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Tanta Dental Journal 10 (2013) 97–102

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Fracture resistance of endodontically treated roots using different preparation–obturation combinations

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Abstract

Aim: To evaluate the fracture resistance of endodontically treated roots using different root canal preparation/obturation combinations including ProTaper, RaCe and hand preparation systems combined with Soft-Core/AH26, RealSeal and EndoREZ obturators.

Materials and methods: 120 recently extracted maxillary central incisors were selected. The coronal portions of all teeth were removed near the cemento-enamel junction leaving the root segment of nearly 16 ± 1 mm length. Roots were randomly divided into 3 groups ($n = 40$) according to the system used in root canal preparations, Group I: ProTaper, Group II: RaCe and Group III: Hand instrumentation. Each main group was further subdivided into 4 equal subgroups according to the obturation system being used, Subgroup A: Soft-Core/AH26 obturator, Subgroup B: RealSeal system, Subgroup C: EndoREZ system and Subgroup D: in which roots were left unobturated as control subgroup. Fracture resistance of each sample was measured by loading in universal testing machine. The force was applied at a crosshead speed of 1 mm/min until fracture occurs and this force was recorded in Newton.

Results: No significant difference among the obturation systems was recorded however a significant difference with the control subgroup (ID) prepared with ProTaper was obvious.

Keywords: ProTaper; RaCe; RealSeal; EndoREZ; Soft-core; Fracture resistance

1. Introduction

Endodontic success depends on multiple factors including canal preparation, disinfection and obturation, however root canal cleaning and shaping is the most important step for endodontic success [1]. Several automated instrumentation systems based on rotary modified nickel-titanium have been developed with various designs of taper, blades, grooves and tips [2]. The varieties in designs were suggested to allow predefined canal shapes with fewer instruments and fewer procedural steps [3] and facilitating the use of crown-down preparation technique to improve radicular access [4].

ProTaper system is a modified Ni–Ti rotary instrument with progressive taper that can shape canals more quickly than constant taper instruments [5]. On the other hand, Reamer with Alternating Cutting Edges "RaCe" has been developed with a triangular cross-sectional design except for smaller instruments

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Peer Review under the responsibility of the Faculty of Dentistry, Tanta University

Production and hosting by Elsevier

1687-8574 http://dx.doi.org/10.1016/j.tdj.2013.08.008

(15/0.02 and 20/0.02) which have square cross-sectional design. According to the manufacturer, the combination of triangular cross-section with sharp edges and alternating cutting edges eliminates screwing, enhances cutting efficiency and ensures efficient evacuation of debris [6].

Since Endodontic treatment results in reduction of fracture resistance of teeth [7]. Therefore, one of the objectives of root canal obturation is to reinforce the root canal and increase root fracture resistance. It is thought that adhesion and mechanical interlocking between the root canal filling material and radicular dentin reduces the risk of fracture and strengthens the remaining tooth structure [8].

The most commonly used root canal filling material in Endodontics is gutta-percha in combination with a root canal sealer using cold lateral condensation technique. Alternative techniques have been introduced which incorporate the use of thermal or frictional heat to plasticize the gutta-percha. One of these techniques is Soft-Core system that consists of biocompatible central plastic nonremovable carrier coated with thermoplastic alpha-phase gutta-percha which is heated before being inserted into the canal [9].

Recent introduction of an alternative root filling material offers the promise of adhesion to root canal dentine [10]. RealSeal is an alternative adhesive resin-based root canal filling material, composed of thermoplastic synthetic polymer core material that can be used in conjunction with a dual-cured resin sealer “RealSeal” [11].

Another recent root canal filling material “EndoREZ” is resin-coated gutta-percha points which bonds chemically with EndoREZ sealer and/or other resin-based sealers creating a true monoblock in the canal space [12].

Previous researches were concerned with the effect of either instrumentation or obturation on the treatment quality and few literatures dealt with multifactorial complex that investigate the interaction of these factors. Thus this research was conducted to evaluate the effect of different preparation–obturation combinations on the fracture resistance of endodontically treated roots.

2. Materials and methods

One hundred and twenty freshly extracted human maxillary central incisors were selected, each tooth was decoronated by using slow speed water-cooled diamond disc*1 to obtain 16 ± 1 mm long root segment. Stainless steel K-file**2 (#15/0.02 taper) was introduced into the root canal until its tip is just visible at the apical foramen. WL was determined visually by subtracting 1 mm from this length.

