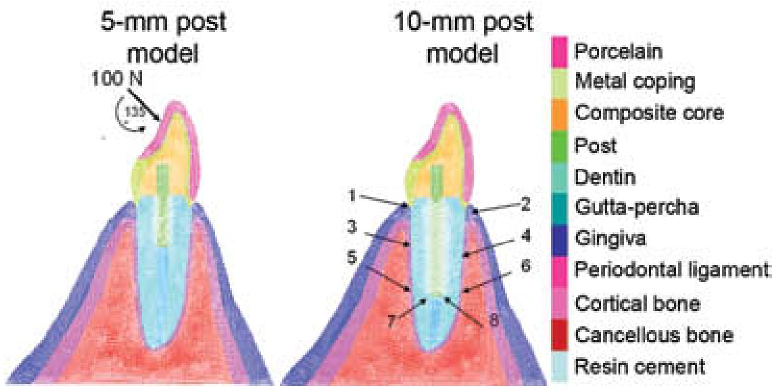
Fracture strength was defined as maximum load sustained before failure occurred. Data were first analyzed by the Kolmogrov-Smirnov test to confirm normal distribution, then a 2-way ANOVA was used to examine the effect of the post mate-

2 Post-and-crown restored tooth secured in jig and testing machine to receive load.

TABLE I. Material properties applied in FE analysis

Material	Young's Modulus (GPa)	Shear Modulus (GPa)	Poisson's Ratio
Dentin	18.6[30]		0.31[30]
Gingiva	0.0196[14]		0.30[14]
Periodontal ligament	0.0000689[31]		0.45[31]
Cortical bone	13.7[32]		0.3[32]
Cancellous bone	1.37[32]		0.3[32]
Gutta-percha	0.14[33]		0.45[33]
Porcelain	65[34]		0.24[34]
NiCr coping	200[35]		0.33[35]
Resin composite core	7[27]		0.3[27]
Resin cement	2.6[27]		0.33[27]
Stainless steel	210[26]		0.3[26]
Carbon fiber[a]	E_L=125[27] E_T=$E_{T'}$=8.5[27]	G_{LT}=$G_{LT'}$=3.1[27] G_{TT}=3.0[27]	ν_{LT}=$\nu_{LT'}$=0.25[27] ν_{TL}=$\nu_{T'L}$=0.017[27] $\nu_{TT'}$=0.32[27]
Glass fiber[a]	E_L=40[27] E_T=$E_{T'}$=11[27]	G_{LT}=$G_{LT'}$=4.2[27] G_{TT}=4.1[27]	ν_{LT}=$\nu_{LT'}$=0.26[27] ν_{TL}=$\nu_{T'L}$=0.07[27] $\nu_{TT'}$=0.32[27]

[a]E_L, E_T, and $E_{T'}$: elasticity modulus in longitudinal (parallel to fibers) and 2 perpendicular directions in transverse plane of fiber posts.
G_{LT} and $G_{LT'}$: longitudinal in-plane shear modulus. G_{TT}: transverse shear modulus.
ν_{TL}, $\nu_{T'L}$, and $\nu_{TT'}$: first subscript in Poisson's ratio refers to direction of load, and second to direction of displacement.



3 Illustrations of FE model geometries. Regions 1 to 8 indicate areas of interest for critical stress in root dentin.

rial and length, as well as the interaction between each variable. The statistical differences in various post groups were analyzed with a 1-way ANOVA test followed by a post hoc Tukey's Honestly Significant Difference (HSD) test, while the differences in groups with the same posts but different lengths were analyzed with a 2-sample *t* test. An alpha of .05 was used for all statistical testing.

Subsequently, the teeth were removed from the mounted jigs and fracture patterns were examined using a stereomicroscope (Stemi SV 6; Carl Zeiss AG, Oberkochen, Germany). The locations and directions of fracture surfaces, and whether the fracture plane passed through the post end, were recorded and analyzed by Fisher's exact tests.

A longitudinal buccolingual section of a maxillary central incisor, with the average length and diameter of the teeth from the fracture tests, was developed as a 2-D FE model using software (ANSYS v. 9.0; ANSYS, Inc, Canonsburg, Pa). The geometry of the tooth model consisted of a metal ceramic crown, composite resin core, parallel post, dentin, gutta-percha, surrounding periodontal ligament, and cortical/trabecular bone. In the simulated models, the geometry of the post was adapted from the GF post with a diameter of 1.40 mm. In the 5-mm post models, the entire post was located in the root canal space. But for the 10-mm post model, the apex of the post was located deeper in the root dentin. For all models, the post was assumed to be bonded to the root dentin with a 30-μm-thick layer of resin cement. A bonded condition was assigned among all of the components. Two basic models were fabricated by changing the post lengths to either 5 or 10 mm. Finally, a total of 6 models were generated by applying properties of the different post materials to the 2 basic models.

