ORIGINAL ARTICLE

Influence of different final irrigation regimens and various endodontic filling materials on vertical root fracture resistance

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Abstract

Aim: The aim of this study was to evaluate the influence of different endodontic materials and final irrigation regimens on vertical root fracture (VRF) resistance.

Materials and Methods: Eighty human teeth were prepared then assigned into two groups (n = 40) according to the final irrigations. G1: 5 mL, 5.25% sodium hypochlorite (NaOCl), G2: 5 mL, 2% chlorhexidine gluconate (CHX). Each group was assigned into four subgroups according to the obturation system used (n = 10): A: iRoot SP/single gutta-percha cone (SGP), B: Only iRoot SP, C: Mineral trioxide aggregate (MTA)-Fillapex/SGP, D: AH26/SGP. The specimens were embedded in acrylic molds and subjected to compressive loading at a rate of 1 mm min until VRF occurred. Data were analyzed via three-way ANOVA tests.

Results: The statistically significant difference was found among groups (P < 0.05). The G1A and G1B and G1D revealed significantly higher-VRF values than G1C (P = 0.023). The roots filled with MTA-Fillapex revealed lower-VRF values than the other subgroups (P < 0.05). Groups irrigated with NaOCl had significantly lower-VRF values than the groups irrigated with CHX (P < 0.05).

Conclusion: Final irrigation regimens could alter VRF resistance of root canals filled with different obturation technique and root canal sealers.

Key words: Chlorhexidine gluconate, root canal sealers, sodium hypochlorite, vertical root fracture

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Introduction

Endodontic procedures result in structural changes in dentin and makes root canals prone to vertical root fracture (VRF). Very limited dehydration has been observed in root canal dentin after devitalizing,[1] and it is clear that this limited dehydration did not weaken the dentin structure.[2] Endodontic procedures including caries removal access cavity preparation and root canal instrumentation result in loss of tooth structure. However, it has been shown that optimal preparation causes limited changes in biomechanical properties of the tooth.[3,4] On the other hand, the tooth biomechanics are altered when irrigated with sodium hypochlorite (NaOCl)[5] and ethylenediamine tetraaceticacid (EDTA)[6,7] and when dressed with long-term intracanal calcium hydroxide.[8] Therefore, the residual tooth structure should be reinforced via root canal filling materials to prevent VRF.[9,10]

Epoxy resin-based AH26 sealer (Dentsply, DeTrey GmbH, Germany) has been widely used due to its favorable physical properties, reduced solubility, apical sealing ability, micro-retention to root dentin, and adequate biological performance.[11] A recently introduced bioceramic-based root canal sealer, iRoot SP (Innovative Bioceramix, Vancouver, Canada), is described by the manufacturer as

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an insoluble, radiopaque, aluminum-free material composed of calcium silicate, calcium phosphate, calcium hydroxide, and zirconium oxide, which requires the presence of water to set and harden. Furthermore, the manufacturers claim that iRoot SP forms excellent bonding by penetrating into the dentin structure and that it can be used directly for filling of root canals with or without gutta-percha points. Another novel root canal sealer, mineral trioxide aggregate (MTA)-Fillapex (Angelus Indústrıa De Produtos Odontológıcos S/A, Londrina, PR, Brazil), is marketed as a radiopaque, insoluble material composed of resins (salicylate, diluting, natural), radiopaque bismuth, nanoparticulated silica, MTA, and pigments. It sets only when there is contact with moisture coming from the dentinal tubules and periapical tissues.

It is essential to use root canal irrigants such as NaOCl, EDTA, and chlorhexidine gluconate (CHX) to achieve adequate disinfection of the root canal system.[12] However, it has been reported that these reagents negatively affect various physical properties of root canal dentin including microhardness, elasticity, and flexural strength[5,13] and also that they alter the bond strengths of root canal filling materials to root canal dentin, which is effective in reinforcement of residual root canal dentin.[10] Few data are available on the effect of final irrigation with NaOCl and CHX on the VRF of roots filled with these novel root canal sealers.

The aim of this study was to evaluate the fracture resistance of root canals filled with different sealers combined with/without gutta-percha following final irrigation regimens with NaOCl or CHX.

