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THE EFFECT OF FILES TAPER AND ROOT CANAL SEALER MATERIALS ON FRACTURE RESISTANCE OF THE ROOTS (IN VITRO STUDY)

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ABSTRACT

Aim of the study was to investigate the effect of taper and sealer materials on the fracture resistance (FR) of roots.

Material and method: Total number of 120 single-canalled human mandibular central and lateral teeth with equal size were chosen and kept in distilled water until needed, all teeth were decoronated and divided into one positive control group (n=12) and three experimental groups (n=36) according to the degree of taper used for root canal instrumentation using K3XF** files system (#25/4%, #25/6% and #25/8%), each experimental group was further subdivided into one negative control subgroup (n=12) in which the root canal instrumented but not obturated and two experimental subgroups (n=12) according to type of root canal sealer used for obturation (AH Plus*** and MTA Fillapex****). Each specimen was embedded in acrylic mould and subjected to FR test using a universal testing machine. The force required to fracture each specimen was recorded and the data obtained were statistically analysed.

Results: Group 1 showed highest FR among all experimental groups followed by group 2 with non-significance difference between both groups while group 3 (#25/8%) showed the least FR. MTA Fillapex subgroup showed less non-significantly difference from AH Plus subgroup regardless the degree of taper used for preparation.

Conclusion: Using 4% and 6% taper preparation have non-significant difference from each other when using AH plus or MTA Fillapex sealer. MTA Fillapex did not significantly improve the FR of the root regardless the preparation taper used.

Keywords: AH plus, MTA Fillapex, taper, fracture resistance

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INTRODUCTION

Tooth fracture is one of the major problems in dentistry since it is one of the important reasons for tooth extraction[1,2]. The main cause of tooth fracture is the loss of tooth structure. Teeth, which need root canal treatment, have generally loss of tooth structure due to caries. In addition, tooth structure is removed during root canal treatment procedures such as access cavity preparation, root canal instrumentation and irrigation. Therefore, this makes endodontic treatment an aetiological factor for tooth fracture[3,4]. Root canal shaping procedures mainly depending on the taper of the files system, increasing root canal taper make more space for the irrigation fluids making cleaning process more efficient[5] and facilitate root canal obturation, at the same time larger taper leads to cutting a larger amount of dentin from the canal walls[6], that resulted in a lower FR[7]. Using larger tapers can be concerning due to the influence of increased removal of tooth structure on reduced FR[8]. Fundamentally, any removal of hard tissue from the canal walls increases the chance of root fracture[9]. On the contrary, some authors claim that increased canal preparation taper allows forces to be better distributed in the apical third of the canal; this better distribution increases the tooth's FR[10]. Minimally invasive dentistry is the application of a systematic respect of the original tissue[11], its application in endodontics could be approaches by removing pulpal tissues with conservative concerns and minimal damage during shaping process by using file taper that is strictly below 6%[12]. One of the objectives of root canal obturation is to reinforce the root canal and increase root FR[13]. The most used root canal filling material is gutta-percha in combination with sealer[14], but the low elastic modulus of gutta-percha presents little or no capacity to reinforce roots after treatment[15]. The ability of sealer to bond to radicular dentin is advantageous in maintaining the integrity of the sealer- dentin interface during mechanical stresses, thus increasing resistance to fracture[16]. This meant that retention of the filling material might be improved by mechanically locking it into place, hence reinforcing root canal dentin to increase its FR with much attention on the adhesive properties and sealing ability of epoxy resin-based root canal sealers[17]. The FR of roots is a common subject in endodontics. However, there are not many studies evaluating the effect of both taper and sealers type on the FR of roots.

MATERIAL AND METHOD

Ethical approval for this study was obtained from the ethical committee (KD/16/21) of Faculty of Dentistry, kafrelsheikh University**.** 120 intact mandibular central and lateral teeth, with one straight root and one canal, were selected for this study. The teeth were thoroughly cleaned by removing the hard deposits using sharp curettes and the soft deposits by soaking in 5.25% sodium hypochlorite solution (NaOCl) for 30 minutes. Digital radiographs were taken in buccolingual and mesiodistal directions to confirm the presence of a single root canal. Teeth with immature apices having root caries or restorations and having root fractures or cracks were excluded from the study. The teeth were decoronated to obtain a standardised root length of 12 mm. The teeth, whose apex could be reached with a size 10 K-type file* but not a size 15 K-type file, were included. The buccolingual and mesiodistal dimensions of the teeth were measured using a digital calliper, teeth with more than 20% deviation were replaced with another tooth meeting the previously mentioned criteria. Teeth were divided into one positive control groups (n=12) in which roots were neither instrumented nor filled and three experimental groups (n=36) as the following:

Group 1 (25/0.04 group) (n=36)**:** 15/0.04, 20/0.04 and 25/0.04 K3XF files were used for root canal preparation, respectively.