All materials in the FE analysis were considered as linearly elastic and isotropic, except for the CF and GF posts, which were modeled as transversally isotropic materials (Table I).[14,26,27,30-35] For the 2 fiber posts, elastic constants, including the Young's modulus at the longitudinal axis E_L, 2 identical Young's modulus at the transverse axes E_T=$E_{T'}$, the shear moduli, and 3 Poisson's ratios were required to describe their mechanical properties in different directions.[27] Plane strain conditions were assumed for the analysis. All of the models were meshed with an 8-node element (plane 183 element) using a higher degree of interpolation function. The meshing process generated at least 9222 elements and 28,024 nodes for each model (Fig. 3).

As a boundary condition, no displacements were allowed for the base of alveolar bone. Teeth were subjected to a 100-N force on the lingual surface of the crown, 2 mm below the incisal edge and at a 135-degree angulation to the long axis of the tooth. Under the defined loading and boundary conditions, linear static structural analyses were performed. Since root fracture is the primary cause of failure in these restored teeth, the stress distribution in the root dentin was analyzed to identify the locations of peak stresses under the loading condition. The peak von Mises equivalent stress values at 8 regions of interest were recorded (Fig. 3): regions 1 and 2, the palatal and buccal areas around cervical margins, respectively; regions 3 and 4, the palatal and buccal areas on middle root dentin, 5 mm apical to cervical margins, respectively; regions 5 and 6, the palatal and buccal areas on middle root dentin, 10 mm apical to cervical margins, respectively; regions 7 and 8, dentin opposed to palatal and buccal sides of the post end, respectively.

Shear stress was mapped as the average of the values between 2 adjacent elements. Since the post of each model was aligned along the Y-axis, the shear stresses τxy around the post/cement/dentin interface were measured.

RESULTS

The results of the fracture test are listed in Table II. The 2-way ANOVA was not significant for either post material or length, and the interaction effect was influenced by length for SS material, but not for the CF or GF material (Table III). The *t* test for the pairwise comparison of the same post groups showed that the SS/10 group exhibited lower mean failure load (973 N) than the SS/5 group (1339 N). There was no significant difference in the mean failure loads among the 4 fiber post groups. Teeth restored with posts of the same material demonstrated a similar distribution of fracture locations and directions. Middle root fracture was the primary pattern in the SS post groups (60%), followed by cervical root fracture. In the fiber post groups, cervical root fracture accounted for approximately half of

TABLE II. Fracture strength and fracture patterns in each group (n=10)

Group	Failure Load (N)[a]	Fracture Plane Location[b]				Fracture Plane Direction[c]			Fracture Plane Through End of Post[d]	
		Cervical	Middle	Apical	Multiple	Horizontal	Oblique	Complicated	Not Through End	Through End
SS/10	973.27 (115.42)	3	6	1	0	2	7	1	2	8
SS/5	1338.79 (121.84)	3	6	0	1	1	8	1	4	6
CF/10	1248.81 (117.60)	5	2	3	0	0	10	0	7	3
CF/5	1253.76 (79.68)	5	2	3	0	1	9	0	7	3
GF/10	1292.33 (185.86)	5	4	1	0	3	7	0	9	1
GF/5	1247.17 (53.03)	4	3	2	1	2	7	0	9	1

[a]One-way ANOVA test and Tukey HSD test: significant difference between groups SB/10 and SB/5, and groups SB/5 and GF/10.
[b]Fisher's exact test: P=.373
[c]Fisher's exact test: P=.881
[d]Fisher's exact test: P=.012