Materials and Methods

Specimen preparation

Ninety extracted caries-free and single-rooted mature mandibular premolar human teeth of similar dimensions were used in this study. Buccolingual (BL) and mesiodistal (MD) dimensions of the coronal 1 mm of the roots were measured via a digital caliper for specimen standardization, and those between 6.1 ± 0.2 mm in BL and 4.8 ± 0.2 mm in MD dimensions were used in the experiment. The teeth were examined under ×25 with an operation microscope (Zeiss, Oberkochen, Germany) and those with micro-cracks were excluded from the analysis. The teeth were stored in saline containing 0.2% sodium azide at room temperature prior to experiments. The teeth were decoronized-leaving roots of 12 mm in length. The working length was established by placing a size 10 FlexoFile (Dentsply Maillefer, Tulsa, OK) into the canal until it was observed at the apical foramen, then decreasing the file length by 1 mm.

Five of the noninstrumented roots were selected randomly as negative controls. The remaining 85 specimens were prepared using ProTaper rotary files (Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer's recommendations, in turn SX, S1, S2, F1, F2, F3, and F4. Instruments were used 5 times and then discarded. During the instrumentation, 2.5 mL of 5.25% NaOCl was applied between each change of the file. After instrumentation, all of the specimens were irrigated with 5 mL 17% EDTA for 1 min to remove the smear layer. Prior to obturation, 5 of the specimens were randomly assigned as the positive control group, and the remaining 80 specimens were divided randomly into 2 experimental groups (G1 and G2) according to the final irrigation regimens they were subjected to: G1, 5 mL 5.25% NaOCl for 1 min; G2, 5 mL 2% CHX for 1 min. Two milliliters of distilled water was applied between different irrigants. The root canals were dried with ProTaper paper points. Before root canal filling, each group was further divided into 4 subgroups ($n = 10$) according to the obturation system used: A, iRoot SP and single gutta-percha cone (SGP); B, only iRoot SP; C, MTA-Fillapex and SGP; D, AH26 and SGP [Table 1].

A ProTaper F4 master gutta-percha, corresponding to the final instrument, was used as a master cone, except for group B. Root canal walls were covered with sealer using a paper point, and then the apical portion of the gutta-percha master cone was coated with sealer and inserted into the canal. Excess gutta-percha was removed with a hot instrument. Group B was filled only with iRoot SP sealer using the intracanal tip. The tip was inserted into the root canal, and sealer was injected until it extruded from the apex, then the tip was slowly withdrawn, resulting in complete filling of the canal. Coronal root canal openings were sealed with a temporary filling material, Nucavfill (PSP Dental Co. LTD., Belvedere, Kent, UK). Obturated teeth were stored at 37°C at 100% humidity for 14 days to allow for the complete setting of sealers.

Mechanical testing

After 2 weeks, 3 mm of the roots was embedded in self-cure acrylic resin (Imicryl, Konya, Turkey) by using cylindrical molds of 15 mm diameter and 13 mm height, leaving 9 mm of root length exposed.[9] The temporary filling material was removed with an excavator. The specimens were mounted on the lower plate of a universal testing machine (INSTRON; Lloyd LRX; Lloyd Instruments Ltd., Fareham, UK). Compressive loading force was applied vertically to the coronal surfaces of roots with a loading rate of 1 mm/min until VRF occurred. The maximum load at which failure occurred was recorded in Newton via data analysis software (Nexygen-MT, Lloyd Instruments, Fareham, UK). Data were recorded and statistically analyzed using three-way ANOVA and pairwise comparison bonferroni tests. All the experimental procedures were conducted by one operator specialized in endodontics.

Results

Table 2 presents the minimum, maximum, median, and interquartile range values of all groups (N). The fracture resistance values of the negative group were higher than all

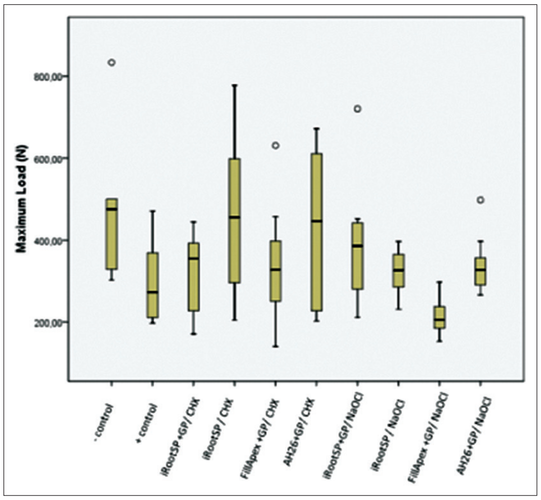

Figure 1: Box and whisker plots of fracture loads in all experimental groups (Upper and lower end of [whisker] line are highest and lowest load at fracture, respectively. Upper and lower end of the box are 75 and 25 percentile, respectively. Horizontal line is median circles represent excessive values)