Group 2 (25/0.06 group) (n=36)**:** 15/0.04, 20/0.04, 25/0.04 and 25/0.06 K3XF files were used

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for root canal preparation, respectively.

Group 3 (25/0.08 group) (n=36)**:** 15/0.04, 20/0.04, 25/0.04, 25/0.06 and 25/0.08 K3XF files were used for root canal preparation, respectively.

The instruments were used with the K3XF program using an electrical endodontic motor. During instrumentation, 5.25 % NaOCl and 17% EDTA were used for root canal irrigation, finally the root canals were flushed with 3 distilled water and then dried with paper points. Each experimental group was further subdivided into three subgroups (n=12) as the following:

Subgroup A (Negative control subgroup): root canals were left empty without obturation,

Subgroup B (AH Plus subgroup): root canals were obturated with AH plus/Gutta-percha point using lateral compaction techniques,

Subgroup C (MTA Fillapex subgroup): root canals were obturated with MTA Fillapex/Gutta-percha point using lateral compaction techniques.

The teeth were wrapped with very thin layer of wax and mounted vertically in standardised cylindrical autopolymerising acrylic resin, after the curing of the acrylic resin, the teeth and wax were removed, and any remaining wax were washed out. A light-body silicone* were placed into the teeth cavity to simulate periodontal ligament, and the teeth were reinserted. A cone-shaped rod with a diameter of 3.5 mm was mounted on a universal test machine** directly over the specimens. A load in a vertical direction at 1 mm/min speed were applied until a fracture occurred. The applied force was recorded (in Newtons).

All statistical analysis were performed using SPSS*** version 26. The statistical significance level was set at 5%. The results were subjected to statistical analysis using two-way ANOVA and post hoc tests to determine differences between the groups.

RESULTS

Results were summarized in Table (1) and Figure (1).

TABLE (1): The means, standard deviation (SD) values and results of ANOVA test for the comparison between fracture resistance between groups.

Groups	Subgroup \ Experimental Gp	Experimental Groups: Group 1: #25/4%	Group 2: #25/6%	Group 3: #25/8%	positive Control Group	p-Value
Experimental Subgroups	Subgroup A: (Negative control subgroup)	409.5 ± 74.5 $^{c\,B}$	376.4 ± 99.7 $^{c\,B}$	213 ± 68.6 $^{c\,C}$	664.5 ± 96 ^{A}	0.0001*
	Subgroup B: (AH Plus subgroup)	580.6 ± 75 $^{bd\,AB}$	565.8 ± 90.3 $^{b\,B}$	372.7 ± 88.2 $^{b\,C}$	664.5 ± 96 ^{A}	0.0001*
	Subgroup C: (MTA Fillapex subgroup)	502.3 ± 69.7 $^{b\,B}$	489.1 ± 77.9 $^{b\,B}$	326.1 ± 82.7 $^{b\,C}$	664.5 ± 96 ^{A}	0.0001*
Positive Control Group		664.5 ± 96 ^{ad}	664.5 ± 96 ^{a}	664.5 ± 96 ^{a}	664.5 ± 96	
p-Value		0.0001*	0.0001*	0.0001*		

**** Significant at P≤0.05. Different small letters indicate a significant difference between positive control group and subgroups within the same experimental group, different capital letters indicate a significant difference between positive control group and experimental groups within the same subgroup.***

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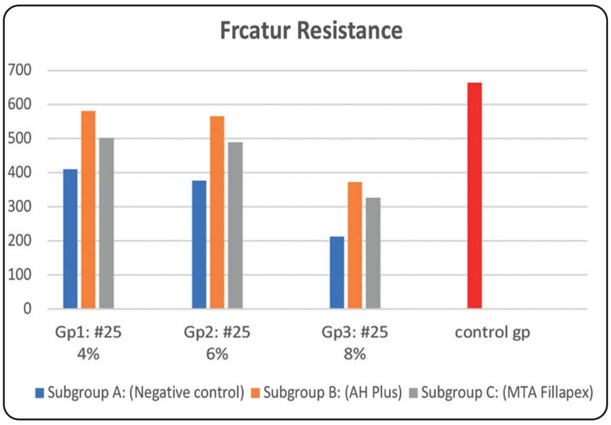
** Instron, Canton, MA, USA.

