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Research Article

Evaluation of the Effect of Different Root Canal Obturation Materials on the Fracture Resistance of Endodontically Treated Roots

Yaman Y[1]* and Gulsahi K[2]
[1]Private Practice, Turkey
[2]Department of Endodontics, Faculty of Dentistry, Baskent University, Turkey
***Corresponding author:** Yaman Y, Private Practice, Ankara, Turkey

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Abstract

Objectives: The purpose of this study was to compare fracture resistance of endodontically treated teeth using different root canal filling sealers and techniques.

Materials and Methods: One hundred and twenty mandibular premolar teeth were selected and decoronated, then randomly divided into 8 groups (n=15). Except one group (negaive control), samples in the other groups were instrumented using Protaper nickel-titanium (Ni-Ti) rotary system. One group was saved as positive control and then remainingsix exprimental groups were filled as follows: Group 1: AH Plus / matched-taper single-cone technique (MSCT), Group 2: AH Plus / coated carrier system (Thermafil), Group 3: iRoot SP / MSCT, Group 4: iRoot SP / Thermafil, Group 5: MetaSEAL / MSCT and Group 6: MetaSEAL / Thermafil. All specimens were stored at 37°C and 100% humidity for 2 weeks. Vertical loading was carried out using a universal testing machine. For each root, the force at the time of fracture was recorded in Newtons (N). The statistical analysis was performed by using Kruskal-Wallis and multiple comparison tests.

Results: The highest and lowest fracture values were observed in negative and positive control groups, respectively. The highest and lowest fracture values of experimental groups were observed in iRoot SP / Thermafil and AH Plus / MSCT groups, respectively. There were no significant differences among the negative and Thermafil Obturator groups.

Conclusion: Within the limitations of this study, using of coated carrier obturation system conjunction with a calcium silicate-based sealer increased the fracture resistance of instrumented roots.

Keywords: MetaSEAL; iRoot SP; Coated carrier obturation system; Matched-taper single-cone technique; Fracture resistance

Introduction

Endodontically treated teeth are more porne to fracture than vital teeth. There are a few reasons such as; caries, trauma, access cavity and excessive biomechanical preparation results in a decrease of tooth structure, using of irrigants results in dentin dehydration, excessive pressure during root canal obturation [1]. It is thought that the risk of fracture is reduced by the adhesion and mechanical interlocking between the filling materials and the root canal dentin [2]. The most frequently used root canal filling material is gutta-percha incombination with sealer [3], but the low elastic modulus of gutta-percha presents little or no capacity to reinforce roots after treatment [4]. The ability of sealer to bond to radicular dentin is advantageous in maintaining the integrity of the sealer dentin interface during mechanical stresses [5]. New root obturation materials have been developed in an attempt to provide all of the favorable properties.

The use of techniques utilizing thermoplasticized gutta-percha has gained popularity over time. Thermafil Obturator is one of the coated carrier systems. The system includes a plastic central carrier coated with a layer of α-phase gutta-percha, which is softened by heating until a specific temperature before insertion into the prepared root canal [3,6,7].

Recently, commonly using of Ni-Ti rotary instruments and the advent of cones that closely match to instrument and hence the root canal space, Matched-Taper Single-Cone Obturation Technique (MSCT) has become popular [8].

MetaSEAL (Parkell Inc, Edgewood, NY, USA) is the first commercially available fourth generation methacrylate resin–based, self adhesive dual-cured sealer. MetaSEAL is also marketed as Hybrid Bond SEAL (Sun Medical Co Ltd, Shiga, Japan) in Japan and as Hybrid Root Seal (J. Morita Europe, GmbH, Dietzenbach, Germany) in Europe. The inclusion of an acidic resin monomer, 4-methacryloyloxyethyl trimellitate anhydride (4-META), makes the sealer self-etching, hydrophilic, and promotes monomer diffusion into the underlying intact dentin to produce a hybrid layer after polymerization. The sealer purportedly bonds to thermoplastic root filling materials as well as radicular dentin via the creation of hybrid

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Table 1: Composition of obturation material used in this study.