TABLE III. Two-way ANOVA of fracture strength values

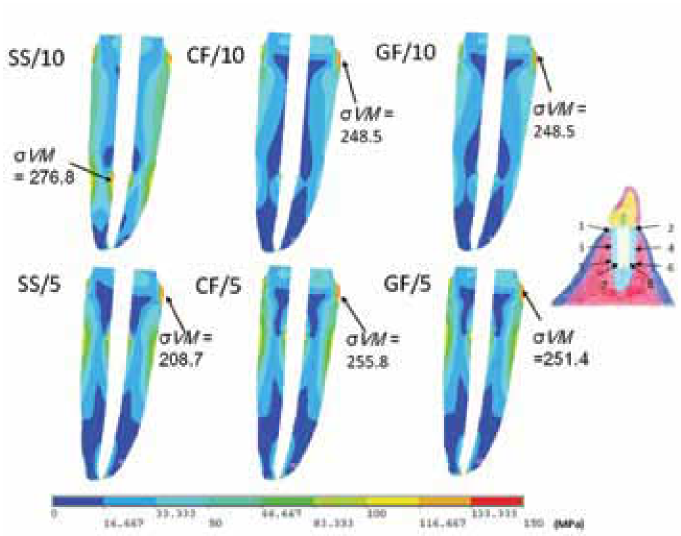
Source of Variation	*df*	Sum of Squares	Mean Square	F	*P*
Post material	2	234960	117480	0.93	.402
Post length	1	384758	384758	3.04	.087
Material × length	2	337844	168922	1.34	.272
Error	50	6326195	126524		
Total	56	93448435			

the fracture locations. In all groups, oblique fracture was the dominant pattern. Most oblique fractures extended from the palatal to the buccal side of the roots. The Fisher's exact test showed that the SS post groups exhibited higher frequency of the fracture plane passing through the post end (80% and 60% in groups SS/10 and SS/5, respectively) compared to the CF and GF post groups (P=.012).

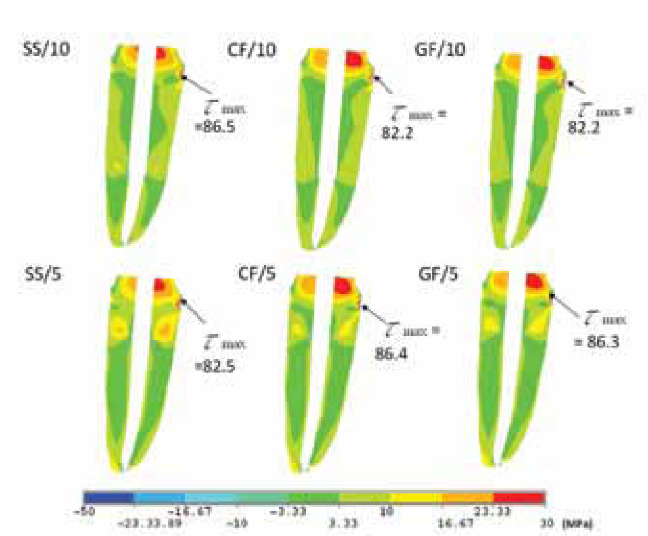
From the analytic results, the peak von Mises stresses at the 8 regions of interest were measured (Table IV). The locations of the maximum von Mises stresses varied among models (Fig. 4). Among 6 groups, the SS/10 model showed the highest value of maximum von Mises stress in the dentin opposing the palatal side of the post end (region 7). For the other models, peak stresses were found to be located at the cervical area of the compression side (region 2). Increases in peak von Mises stress values around the middle root (regions 3 and 4) were found in the 5-mm post models. The

Table IV. Peak von Mises and XY shear stress values (MPa) in root dentin of FE models

Group	Peak von Mises Stresses								Peak Shear Stress
	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	
SS/10	166.8	204.3	68.1	72.6	117.7	107.9	276.8	202.3	86.5
SS/5	126.5	208.7	105.7	99.7	44.7	49.2	181.2	152.5	82.5
CF/10	155.5	248.5	52.8	46.2	46.7	43.5	113.8	93.2	82.2
CF/5	166.1	255.8	102.4	97.3	44.1	43.6	161.4	129.5	86.4
GF/10	150.4	248.5	50.6	46.7	47.5	45.2	92.8	77.9	82.2
GF/5	157.4	251.4	102.8	98.9	56.0	76.2	138.7	114.8	86.3



4 von Mises stress (σVM) distribution maps in FE analysis results. Locations and values of peak von Mises stresses are shown. Color bar indicates range of 0 to 150 MPa.



5 Shear stress (τ) distribution maps in FE analysis results. Locations and values of maximal shear stresses are shown. Color bar indicates range of -30 to 30 MPa.

peak stress of the fiber post models was primarily located at the cervical margins. The maximum shear stress was located at cervical regions for all models (Table IV; Fig. 5). For all of the models, the values of maximal shear stress were similar.