The roots were randomly divided into three equal groups ($n = 40$) according to the system used in root canal preparation. *Group I (ProTaper):* Root canals were prepared using ProTaper rotary instruments***3 in a crown down manner up to an apical size corresponding to F3 (# 30/0.09). *Group II (RaCe):* Root canal preparations were perfomed using RaCe files^{+}4, in a crown-down manner up to MAF #35, 0.08 taper according to manufacturer’s instructions. *Group III (Hand instrumentation):* Coronal flaring was performed using Gates-Glidden drills*** # 4, 3 and 2 successively. Root canal preparation was completed using stainless steel K-hand files** in a crown-down manner up to MAF #50/0.02 taper.

In all groups, each root canal was flushed with 5 ml of freshly prepared 2.5% sodium hypochlorite solution during instrumentation. The canals were then irrigated with 2 ml of 17% ethylenediamine tetraacetic acid*5 and finally rinsed with a 5 ml sterile saline solution and dried with paper points**6.

Each main group was randomly subdivided into four equal subgroups of 10 roots each according to the obturation system being used as follow:

Subgroup A: Soft-Core obturators: The selected Soft-Core obturator***7 was of the same size of MAF (#30, #35 and #50 in groups I, II, III respectively) and used in combination with AH26 sealer^{+}8 according to manufacturer instructions. *Subgroup B* (*RealSeal system):* Root canals were obturated using RealSeal points with its self-etch primer and RealSeal sealer^{++}9 according to manufacturer instructions using lateral condensation technique (LCT). *Subgroup C (EndoREZ system):* The canals were filled using EndoREZ points in combination with EndoREZ sealer^{+++}10 according to manufacturer instructions using LCT. *Subgroup D (Control):* The remaining 10 roots in each main group were left unobturated and represent the control specimens.

2.1. Sample preparation

The middle third of each root was coated with uniform thickness of light body rubber base$^{\#}$11 to provide a simulated periodontal ligament then each root was embedded in acrylic resin cylinder using self-cured acrylic resin##12 except for the coronal 4 mm.

2.2. Fracture resistance test

A specially designed jig was constructed to align the root specimens at an angle of 45° to the horizontal

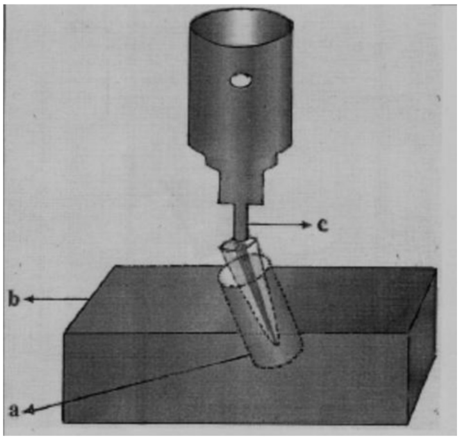

Fig. 1. Diagram of Universal testing machine: (a) Receptacle containing acrylic resin block (b) horizontal metal plate (c) Loading rod.

plane and attached securely to the lower member of universal Testing Machine*13 Fig. 1. Load was applied with a specially designed loading steel rod with round end 3.4 mm diameter. This rod was attached to the loading cell of the upper member of the testing machine which was lowered to allow it to contact the entire circumference of the root so the applied force was equally distributed in all directions. The maximum force required to fracture each specimen was recorded in Newtons (N).

3. Results

Mean and standard deviation values (mean ± SD) of forces required for fracturing the roots of the tested groups and subgroups are expressed in Newtons and presented in Table 1. Statistical analysis was performed using two way analysis of variance (two-way ANOVA) to determine significance differences among groups and subgroups, then multiple pairwise comparisons were performed using Tukey test to determine which mean value differed from one another with significance level of $P < 0.05$.

Regarding root canal preparation using ProTaper system (group I), the mean fracture resistance values for different subgroups were arranged from the highest to the lowest as 1397.86 ± 139.29, 1370.57 ± 72.97, 1228.86 ± 246.93 and 925 ± 238.52 N for RealSeal (IB), Soft-Core/AH26 (IA), EndoREZ (IC) and control (ID) subgroups respectively. Two-way ANOVA revealed a statistical significant difference among tested subgroups ($P = 0.002$).

Tukey pairwise comparisons revealed no statistical significant differences between RealSeal and Soft-Core/AH26, Soft-Core/AH26 and EndoREZ, RealSeal and EndoREZ and between EndoREZ and control (*P*-values = 0.994, 0.536, 0.387 and 0.063 respectively). However, there were statistical significant differences between Soft-Core/AH26 and control and between RealSeal and control ($P = 0.004$ and 0.002 respectively).

On the other hand, after root canal preparation using RaCe system (group II), the highest mean fracture resistance value (1374.86 ± 357.64 N) was associated with Soft-Core/AH26 obturation (subgroup A) while the lowest value was for control subgroup (985.40 ± 186.29 N), however there was no statistical significant difference ($P = 0.078$) among all tested subgroups.