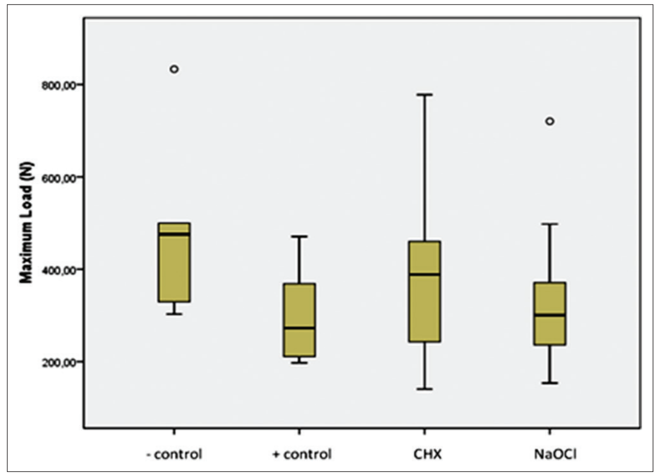

Figure 2: Box and whisker plots of fracture loads in control, chlorhexidine gluconate, and sodium hypochlorite groups (upper and lower end of [whisker] line are highest and lowest load at fracture, respectively. Upper and lower end of the box are 75 and 25 percentile, respectively. Horizontal line is median circles represent excessive values)

Table 1: Experimental groups

Group	Filling techniques	Irrigation solutions	Filling materials
G1A	Single cone gutta-percha	NaOCl	iRoot SP
G1B	Without gutta-percha	NaOCl	iRoot SP
G1C	Single cone gutta-percha	NaOCl	MTA Fillapex
G1D	Single cone gutta-percha	NaOCl	AH26
G2A	Single cone gutta-percha	CHX	iRoot SP
G2B	Without gutta-percha	CHX	iRoot SP
G2C	Single cone gutta-percha	CHX	MTA Fillapex
G2D	Single cone gutta-percha	CHX	AH26
Negative control	Noninstrumented, non-filled		
Positive control	Instrumented, non-filled		

NaOCl=Sodium hypochlorite; CHX=Chlorhexidine gluconate; MTA=Mineral trioxide aggregate

Table 2: Minimum, maximum, median, and IQR values of all groups (*n*)

Groups	Minimum	Median	Maximum	IQR
Negative control	302.82	475.62	833.32	350.48
Positive control	197.32	272.81	470.78	215.51
G1A	231.28	326.70	396.75	111.04
G1B	211.13	386.00	720.39	171.06
G1C	153.53	205.54	297.62	60.13
G1D	266.46	327.58	497.88	77.17
G2A	171.35	354.66	444.09	171.44
G2B	204.93	455.63	777.88	335.64
G2C	140.13	328.07	631.15	180.8
G2D	202.54	446.14	671.86	407.6

IQR=Interquartile range

experimental groups ($P < 0.05$). The measure of ANOVA showed that there were significant differences between the groups ($P < 0.05$). Independent of final irrigation regime and obturation system when compared to the root canal sealer, iRoot SP with or without gutta-percha (group A and B) showed similar VRF resistance (uncountable) compared to AH 26 (Group D). However, VRF resistance of group A, B, and D was significantly higher than group C ($P < 0.05$). Independent of root canal sealers and obturation system, which has irrigation solution in it, the comparison, showed that the VRF resistance of group 1 were significantly lower than group 2 ($P < 0.05$). When three variables (final irrigation regime, obturation system, and sealer) were evaluated together, there was a statistically significant difference among groups ($P < 0.05$) [Figure 1]. Pairwise comparisons revealed that when NaOCl was used as a final irrigant, root canals filled with iRoot SP and AH 26 showed higher VRF resistance then MTA-Fillapex ($P = 0.023$). The roots filled with MTA-Fillapex revealed significantly lower VRF values than the other subgroups ($P < 0.05$).

When the obturation systems were compared, G1A showed significantly higher VRF resistance than G1B ($P < 0.05$); while they showed no significant difference than the other groups ($P > 0.05$).