Obturation material	Composition
AH Plus	Epoxide paste: Diepoxide, Calcium tungstate, Zirconium oxide, Aerosil, Pigment Amine paste: 1-adamantane amine, N,N'-dibenzyl-5-oxa-nonandiamine-1,9, TCD-Diamine, Calcium tungstate, Zirconium oxide, Aerosil, Silicone oil
MetaSEAL	Powder: Zirconia oxide filler, silicon dioxide filler and polymerization initiators Liquid: 4-META (4-methacryloxyethyl trimellitate anhydride), mono-functional methacrylate monomers and photo-initators
iRoot SP	Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents
Gutta-percha (single cone)	Gutta-percha polymer, Zinc oxide, Heavy metal salts, Wax or resin
Thermafil Obturator	Alpha-phase gutta-percha, Plastic carrier

Table 2: Mean ± standard deviation, 95% confidence interval, median, maximum and minimum values of fracture strength for each group (in Newtons).

Groups	N	Mean ± SD	95% CI		Median	Max	Min
			Lower Bound	Upper Bound			
1 (AH Plus/MSCT)	15	354.94 ± 56.93	323.41	384.47	380.07	449.2	275.83
2 (AH Plus/Thermafil)	15	410.84 ± 70.38	371.86	449.81	404.68	574.43	290.66
3 (iRoot SP/MSCT)	15	436.07 ± 50.00	408.37	463.76	442.71	508.24	351.01
4 (iRoot SP/Thermafil)	15	461.34 ± 80.41	416.81	505.87	443.89	656.16	386.07
5 (MetaSEAL/MSCT)	15	394.19 ± 65.03	358.17	430.21	396.06	509.38	324.39
6 (MetaSEAL/Thermafil)	15	455.99 ± 98.41	401.49	510.49	453.19	684	325.52
Negative control	15	529.25 ± 114.8	465.65	592.85	527.1	739.79	309.22
Positive control	15	335.22 ± 53.30	305.7	364.73	314.25	434.22	259.9

SD: Standard Deviation; CI: Confidence Interval; Max: Maximum; Min: Minimum;MSCT: Matched-Taper Single-Cone Technique

layers in both substrates [8,9].

A bioceramic root canal sealer, iRoot SP (Innovative BioCeramix, Vancouver, Canada; also known as EndoSequence BC sealer, Brasseler USA, Savannah, Georgia) has been marked. iRoot SP is composed of zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler and thickening agents. The manufacturer indicates that it is premixed, injectable, radiopaque, insoluble, hydrophilic (using of moisture in dentinal tubules to initiate and complete its setting reaction) and aluminum-free material [1,10].

The aim of this study was to evaluate and compare the effect of different root canal obturation sealers and techniques on the fracture resistance of endodontically treated roots.

Materials and Methods

Tooth selection, preparation and obturation

This study was approved by Baskent University Institutional Review Board (project no: D-DA15/03). One hundred-twenty extracted human mandibular premolar teeth with similar dimensions at the Cemento-Enamel Junction (CEJ) were selected; buccolingual and mesiodistal dimensions of the roots were measured using a digital caliper. Preoperative radiographs were taken in the mesiodistal and buccolingual directions to confirm the presence of a single canal without previous root canal treatment, resorptions, or calcifications. The teeth were carefully examined under an operating microscope (Zeiss, Oberkochen, Germany) with x 20 magnifications. Teeth with immature apices, had root fractures or cracks were excluded from the study. Crowns of the selected teeth were removed at the CEJ and root lengths were standardized to 13 mm. Working length was determined 0.5 mm shorter than actual root canal length. The roots randomly divided into eight groups (n=15). All the root canals in groups, except those in negative control group (n=15, unprepared and unfilled), were instrumented using Protaper Ni-Ti rotary system up to master apical size file of F3 (DentsplyMaillefer, Ballaigues, Switzerland). Irrigation was performed with 2,5 mL 5% NaOCl after each instrument. For removal of smear layer, all samples irrigated with 2 mL 5% NaOCl for 1 min and 2 mL 15% EDTA for 1 min. Final rinse was performed using 10 mL distilled water and then roots dried with paper points. One group was saved as positive control (unfilled, n=15) and then remainingsix experimental groups (n=15/each) were filled as follows:

Group 1 (AH Plus / MSCT): Each canal was fitted with a single gutta-percha cone (size F3, DentsplyMaillefer). AH Plus sealer was mixed according to the manufacturer's instructions and inserted into the empty canal space using a paper point. An F3 cone was then coated with the sealer and gently inserted into the canal until the working length was reached. Excess cone was removed with a warm excavator.

Group 2 (AH Plus / Thermafil): Each canal was fitted with a Thermafil Obturator (size F3, DentsplyMaillefer). AH Plus sealer was inserted into the canal in the same manner as group 1. A Thermafil Obturator size F3 was heated in a Thermaprep oven (Dentsply, Maillefer, Ballaigues, Switzerland) according to the manufacturer's recommendations. The F3 Obturator was slowly inserted into the canal to the working length with firm pressure. Excess coronal gutta-percha and the plastic handle were removed with a round bur (Thermocut, DentsplyMaillefer).