In hand instrumentation (group III), similar findings were recorded, the highest mean fracture resistance value was recorded for subgroups A (1367.43 ± 234.50 N), followed by subgroup C (1354.71 ± 253.17 N) and subgroup B (1282.43 ± 432.03 N) while the lowest value

Table 1
Means and standard deviations of forces required to fracture the roots of the tested groups and subgroups and comparison of the tested subgroups regardless of root canal preparation technique.

Obturation system	Preparation technique					
	ProTaper (Group I)	RaCe (GroupII)	Hand instrumentation (Group III)	(*P*-value)	Comparison of the tested subgroups regardless of root canal preparation technique	(*P*-value)
Soft-Core/AH26 (Subgroup A)	1370.57[a] ± 72.97	1374.86[a] ± 357.64	1367.43[a] ± 234.50	0.998	Soft-Core/AH26 vs. RealSeal	0.079
RealSeal (Subgroup B)	1397.86[a] ± 139.29	1209.71[a] ± 108.12	1282.43[a] ± 432.03	0.437	Soft-Core/AH26 vs. EndoREZ	0.660
EndoREZ (Subgroup C)	1228.86[a,b] ± 246.93	1254.71[a] ± 222.33	1354.71[a] ± 253.17	0.597	RealSeal vs. EndoREZ	0.996
Control (Subgroup D)	925[b] ± 238.52	985.40[a] ± 186.29	1120.6[a] ± 334.03	0.533	Soft-Core/AH26 vs. control	0.001*
(*P*-value)	0.002*	0.078	0.567		RealSeal vs. control	0.009*
					EndoREZ vs. control	0.015*

Mean values that have different superscripts within the same group were significantly different at the 5% level of significance (Two-way ANOVA, Tukey pairwise comparison).
*Significant result.

was for subgroup D (1120.6 ± 334.03 N). There was no statistical significant difference among the tested obturation systems and control subgroup recording *P*-value of 0.567.

The effect of tested root canal preparation techniques on fracture resistance of endodontically treated roots was evaluated for each root canal obturation system.

Regarding root canal obturation using Soft-Core/AH26 (subgroup A), the mean fracture resistance values were arranged from the lowest to the highest as 1367.43 ± 234.50, 1370.57 ± 72.97and 1374.86 ± 357.64 N for groups III, I and II (hand, ProTaper, RaCe) respectively.

Concerning subgroup B where root canals were obturated using RealSeal system, the highest mean fracture resistance value (1397.86 ± 139.29 N) was recorded for ProTaper (group I) while the lowest value (1209.71 ± 108.12 N) for RaCe (group II).

On the other hand, for root canals obturated with EndoREZ system (subgroup C), the lowest mean fracture resistance value (1228.86 ± 246.92 N) was recorded for group I (ProTaper system), while the highest value (1354.71 ± 253.71 N) was for group III (hand instrumentation).

Regarding control subgroup, the lowest mean fracture resistance value (925 ± 283.52 N) was recorded with ProTaper (group I) while the highest value (1120.6 ± 334.03 N) was for hand instrumentation (group III).

Using two-way ANOVA, no statistical significant differences were recorded for all tested subgroups recording *P* values of 0.998, 0.437, 0.597and 0.533 for subgroups A, B, C and D respectively.

It seemed necessary to compare the mean values of fracture resistance among the tested root canal obturation systems and control subgroups regardless of the root canal preparation technique used (Table 1). The highest mean value of fracture resistance was recorded for Soft-Core/AH26 (1370.95 ± 237.65 N) followed by RealSeal (1296.67 ± 267.62 N) and EndoREZ (1279.43 ± 235.46 N), while the lowest value was for control subgroups (1010.33 ± 268.19 N) with statistical significant difference among the different subgroups ($P = 0.001$).

Using Tukey test, statistical significances were recorded between control subgroup and all experimental subgroups.

4. Discussion

One of the most important stages of endodontic treatment is biomechanical preparation of the root canal. Furthermore, adequate obturation of the root canal system following intracanal preparation is a major objective of endodontic treatment. It is necessary to select root canal obturating material that has a potential to reinforce the root structure [13], could contribute to reduction in the incidence of vertical root fractures [14].

A variety of materials and techniques have been developed to improve the sealing quality and reinforcing effect of root canal obturation. Three obturation systems were chosen in this study to represent different categories of products currently available for adhesion to root dentin. Two resin-based systems: RealSeal (secondary monoblock) and EndoREZ (tertiary monoblock). In addition, Soft-Core solid core carrier with AH26 epoxy-resin sealer has been used because it has accepted sealing properties [15–17], accepted physical properties such as longer setting time, low solubility, high flow rate and less volumetric polymerization shrinkage [18,19]. Furthermore, AH26 sealer is considered as the gold standard against which all new sealers and bondable root canal obturation materials should be compared [20].

