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Effect Of Four Root Canal Preparation Techniques On Root Fracture Susceptibility And Fracture Pattern – An Invitro Study

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Abstract
Aim: To assess the root fracture susceptibility and the fracture pattern following root canal preparation by four different techniques.
Methodology: Fifty extracted mandibular first premolars were grouped into 5 categories. The specimens (n=10) in Group I acted as the minimally instrumented control. Specimens from Group II were instrumented with step-back technique with hand stainless steel K & H files. For the specimens in Group III, the coronal canal instrumentation was done using gates glidden drills following stepping back with hand files. Group IV specimens (rotary NiTi ProTaper) and Group V (rotary NiTi RaCe) were instrumented in crown-down manner. Following root canal preparation, the canals were obturated using lateral condensation. Periodontal ligament simulation was done using light body silicone impression material. Load was delivered into the canal through a spreader mounted on an Instron testing machine. The obtained values were analyzed and compared using ANOVA. The fracture pattern was also observed under a microscope.
Results: There was no significant ($p<0.05$) difference among the different groups tested with respect to their fracture susceptibility. Most of the specimens fractured in bucco-lingual plane, with fractures ranging from incomplete to complete or compound.
Conclusions: The type of canal preparation technique and system does not appear to influence fracture susceptibility of a tooth significantly. The findings of this study indicate that the instrumentation with greater taper rotary NiTi instruments do not increase the fracture susceptibility of roots. Fracture susceptibility of a tooth depends on various factors other than root canal instrumentation alone.

Key Words
root fracture susceptibility, fracture pattern, automated root canal preparation

Introduction

For over a century, root canal therapy has been used to treat teeth affected extensively by dental caries or trauma. It has proved to be successful in prolonging the life of pulpally involved teeth indefinitely. The success of endodontic therapy depends mainly on two factors – effective cleaning and shaping of the root canals and a three dimensional compact obturation of the prepared root canal system. However, under function, root treated teeth do tend to fail after several years due to various reasons[1],[2]. Several factors have been implicated as causes of vertical root fractures in root canal treated teeth. The most common cause of vertical root fracture in endodontically treated teeth is the excessive force used during the lateral condensation of gutta percha[3]. But the loads generated during lateral condensation have been shown to be far lower than the loads that are required to cause root fractures[4],[5]. Nevertheless, root canal preparation involves considerable removal of infected as well as sound dentin within the canal. Some studies have shown direct relationship of root canal enlargement to finger-spreader induced vertical root fracture[6]. Non-vital teeth have been known to have about 9 % less moisture compared to their vital counterparts[7] and this is thought to make endodontically treated teeth more brittle. Messer et al (1992) found no difference between the biomechanical properties of endodontically treated teeth and their contra-lateral vital pairs in their study & suggested that other factors like cumulative loss of tooth structure, root canal aberrations may be more critical factors[8].

Traditionally stainless steel hand and rotary instruments were used for root canal preparations. Studies have shown that canal shape after preparation with hand files can be quite irregular[9],[10]. From the fracture mechanics point of view, the presence of any structural defects, cracks, or canal irregularities is likely to play a major role in determining the fracture susceptibility of endodontically prepared teeth because an applied stress may be exponentially amplified at the tip of these defects[11]. The newer rotary NiTi instruments result in a more uniform canal shape, size and taper, involving the canal irregularities in the preparation and eliminate them[12]. Theoretically, smoothly tapering canals prepared using rotary NiTi should not result in significant change in fracture resistance of endodontically treated teeth except in systems which remove more radicular dentin especially in the coronal third. Since these techniques produce a more rounded preparation, the pattern of fracture is expected to be different, compared to the commonly noticed patterns.

The hypothesis tested was that the canals prepared using the newer rotary NiTi instruments followed by lateral condensation obturation technique may result in increased root fracture susceptibility when compared to that of hand stainless steel instruments.

The purpose of this in-vitro study was to compare the effect of four root canal preparation techniques: step-back instrumentation with hand stainless steel K and H files, step-back instrumentation of hand stainless steel files and Gates Glidden drills, crown-down

instrumentation with rotary NiTi ProTaper system and crown-down instrumentation with rotary NiTi RaCe system, on root fracture susceptibility & fracture pattern.

Methodology

Fifty freshly extracted human mandibular premolars with fully developed roots collected from the department of Oral and Maxillofacial Surgery were used in this study. The fifty extracted teeth were grouped into five categories depending on the type of instrumentation to be done :

Group I – Minimally instrumented control (instrumentation to size 25 ISO K-file).
Group II – Root canals were prepared using stepback technique with hand stainless steel K and H files.
Group III - Root canals were prepared using stepback technique with hand stainless steel files and Gates Glidden drills for coronal flaring.
Group IV –Root canals were prepared using crown down technique using ProTaper NiTi instruments.
Group V – Root canals were prepared using a crown down technique with rotary NiTi RaCe instruments.