DISCUSSION

Based on the results of this study, the null hypothesis that neither the post material nor length would be found to have an effect on the fracture strength and stress distribution of endodontically treated teeth was rejected. For the long-term restoration of endodontically treated teeth with minimal remaining coronal structure, the proper design of a post and core is essential. Numerous studies assessed variables related to the use of posts using mechanical tests, including quasi-static fracture tests and cyclic loading, but their results were often inconclusive.[2,5,7,17] Finite element analysis has been used in related investigations for selecting optimal design, failure analysis, and prognosis prediction. Improved insight into the biomechanical behavior of endodontically treated teeth is possible when numerical analysis is matched to experimental testing. Both the FE analysis and the experimental results of this study revealed that the long SS post presented a higher risk of root fracture.

This study attempted to evaluate different post designs using a fracture test in combination with a theoretical approach. The integration of experimental and numerical analyses presented some limitations. Although the teeth were selected to be of similar length and buccolingual and mesiodistal dimensions, different root shapes, such as the presence of root concavities, resulted in variations in the fracture patterns in each group.

Finite element analysis was used to examine different groups by changing the length and material properties of posts in the basic model. The analytic results were generally applied to compare the effects of test parameters on the critical stress distribution, but may not be related to the condition of each tooth. Furthermore, the boundary conditions of the in vitro experiment were different from the clinical situation, as the simulated alveolar bone of the FE model consisted of teeth embedded in an epoxy resin cylinder. However, the analytic results were generally consistent with the experimental results.

The numerical results indicated that the mechanical behavior in the root dentin was affected by both post material and post length. From the experimental results, the differences between 2 of the experimental parameters were not significant, while the root fracture patterns tended to correlate with the post material. The SS post groups showed a higher incidence of apical root fracture, with the fracture plane at the end of the post, while the fiber post groups exhibited more cervical root fractures. The locations of high von Mises stress in the SS/10 and SS/5 models were in the cervical regions and around the post ends, respectively, which corresponded to the fracture patterns in the experimental results. The higher peak dentin stress in the SS/10 model was also consistent with the lower root fracture resistance of group SS/10 as compared to group SS/5. These findings suggest that the FE analysis is supportive of the mechanical test and provides additional evidence in explaining the experimental results.

The problems associated with changing the length of cast posts or prefabricated metal posts have been extensively investigated with respect to root strength or restoration integrity.[2,18] When conventional cast posts are used, intraradicular post lengths are recommended to be at least as long as the crown length, usually placed 3 to 5 mm from the root apex. Increasing post length facilitates the stress-sharing effect by evenly distributing the occlusal load to the bonded root dentin.[13,14] For prefabricated metal posts, most studies have also supported the concept that sufficient post length was required to sustain occlusal loads.[15,16]

However, some investigators found that post length did not influence the fracture resistance of crowned endodontically treated teeth when a sufficient ferrule was present.[2] In contrast, the current study showed that long metal posts did not provide equivalent root fracture resistance compared to the short metal posts. The fracture patterns in the SS/10 group were unrestorable, primarily those in the middle of the root and through the post end. This result was confirmed by FE analysis, with high von Mises stresses found in dentin around the post end. These results correspond to those of a previous report that showed that a deeper post space preparation may jeopardize the root and, consequently, reduce root strength when residual dentin is weakened.[20]

The analytic results of FE analysis vary with model geometry. For FE studies designed with a long post extending into the root canal,[23,29] the local stress concentration effect was less evident because surrounding dentin at the coronal portion of the root absorbed the stress. In the present FE analysis, models were adjusted to mimic different post-root configurations as the post length changed. In the long post model, the root canal space was enlarged to accommodate a 10-mm post, with the post apex engaging dentin in the apical portion of the root. In the short post model, the apex of the post did not fit well into the root canal. The resultant local high stress around the long post ends was apparently related to the model design.