For root fracture resistance evaluation, currently the force was applied at 45° angle along the long axis of the root [21,22] because under clinical conditions, anterior teeth are stressed not only vertically down the long axis of the root but the occlusal load also is directed more likely at a certain angle [23]. Each root sample had only 4 mm of root dentin exposed above the embedding material to better simulate the support given to healthy teeth by alveolar bone.

According to the results of the present study, all tested obturation systems were able to strengthen the roots prepared either with rotary ProTaper, RaCe system or hand instruments compared with control subgroup. These results are in agreement with the findings obtained by Cobankara et al. [22] who concluded that the obturated roots were stronger than the roots whose canals were instrumented but not obturated.

The results of this study contradict the findings obtained by Hammad et al. [14] as they showed that preparation of roots with ProTaper rotary instruments and obturation with EndoREZ points and sealer increased the fracture resistance compared to Resilon/RealSeal, gutta-percha/eugenol-based sealer and gutta-percha/Gutta-Flow. This discrepancy may have resulted from the difference in the experimental design, in which they applied load with spreaders instead of steel spherical tip used in the present study. The spreader provided better force distribution inside the canal and fracture occurred as a result of forces transmitted via the obturating materials.

In the current study, the best fracture resistance results were recorded for Soft-Core/AH26 system when the canals were prepared with either RaCe rotary system or hand instruments. This may be due to that Soft-Core obturator was coupled with AH26 sealer. This epoxy resin-based sealer with its high polymerization time and creep capacity may enable better penetration into the dentinal tubules [24] which in turn, facilitate the interlocking between sealer and dentin; promote more adhesion and higher resistance to sealer dislodgement from dentin surface [25]. In addition, the formation of covalent bond by an open epoxide ring of that sealer to any exposed amino groups in collagen of dentin and its high quality properties including very low shrinkage while setting and long-term dimensional stability may enhance the root fracture resistance [26]. However, this bonding capacity is not able to totally reduce the susceptibility of roots to fracture [13,22,27].

It was necessary to evaluate the effect of root canal preparation technique on root fracture resistance for each obturation technique. Regarding Soft-Core/AH26 system, the highest fracture resistance was recorded for RaCe while the lowest for hand instrumentation although there was no significant difference, this may be related to rotary root canal preparations results in a more rounded cross section that may have a positive effect on force distribution inside the canal and consequently higher root fracture resistance compared to hand preparation [28].

When RealSeal system was considered, the highest fracture strength value was recorded for ProTaper while the lowest was for RaCe although there was no significant difference. This may be due to that increased canal taper associated with ProTaper preparation in coronal and middle thirds allowed forces to be better distributed in the apical third of the canal and potentially increasing fracture resistance of the root [29]. This finding was supported by Patasandra et al. [30] and Chankhrit and Yun [31] who concluded that greater apical enlargement did not increase the fracture susceptibility of the roots. This finding was also in agreement with the study by Lam et al. [32] who found that increased taper of rotary instruments did not further weaken roots than conventional hand preparation and may even increase fracture resistance. This may be due to the effect of rounded canal shapes prepared with rotary instruments leading to reduced areas of stress concentrations which may offset the effect of dentin removed.

In contrary to the current results, Singla et al. [33] demonstrated that the least vertical root fracture resistance was found in canals instrumented with ProTaper instruments. This discrepancy may be attributed to the difference in the experimental design, in which the samples were loaded using a spreader attached to the upper member of universal testing machine and the root canals were prepared to F4 ProTaper instrument (#40/0.06).

When control subgroups and EndoREZ system were considered, the highest fracture resistance was recorded for hand preparation technique whiles the lowest for ProTaper although there were no significant differences. Probably, the reasons for these results are the marked differences in the amount of dentin removed in the middle and coronal parts of root canal with ProTaper files (taper up to 19%) compared to common taper hand instruments or RaCe files with tapers ranging between 2% and 10%. Also RaCe file with its new design (reamer with alternating cutting edges) is not as effective compared with other active Ni–Ti rotary instruments (e.g. ProTaper) due to the straight sections of the instrument which reduce the contact area between dentin and instrument [34]. This finding was in agreement with Zandbiglari et al. [35]. They demonstrated that fracture resistance of instrumented roots is significantly lower when root canals are prepared with instruments of greater taper.

5. Recommendations

Alternative strategies to reinforce endodontically treated roots should be considered as the currently available obturation materials don't have the necessary physicomechanical properties to achieve a strengthening effect.

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