Root canal preparation was done till size 30 for hand files, size 30 taper 6 % for RaCe rotary NiTi group and size 30 taper 9 % (F3) for ProTaper rotary NiTi group to standardize the apical preparation as much as possible. The canals were irrigated with 2 ml of 1 % sodium hypochlorite solution in between the instrumentation. The canals were then obturated using gutta percha and AH Plus sealer by lateral condensation technique. Lateral condensation of gutta percha was done until the spreader no longer penetrated more than 3 mm. During the root canal treatment the specimens were held in a moist guaze to prevent dehydration. The prepared and obturated teeth were stored at 37º C for a week to allow the complete setting of the sealer while maintaining 100% humidity.

The specimens were wrapped with a lead foil of 0.15 mm thickness determined using a digital caliper. The wrapped teeth were coated with white petroleum jelly. Autopolymerizing resin was mixed and placed into a machined metallic ring. The specimens were placed upright in the setting resin such that about 2 mm of tooth structure was above the resin. Once the resin had set, the tooth specimens were removed and the lead foils were taken off. A light body silicone impression material (Reprosil, Dentsply) was mixed and placed inside the artificial socket which had been created in the autopolymerizing resin and the specimens were repositioned. The excess silicone impression material was later cut off, leaving behind a thin layer which acts as an artificial periodontal ligament and the stiffer resin block as the artificial alveolar bone.

Load was delivered into the canal through a spreader mounted on an Instron testing machine **(Fig.1)**. The load at fracture and the fracture pattern was noted. The values obtained and analysed, using ANOVA and the results were compared.

The fractured roots were later examined under a light microscope with a 20 X magnification to determine & note the fracture pattern. The patterns were categorized into bucco-lingual or mesio-distal fracture. Photographs of the fractured specimens **(Fig. 2)** were taken using a digital camera.

Results

There were five groups tested, the first being the control group and the remaining four being the experimental groups.
Descriptive data are presented as values obtained with corresponding fracture susceptibility scores for each group.

Fig. 1: Loading Of Specimen To Fracture

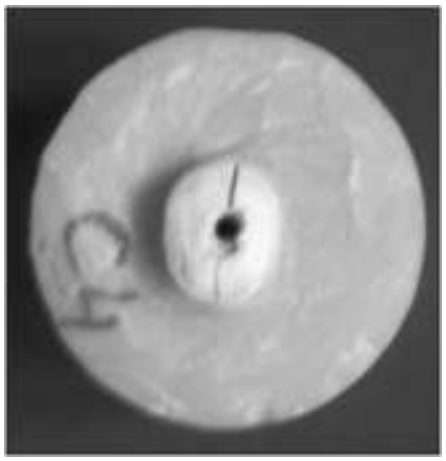
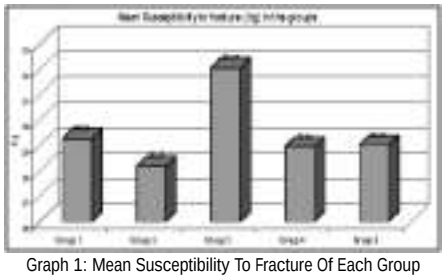


Fig. 2: Fracture Pattern

Statistical analysis was done using one-way ANOVA or analysis of variance test.
It was found that Group 3 offered least values for fracture susceptibility compared to all the other groups followed by Group 1 and Group 5 respectively **(Table 1)**. The mean values of Group 4 and Group 2 seem to suggest that they are more susceptible to fracture comparatively **(Graph 1)**. But the difference between the mean susceptibility to fracture is not statistically significant between the groups (P>0.05) **(Table 2)**.

Table 1: Descriptive Statistics Of All 5 Groups

Group	N	Mean	Std. Deviation	Minimum	Maximum
Group 1	10	29.26	14.62	13.01	59.79
Group 2	10	28.17	8.02	19.15	45.41
Group 3	10	32.05	11.68	18.88	55.81
Group 4	10	28.94	6.48	22.14	41.45
Group 5	10	29.01	5.32	19.4	37.21



Graph 1: Mean Susceptibility To Fracture Of Each Group

Table 2: Anova Results Comparing Fracture Susceptibility Between The Groups

Susceptibility to fracture (Kg)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	88.705	4	22.176	.229	.921
Within Groups	4364.595	45	96.991		
Total	4453.299	49			

Discussion

In the last few decades root canal treatment has gained popular acceptance and is responsible for saving many teeth that may otherwise have been condemned for extraction. Due to rapid technological advances of endodontic instruments and their method of use, there has been a shift from narrow, minimally instrumented canal preparations obturated with a single point, to wider, better flared preparations and excellent three-dimensional obturations.