With the increasing use of fiber and resin-reinforced posts, determining the proper length of posts has been a concern to clinicians. Several investigators have concluded that increasing post length did not affect tooth fracture resistance, since fiber posts exhibit similar mechanical properties to dentin.[15,16,22] One study proposed that the use of posts shorter than the clinical crown should be avoided to prevent clinical failure.[24] The present results demonstrated that both carbon and glass fiber posts provided restored teeth with root fracture resistance similar to that provided by long prefabricated stainless steel posts. In the fiber post groups, changing the post lengths had less effect on fracture resistance than in the steel post groups. Despite the different material properties between CF and GF posts, the maximal von Mises stress in all the fiber post models were equivalent and located in the cervical area. This analytic result was in accordance with the results of an 3-D FE study by Ferrari et al,[29] which did not show a perceptible change in stress values when the post length changed. In the present study, the proposed influence of post length was not observed when using fiber posts.

The fracture planes for the metal and fiber posts groups were quite different. Most fractures in the SS post groups were located in the middle of the root, traveling transversely or obliquely through the post ends, while the fracture planes in most specimens of the CF and GF post groups were at the cervical or near the cervical regions. These fracture patterns corresponded with the stress field in the FE analysis (Figs. 4 and 5). For all of the FE models, the location of stress concentration correlated with regions that had structural and material property discontinuities.

The modulus of elasticity (210 GPa) of the stainless steel posts is significantly higher than that of dentin. For long SS post models, the stiffer posts exhibited a stress-shielding effect by absorbing more of the load.[26] As the force was transmitted apically, greater stress was transferred to the root dentin around the post end, further enhanced by material property differences and resulting in stress accumulation. The short SS posts and fiber posts did not absorb equivalent stress as compared to the long SS post due to their shorter length and lower modulus of elasticity, respectively. For the FE models, the stress at the crown margin in the cervical region increased due to the relatively significant material property differences between the crown and dentin.

The high incidence of cervical and middle root fracture in the experiments corresponds with the high stress around the cervical margin in these fiber post models. Previous FE studies that included simulated crowns and ferrules also reported that the stress fields in teeth restored with fiber posts and composite resin cores were generally homogeneous, except in the cervical region.[4,25,27] In some studies, the investigators excluded the crown restoration procedure to prevent errors derived from individual crown morphology and the additional interfacial bond failure. Post-restored teeth without coronal crown coverage may lead to different results, such as core debonding or bending of the post upon loading.[15]

Based on the results of the present experimental FE study, no core dislodgement or fiber post bending occurred after the fracture test. Therefore, designs with coronal crown coverage and the ferrule effect should be included in future investigations to prevent a result that does not replicate clinical usage.

CONCLUSIONS

Within the limitations of this study, the results indicate that the endodontically treated tooth was not strengthened by increasing post length, regardless of whether metal or fiber posts were used. Using long metal posts may reduce the fracture resistance of restored teeth when additional root canal instrumentation is required for the post extension. The fracture patterns of the teeth were found to be associated with the post materials, while the post length had less influence on either the fracture strength or patterns. Fiber posts may provide comparable strength and more favorable fracture patterns at the cervical regions compared to the metal prefabricated post.

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NOTEWORTHY ABSTRACTS OF THE CURRENT LITERATURE

Altered vertical dimension of occlusion: A comparative retrospective pilot study of tooth- and implant-supported restorations

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Purpose. Altering the vertical dimension of occlusion (VDO) by increasing the interarch distance is common in oral rehabilitation, but little is known about the ability of implant patients, who lack sensory perception in implanted regions, to adapt to such changes. This study sought to evaluate the outcome of increasing VDO in patients restored with implant-supported fixed restorations opposed by restored natural teeth or implant-supported restorations.

Materials and Methods. VDO was increased by 3 to 5 mm to address the individual prosthetic needs of 30 patients. Group A (control) consisted of 10 patients with fixed restorations on natural dentition that opposed the natural dentition in a new VDO relationship. Two test groups consisted of 10 patients each, with fixed implant-supported restorations opposing either the restored natural dentition (group B) or fixed implant-supported restorations (group C). After an average follow-up of 66 months, marginal bone changes were calculated using standardized periapical radiographs, and mechanical prosthetic maintenance data were collected from patient files. The results were analyzed using Kruskal-Wallis one-way analysis of variance to identify significant differences between the groups.

Results. All patients successfully adapted to the new VDO. Two patients in group B and four in group C reported tooth clenching or grinding, which abated after 2 to 3 months ($P < .05$). More bone loss and tooth failures were observed in group A, and more mechanical complications, such as porcelain fractures, were observed in group C ($P < .05$).

Conclusion. Within the limitations of this study, alteration of VDO was an acceptable procedure in patients with implant-supported fixed restorations, but precautions should be taken to prevent mechanical problems.