Group 3 (iRoot SP / MSCT): iRoot SP was injected through the intracanal tip to fill the coronal part of the canal. Filling procedure of canal with F3 cone was performed in the same manner as group 1.

Group 4 (iRoot SP / Thermafil): iRoot SP was injected through the intracanal tip to fill the coronal part of the canal. Filling procedure of canal with F3 Obturator was performed in the same manner as group 2.

Group 5 (MetaSEAL / MSCT): MetaSEAL was mixed according to the manufacturer's instructions. Filling procedure of canal with F3 cone was performed in the same manner as group 1.

Group 6 (MetaSEAL / Thermafil): MetaSEAL was mixed according to the manufacturer's instructions. Filling procedure of canal with F3 Obturator was performed in the same manner as group 2.

Instrumentation and obturation were done by one operator. The quality of the fillings was confirmed with radiographs. Canals that had not been adequately filled or specimens with cracks were dismissed and replaced by a new sample. The coronal accesses of specimens were filled with a temporary filling material (Cavit-G; 3M ESPE, Seefeld, Germany). All teeth were stored at 37°C and 100% humidity for 2 weeks to allow the sealers to set completely. Table 1 shows composition of obturation materials used in this study.

Preparation for fracture resistance test

To simulate the periodontal ligament, 5 mm of the apical root end was coated with a thin layer (approximately 0.2 to 0.3 mm) of wax, and then was vertically embedded into an acrylic tube (12-mm height, 12-mm diameter) with an autopolymerisable acrylic resin (Meliodent, HeraeusKulzer Mitsui Chemicals Inc, Germany), leaving 8 mm of each root exposed. The roots were positioned at the centre of the acrylic tube. As soon as polymerization of the acrylic resin started, the roots were removed from the resin and the wax was cleaned from the root surfaces by using a curette, leaving a space between the root and the epoxy resin. An addition-cured silicone rubber (Speedex, Coltene/WhaledentInc, Cuyahoga Falls, OH) was coated on the surface of the roots and then they were again embedded into acrylic resin blocks [11-13]. After polymerization, the specimens were mounted on the lower plate of the universal testing machine (Lloyd LRX; Lloyd Instruments Ltd, Fareham, UK). The upper plate of the machine housed a round tip of 1.7 mm diameter which centered over the canal orifice, and then, a compressive loading was applied to the roots (1,0 mm/min^{-1}) until the fracture occurred. The load at which fracture occurred was recorded in Newtons (N). All statistical analyses were performed using the SPSS software package (version 15.0; SPSS, Chicago, IL). The data were first verified with the Kolmogorov-Smirnov test for normal distribution and then subjected to Kruskal-Wallis and multiple comparison tests to determine the differences between the groups. A P value below. 05 was considered to be significant.

Results

Table 2 presents the mean values ± standard deviations, 95% confidence interval, median, maximum and minimum of the force required to fracture the roots. While the negative control group revealed the strongest fracture resistance (529.25 N), the weakest force required to fracture the roots was seen in the positive control group (335.22 N). The mean values of experimental groups were 354.94 N, 410.84 N, 436.07 N, 461.34 N, 394.19 N and 455.99 N for group 1, 2, 3, 4, 5 and 6 respectively. Among the experimental groups, the highest fracture resistance was seen ingroup 4 (iRoot SP / Thermafil), whereas the group 1 (AH Plus / MSCT) revealed the lowest value. There was statistically significant difference in fracture resistance between positive control group with negative control, 3 (iRoot SP / MSCT), 4 (iRoot SP / Thermafil) and 6 (MetaSEAL / Thermafil) groups (P< 0.05). On the other hand, while there were no significant differences in fracture resistance between group 2 (AH Plus / Thermafil), 3 (iRoot SP / MSCT), 4 (iRoot SP / Thermafil), 6 (MetaSEAL / Thermafil) and negative control group (P>0.05); group 1 (AH Plus / MSCT) and group 5 (MetaSEAL / MSCT) showed the lower mean values for fracture than the negative control group (P< 0.05). There was no statistically significant difference in fracture resistance between AH Plus / MSCT, MetaSEAL / MSCT and iRoot SP / MSCT groups (P>0.05).