Instrumentation of the root canal is an integral part of endodontic treatment. It may be expected that as more dentin is removed during instrumentation, a weakening effect on the root is inevitable. However, this logical assumption has been shown to have little significance as the overall fracture susceptibility or strength of the tooth depends on various other factors like the cumulative loss of tooth structure from caries, trauma, restorative and post endodontic procedures[8](Sedgley and Messer 1992). In addition, other factors such as anatomical irregularities in the canal, biologic factors as well as mechanical properties of teeth also influence the ultimate strength[11],[13](Sathorn et al 2005 Saw and Messer, 1995).

The recent introduction and the rapidly increasing popularity of rotary NiTi instrumentation in endodontics, especially those with a greater taper, have made them the technique of choice for canal preparation for clinicians the world over. Not only are they rapid in their action, they also produce a well flared, smoothly tapered preparations ideal for obturation.

In our study, the rotary systems compared were ProTaper (Dentsply) and RaCe (FKG). Several studies have shown ProTaper instruments to produce a round, centered canal with a smooth taper and more flare at the coronal region[14],[15]. Recent publications evaluating RaCe have found them to prepare canals rapidly, maintaining canal curvature well with better centering ability than ProTaper instruments[16],[17].

This study was designed to determine the effect of these new rotary NiTi systems on root strength when compared with conventional canal preparation techniques carried out using hand instruments. The hypothesis tested was that rotary NiTi instrumentation might result in increased root fracture susceptibility when compared to hand stainless steel instrumentation.

Mandibular premolar teeth were selected for the study, as most of these teeth are single rooted with single canals and also they are more or less similar in shape and size.

All the specimens in groups II to V were enlarged to size 30 at the apex and obturated using lateral condensation technique to standardize the root canal preparation as well as the obturation.

Artificial periodontal ligament was created using light body silicone impression material to simulate clinical conditions. The methodology used in this study for testing the fracture susceptibility of endodontically treated teeth is a standard method used by previous investigators[6],[18].

The prepared and obturated specimens were stored for a week before testing. It was noticed while testing that though a few specimens fractured fairly easily whereas some required a high load application to result in fracture. Upon compiling the results it was observed that all groups fractured more or less within the same range of applied force.

It was noted that most fractures were in the bucco-lingual plane as in previous studies[5],[19]. Fractures ranged from complete with fracture line running from buccal surface to the lingual surface through the canal to incomplete root fractures and compound fractures. A finite element analysis carried out by Lertchirakarn et al showed that a tooth root resembles a thick walled cylinder and the stress distribution follows the hoop stresses in a thick-walled cylindrical pressure vessel. Rupture occurs only when the tensile strength of dentin was exceeded, and can occur in any location around the dentin wall. When pressure is applied on a thick walled vessel, the thin part of the vessel is forced to expand more readily than the thicker rigid wall in a radial direction. This asymmetrical expansion creates additional circumferential stresses on the inner surface of the thicker areas. Thus, even progressive decrease in proximal dentin thickness may result in an increased bucco-lingual stress concentration, further predisposing to bucco-lingual fracture.

Another significant finding was that even the lowest force which fractured the specimens was way higher than that which can be achieved clinically. This is in accordance with several previous studies[4],[5]. In clinical conditions, the loading of teeth is a dynamic process wherein the loading force, frequency and direction vary greatly. The fracture susceptibility of teeth depends upon various factors like the amount of radicular as well as coronal tooth structure removed, the amount of intact tooth structure remaining, procedural errors during root canal cleaning and shaping process, lateral condensation forces used during obturation, internal as well as external root morphology, inherent elasticity and strength of the tooth root, the type and frequency of use of endodontic irrigants and medicaments, type of restoration used to restore the tooth after endodontic therapy, the type and position of tooth, the number of teeth present in the oral cavity and duration since the endodontic treatment.

We can therefore conclude that if used by experienced operators following the manufacturer's directions, newer rotary NiTi systems are not excessively aggressive and do not overprepare canals any more than conventional instruments or techniques do, having minimal or no influence on the root fracture susceptibility of treated teeth. This supports the view of various researchers (Sathorn et al 2005, Lam et al 2005)[11],[20].

On the other hand, they may help to prepare smooth, rounder canals eliminating intra-canal irregularities which may act as nidii for crack development and propagation. Also, the deep shape and good flare allows better obturation thereby improving the overall prognosis of the tooth.

It can be stated that canal preparation, regardless of the technique used is only a minor factor in increasing the fracture susceptibility of root treated teeth[20],[21]. Long term follow up of clinical cases treated using these newer techniques will validate the findings of our study.

Conclusion

- In this study, all the groups compared had similar fracture susceptibility with no statistically significant difference between the groups.
- Most of the fractures observed were in a bucco-lingual plane.
- The type of canal preparation technique and system, when used according to manufacturer's guidelines, does not appear to influence the fracture susceptibility of a tooth significantly.
- The findings of this study indicate that rotary nickel-titanium instrumentation does not increase the fracture susceptibility of roots.
- Fracture susceptibility of a tooth depends on various factors other than root canal instrumentation alone.

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