*** IBM SPSS Inc, Chicago, IL, USA.



GRAPH (1): Mean fracture resistance and standard deviations for all groups.

Effect of taper:

The highest FR was recorded for control group (664.5 ± 96), for experimental groups the highest FR was recorded for group 1 (#25/4%) and the lowest FR was recorded for group 3 (#25/8%).

Subgroup A (Negative control subgroup): the experimental groups showed that the highest FR results was recorded when the root canals were instrumented with 4% taper (409.5 ± 74.5), while the lowest result was recorded when the root canals were instrumented with 8% taper (213 ± 68.6). Statistically, there was significant difference among all tested experimental and control groups ($p<0.05$), post hoc Tukey–Kramer test was performed and showed that there was statistically significance difference between all pairs of groups except between group 1 and group 2.

Subgroup B (AH Plus subgroup): the FR for experimental groups were ranked descendingly as 580.6 ± 75, 565.8 ± 90.3 and 372.7 ± 88.2 for group 1, group 2 and group 3 respectively with a statistical significance difference among all tested experimental and control groups ($p<0.001$), post hoc Tukey–Kramer test was performed and showed that there was statistically significance difference between all pairs of groups except between control group and group 1, and between group 1 and group 2.

Subgroup C (MTA Fillapex subgroup): the experimental groups showed that; the group 1 revealed higher FR than group 2 (502.3 ± 69.7, 489.1 ± 77.9 respectively), the lowest FR was recorded for group 3 (326.1 ± 82.7). Statistically, there was significant difference among all tested experimental and control groups ($p<0.05$), post hoc Tukey–Kramer test was performed and showed that there was statistically significance difference between all pairs of groups except between group 1 and group 2.

Effect of root canal sealer

The highest FR was recorded for control group (664.5 ± 96), while for the experimental subgroups the highest FR was recorded for subgroup B (AH Plus) and the lowest FR was recorded for subgroup A (Negative control subgroup).

Group 1 (#25/4%): The FR was ranked descendingly as 580.6 ± 75, 502.3 ± 69.7 and 409.5 ± 74.5 for subgroup B, C and A respectively. Statistical analysis showed that there was statistically significance difference among all tested subgroups and positive control group ($p<0.05$), post hoc Tukey–Kramer test was performed and showed that there was no statistical significance between control group and subgroup B (AH Plus), and between subgroup B (AH Plus) and subgroup C (MTA Fillapex).

Group 2 (#25/6%): The subgroup B showed higher FR than subgroup C (565.8 ± 90.3, 489.1 ± 77.9 respectively), the lowest FR was recorded for subgroup A (376.4 ± 99.7). Statistically, there was significant difference among all tested subgroups and control group ($p<0.05$), post hoc Tukey–Kramer test was performed and showed that there was only non-significant difference between subgroup B (AH Plus) and subgroup C (MTA Fillapex).

Group 3 (#25/8%): The highest FR was recorded for subgroup B (372.7 ± 88.2), while the lowest FR was recorded for subgroup A (213 ± 68.6) with a statistical significance difference among all tested subgroups and control group, the post hoc Tukey–Kramer test showed the same results obtained for group 2.

DISCUSSION

The main reason for the fracture of endodontically treated teeth is loss of hard tissue due to caries or endodontic procedures such as access cavity preparation and root canal preparation(18,19), Most of the new systems incorporate instruments with a taper greater than the ISO standard 0.02 design; indeed rotary nickel-titanium instruments are available with tapers ranging from 0.04 to 0.12(20), vertical root fracture (VRF) is considered one of the most causes of tooth extraction after endodontic treatment of the tooth, it may be due to loss of hard tissue caused by shaping process during biomechanical preparation(21). K3XF file provides clinicians with the basic features of the original K3 plus an extraordinary new level of flexibility and resistance to cyclic fatigue with the proprietary R-phase technology, it undergo post-machining heat treatment(22). The manufacturer claims that K3XF has a third radial land and variable pitch, superior flexibility, and resistance to fatigue, it is available with different taper (4%, 6%, 8% and 10%). In this study all roots were prepared to K3XF size 25 to standardize the apical canal diameter of the enlarged root canals while using different taper (4%, 6% and 8%). A standard irrigation regimen using NaOCl and EDTA were used to remove the smear layer, to increase bonding of the sealers to the root dentin(23).

One of the goals of root canal filling is to reinforce the root to enhance the fracture resistance, thus using a root canal sealer that can strengthen the root would be beneficial(13), the standard filling material is gutta percha. To obtain a hermetic seal, gutta percha is generally used in conjunction with root canal sealers as gutta percha is incapable of bonding to root canal walls. Root canal sealers not only fill the voids between gutta percha points, but they also fill the voids between gutta percha and root canal walls(24). Bondable root canal sealers as (AH plus and MTA Fillapex) purportedly improve the seal and FR of endodontically treated roots(25).