Regarding the final irrigation regimens, it was shown that VRF resistance of the roots irrigated with NaOCl was significantly lower than roots irrigated with CHX ($P < 0.05$) [Figure 2]. Particularly, VRF resistance of roots filled with MTA-Fillapex and SGP after NaOCl irrigation was significantly lower than all other groups ($P < 0.05$), except the positive control group.

Discussion

To simulate clinical conditions, loading forces have been applied in different directions during VRF testing in previous studies.[14,15] However, it has been reported that vertically applied forces to the long axis transmit the force uniformly.[16,17] Thus, in the present study, a steady vertical load was applied along the long axis of the root via a centrally located rounded punch.[9,18]

In the present study, it is essential to standardize the experimental teeth and equilibrate them with respect to shape and dimensions. However, this is not a simple task, and the potential differences among the groups may be considered a limitation of this study. All other variables were standardized, apart from the filling materials and final irrigations. Decoronization prior to experimentation created a situation that is certainly not clinically relevant and might have weakened the teeth. Thus, it has to be taken into account that the results obtained do not reflect the clinical situation directly, but can provide a relative comparison among the different endodontic materials.

It is claimed by the manufacturer that the recently introduced bioceramic-based sealer iRoot SP performs successfully as a root canal filling material with or without gutta-percha points. Recent studies have revealed that iRoot SP has similar bond strengths[19,20] and apical sealing ability[21] to resin-based sealers. In the present study, iRoot SP with or without gutta-percha showed similar VRF resistance compared with AH 26. Zirconium oxide, one of the contents of iRoot SP, has high fracture toughness and tensile strength, and low Young's modulus.[22] Further, calcium silicate in iRoot SP prevents shrinkage during setting.[21] These properties may contribute to the higher VRF resistance observed in the iRoot SP groups. The chemical bonding of the sealer and dentin via hydroxyapatite production during the setting phase functions to create a monoblock system that aims to enhance VRF resistance.[23] Using iRoot SP alone creates a primary monoblock system, while iRoot SP with SGP creates a secondary monoblock system.[23] The use of iRoot SP with conventional gutta-percha resulted in lower VRF values.[24] However, in the present study, iRoot SP with SGP showed higher VRF resistance values than without SGP, although there was no significant difference between these groups.

Mineral trioxide aggregate-Fillapex has been introduced to utilize the advantages of MTA as a permanent root canal sealer (MTA). MTA is a well-known material that bonds to dentin[25] chemically, and this chemical bonding is necessary to reinforce the residual tooth structure to prevent VRF.[18,26] Previous studies have indicated that MTA-Fillapex showed lower bond strengths than AH Plus and iRoot SP.[20,27] This finding may be related to the lower VRF resistance of MTA-Fillapex than iRoot SP and AH26 observed in the present study. Similarly, Tanalp *et al.*,[28] have reported that immature teeth filled with MTA-Fillapex and lateral condensation of gutta-percha yielded the lowest VRF values. Although these sealers have similar properties such as calcium silicate content and hydroxyapatite production during setting phase, the use of MTA-Fillapex yielded significantly low VRF resistance compared with iRoot SP alone, but similar VRF results compared with iRoot SP with SGP.

Irrigation with different solutions such as NaOCl, EDTA, and CHX, is essential for chemomechanical debridement of the root canal system, although they can reduce the VRF resistance by altering the physical properties of root canal dentin, such as reduced flexural strength, elastic modulus, and microhardness.[29] In addition, it has been shown that NaOCl decreases the bond strengths of root canal sealers to root canal dentin,[30,31] particularly, when it is used as the final flush.[32] CHX is used as an endodontic irrigant because of its wide range of antimicrobial activity and substantivity.[33] In the current study, final irrigation with NaOCl reduced VRF resistance more than CHX did. This may be due to the negative effects of NaOCl on bond strengths between resin-based root canal filling materials and the positive effect of CHX on resin–dentin bond stability.[33] The effects of irrigation solutions on MTA-Fillapex and iRoot SP require further investigation.

Conclusion

Final irrigation with NaOCl reduced VRF resistance of root canals filled with MTA-Fillapex compared to CHX. However, the ones filled with AH26 and iRoot SP were not affected by the final irrigation regimens. Further, using iRoot SP with or without SGP did not alter the VRF resistance.

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