Discussion

Vertical root fracture is one of the most serious complications of root canal therapy that can occur before, during, or after root canal obturation [14]. The reasons for the fracture can be attributed to; biomechanical preparation of the root canal system removes significant amount of tooth structure, using of irrigants results in dentin dehydration and the use of unnecessary force during obturation [15,16]. In order to standardize, roots with similar size, length and dimensions were used in the study. Preparation of root canal with rotary systems (Protaper Ni-Ti rotary system, up to master apical size file of F3, was used in this study) results in a more rounded cross-sectional form that has a positive effect on stresses and forcedistribution within the root canal during filling [17]. Many studies reported that smear layer decrease the adaptation, penetration and bond strength of root canal sealers. After the removal of smear layer, there was an alteration in the surface energy allowing the root canal sealer to flow and adapt more easily, enhancing its adhesion to the root canal walls by penetrating into the dentinal tubules, and thereby increased sealing efficiency and strength of the roots [2,18-22]. In this study, removal of smear layer was performed by using NaOCl / EDTA combination, and then, distilled water was used as final rinse to neutralize the effects of irrigations [7,12].

The lateral condensation technique, in particular, has been blamed as a major cause of vertical root fracture. Therefore, in the present study, a matched-taper single-cone filling technique was used because it excluded both the excessive dentin removal required to facilitate the plugger's insertion during vertical compaction and the wedging forces of the spreaders during lateral compaction. For the Thermafil technique, only minimal condensation is recommended, and the condensation is limited to the coronal aspect. This aspect, plus the ease of inserion of the carrier with heat-softened gutta-percha, was responsible for the lower load application observed during condensation [17,23,24]. According to the results of this *in vitro* study (Table 2), positive control group showed the least fracture resistance (335.22 ± 53.30 N), whereas negative control group showed the highest resistance to fracture (529.25 ± 114.84 N). This is in accordance with many previous studies and can be explained preparation of root canals weakened the roots as the amount of remaining dentin thickness was reduced [1,10,17].

In the current study, there was no significant difference among AH Plus / Thermafil, iRoot SP / MSCT, iRoot SP / Thermafil, MetaSEAL / Thermafiland negative control groups (P>0.05). This study showed that, Thermafil system increased fracture resistance of root. This reason may be attributed to the softened gutta-percha is well adapted to the irregularities of dentin wall, and the plastic carrier within the Thermafil cone can be affect the force applied to root and also may be additional support to the root dentin. This is in concurrence with the results of previous studies [7,25]. The results of the present study demonstrated that there was no significant differences between iRoot SP / MSCT and iRoot SP / Thermafil groups (P>0.05) and these combinations had comparable fracture resistance with an intact tooth (negative control, P>0.05) and are able to increase resistance to fracture. This result agreed with the findings of previous studies, [1,10] and it could be related to the properties of iRoot SP sealer. This sealer is based on a calcium silicate composition, which does not shrink during setting and hardens in presence of water. The sealer absorbs water from dentinal tubules and then the setting reaction is initiated and it produces a composite of calcium silicate hydrogel and hydroxyapatite. Both of the compounds will form strong chemical and micromechanical bonding with the dentin hydroxyapatite. Chemical bonding, deep penetration of the sealer into canal irregularities and dentinal tubules enhances the fracture resistance of teeth [10,26,27]. In the present study, although statistically insignificant differences existed in terms of fracture resistance among AH Plus / MSCT, MetaSEAL / MSCT and iRoot SP / MSCT groups, only two groups (AH Plus / MSCT and MetaSEAL / MSCT) showed significantly lower mean values for fracture than negative control group (P< 0.05). At the same time, among these experimental groups (AH Plus / MSCT, MetaSEAL / MSCT and iRoot SP / MSCT), only iRoot SP / MSCT group revealed statistically higher mean values for fracture than positive control group (P< 0.05). This result might depend on features of iRoot SP (chemical bonding to root canal dentin wall, deep penetration into dentinal tubules as a result of the sealer's nanoparticles). In a study, it was shown that the fracture resistance of root filled with AH Plus / MSCT and MetaSEAL / MSCT was higher than prepared but unfilled control group [8]. In contrast, in this study, there was no statistically significant differences were found among AH Plus / MSCT, MetaSEAL / MSCT and positive control groups. This difference could be attributed to the study design (for example; coating of samples with silicone rubber, using of steel spherical tip with 1.7 mm diameter).

Conclusion

Under the limitations of this *in vitro* study, it may be concluded that the use of coated carrier obturation system (Thermafil) conjunction with a bioceramic sealer (iRoot SP) could be increased the fracture resistance of endodontically treated teeth. However, long-term clinical trials are required to support the confident use of these materials.

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