In many studies, AH plus epoxy resin-based sealers showed higher adhesion to root canal dentin and deeper penetration into the dentinal tubules than glass ionomer and ZnOE-based sealers(26,27). This meant that retention of the filling material might be improved by mechanically locking it into place, hence reinforcing root canal dentin to increase its fracture resistance. With much attention on the adhesive properties and sealing ability of epoxy resin-based root canal sealers, a recently introduced root canal sealer is MTA Fillapex. Based on an MTA (mineral trioxide aggregate) composition, other ingredients of MTA Fillapex include resins and silica. According to the manufacturer, it has high radiopacity, low solubility in contact with tissue fluids, low expansion during setting, and excellent viscosity for insertion. It does not stain the tooth and promotes deposition of hard tissue at the the root apex and perforation sites. That is why it was of high importance to shed a light on FR of different sealers in this study.

In the present study, 25/8% groups showed the lowest FR values that differed significantly from other groups regardless of sealer materials used, this can be explained by the greater tooth structure removal and the fact that files with greater taper are more rigid, causing more geometric modification in the root canal. In agreement with our results, a previous study has shown that during instrumentation, maintaining the natural geometry of the root canals is a paramount stabilizing factor for the tooth, and, therefore, if the root canal outline is not substantially altered, tooth FR is relatively unaffected(28). Conceivably, in our study, the decrease in FR that followed 8% taper instrumentation might have been the result of geometric alterations of the root canals because 8% taper files are more rigid and less adaptable, and this in agreement with those results obtained by Sabeti et al.[29] and Zogheib et al.[30], Root fracture occurs as a result of propagation of microcracks created in the root canal shaping process with occlusal forces. Thus, we suggest that the increased risk of fracture with the 8% taper in this study might be associated with the greater number of craze lines and the greater degree of imposed stress in root dentin. Moreover, our findings corroborated the results of a previous study that reported that preparation with larger taper instruments significantly weakened the roots. Also, Zandbiglari et al.[31] suggested that this result was probably caused by the greater amount of dentin removed with larger tapering instruments compared with common taper hand files.

In present study AH plus (subgroup B) showed higher non-significant FR than MTA Fillapex (subgroup C) with preparation taper 4%, 6% and 8%, these higher values might be attributed to the higher adhesion of AH Plus to root dentin. Sağsen et al.[17], showed that AH Plus sealer increased the FR of prepared root canals because of its creep capacity and long polymerization into the micro irregularities[32]. Besides, the covalent bonds between the epoxy resin and the amino groups of the dentinal collagen might result in a stronger bond of AH plus to dentin[33]. The results of our study came in accordance with Mandava et al.[34], who showed that teeth obturated with AH Plus had a higher FR than those with the MTA sealer; MTA Fillapex. Previous studies also showed that AH Plus/GP combination had higher bond strength to dentin than the monoblock system; Resilon/Epiphany, which might be another clue for the ability of this combination to increase FR of prepared root canals[35,36].

When using AH plus as a sealer material (subgroup B) with 4% taper preparation, it has been resulted in non-significant difference with control group and with 6% taper group, while using MTA Fillapex sealer material (subgroup C) with 4% taper preparation showing only non-significant difference with 6% taper group while it showed lower significant value than control group. This could be explained by increase amount of dentine removed with increasing the degree of taper combined with the higher bond strength of AH plus compared to MTA Fillapex[37,38], due to its low shrinkage, accompanied by the long term dimensional stability[39], and high power of penetration to dentinal tubules and micro-irregularity[32,33]. The limitation of the present study is that the teeth were decoronated to obtain standardised root length that do not represent true clinical conditions[40], also it does not take in consideration the impact of access cavity design on the FR of endodontically treated teeth[41,42], in addition to previous limitation; it has found that the coronal tooth anatomy, coronal restoration, occlusion, and parafunctional behaviours all have an indisputable influence on the FR of teeth[43,44].

CONCLUSION

Within the limits of this experimental study, it can be concluded that using 4% taper preparation with AH Plus sealer has non-significant difference from positive control group, using 4% and 6% taper preparation have non-significant difference from each other when using AH plus or MTA Fillapex sealer, in addition using MTA Fillapex did not significantly improve the FR of the root regardless the degree of taper used for preparation. Using 8% taper preparation has lower significant difference from both 4% and 6% taper preparation with both AH plus and MTA Fillapex sealer.

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