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Evaluation of fracture resistance and fracture pattern of roots following canal preparation by hand and rotary instrumentation

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Abstract

The present in-vitro study was undertaken to compare fracture strength of roots following canal preparation by hand (step-back) and rotary (ProTaper) instrumentation and, further, to determine the direction of fracture lines.

Twenty freshly extracted human mandibular premolars were randomly divided into two groups of 10 teeth each. In Group I, canals were prepared with step-back technique using standardized nickel-titanium K-files. In Groups II, canals were prepared with crown-down technique using ProTaper rotary files. After instrumentation, a vertical load was applied by means of a spreader attached to the Instron testing machine and inserted into the canal until fracture occurred. The roots were subsequently examined under a stereomicroscope with 10X magnification to determine the direction of fracture lines. The results were statistically analyzed using paired t-test.

The Mean fracture load was 10.420 ± 3.451 kg for K-files and 12.40 ± 4.064 for ProTaper files, the differences between the two groups were not statistically significant ($p>0.05$). Most of the fracture lines observed were in bucco-lingual direction, followed by proximal and compound fractures.

Increased canal taper by ProTaper instrumentation technique did not increase the fracture susceptibility of mandibular premolars any more than conventional step-back K-file preparations and may even increase the fracture resistance.

Introduction

A vertical root fracture is a longitudinally oriented fracture of the root, extending throughout the entire thickness of dentin from the root canal to the periodontium. It may be initiated in the crown or at the root apex, or, in some cases, along the root between these two points [1]. Vertical root fractures represent between 2-5% of crown and root fractures, with the greatest incidence occurring in endodontically treated teeth and in patients older than 40 years of age [2] The cause of vertical root fractures mainly is iatrogenic, resulting from dental treatment excesses, for example, excessive canal shaping, excessive pressure during compaction of gutta-percha, excessive width and length of a post space in relation to the tooth's anatomy and morphology [3], or excessive pressure during placement of the dowel [4]. Obturation strains [5,6,7] and post placement [8] have been investigated as major causes of vertical root fracture. The lateral condensation technique, in particular, has been blamed as a major cause of vertical root fracture [9,10]. However, Lertchirakarn et al [5] studied forces encountered during lateral condensation and concluded that lateral condensation alone should not be a direct cause of vertical root fracture, as loads generated during lateral condensation were significantly lower than the load required to fracture the root. This indicates the need for further investigation into factors that predispose to root fracture. One possibility is the weakening effect of excessively large canal preparations.

Advancements in rotary nickel-titanium (Ni-Ti) instruments over the last decade have lead to new design concepts and techniques of canal preparation. In order to improve working safety, shorten preparation time and create a continuously tapered, conical flare of preparations advanced instrument designs with non cutting tips, radial lands, different cross-sections, superior resistance to torsional fracture and varying tapers have been developed [11]. Increase canal taper advocated by various greater taper rotary nickel-titanium instruments has allowed different canal shapes and sizes to be achieved. Most of the new systems incorporate instruments with a taper greater than the ISO standard 0.02 taper design, indeed rotary nickel titanium instruments are available with tapers ranging from 0.04 to 0.12 [12].

The aim of this study was to evaluate fracture strength of roots, following canal preparation by hand instrument using standardized K-files (Dentsply Maillefer, Baillaigues, Switzerland), and rotary instrumentation technique using ProTaper files (Dentsply Maillefer, Baillaigues, Switzerland) and, further, to determine the direction of fracture lines.

Materials and method

Selection of Teeth:

Twenty straight, single rooted mandibular premolars with mature root apices and single canal extracted on periodontal or orthodontic reasons were used.

Teeth with caries involving the root, cracks on the root surface, short and thin roots were excluded. All teeth were stored in 0.9% saline solution until they were tested. The teeth were thoroughly cleaned with an ultrasonic scalar (Changsha Deyve, High-Tech., China) then randomly divided into two groups of 10 teeth in each group.

Group I: prepared with step-back technique using standardized Ni-Ti K-files.

Group II: prepared with crown-down technique using ProTaper rotary Ni-Ti files.

Instrumentation:

Each tooth was sectioned 2-mm coronal to the cemento- enamel junction (CEJ) with a diamond disc (Gardeschutzenweg, Berlin, Germany) to facilitate straight line access for instrumentation and testing. Proper access was established by straight diamond bur and the apical patency was determined by inserting an ISO #10 K-file. Working length was determined by placing #10 K-file into the canal until it appeared at the apical foramen; this length was measured and the working length was set 0.5mm short of this distance. The flat surface 2-mm above the CEJ was used as the reference point. The two groups were then prepared as follows:

Group I: Step-back technique using standardized Ni-Ti K- files:

The canals were prepared by ISO 0.02 taper hand instruments with size 25 as the master apical file (MAF). Gates-Glidden drills (size 2 and 3) were used initially to pre flare the canal. This was followed by hand filing to the master apical file and then step-back in 1-mm increments for three additional file sizes. Recapitulation with the master apical file at the working length was carried out after each step back size file.

Group II: Crown-down technique using ProTaper rotary Ni-Ti files:

The canals were prepared with ProTaper nickel titanium instruments (0.06) using a 1:128 reduction hand piece (NiTi Control, Dentsply) at a speed of 300 rpm. Shaping was started with the shaper S1 file using multiple, passive-pressure passes to the anticipated working length until resistant was felt then followed by SX file. This action was repeated until S1 file can passively reach to the estimated working length. Later on S2 file was used to the full working length to establish the coronal preparation of the root.

The apical third of the canal was finished using Finishing file F1 and later F2 to the working length.

The master apical file size was kept constant for all the two groups as 25. Throughout the instrumentation procedure, all canals were irrigated using a long 27-gauge needle with 2.5% sodium hypochlorite and recapitulation with an ISO # 10 K file was done after every instrument use. Teeth were stored in distilled water after the instrumentation to prevent dehydration.

Mounting of roots:

All the specimens were then mounted individually inside copper ring in a putty condensation silicone (silibest, Buonarroti, Capannoli, Italy). Each root was mounted vertically, such that the apex of the root will retain on a hard surface. The putty was allowed to set for at least 30-min before teeth were tested.

Measurement of fracture load:

All the specimens were placed individually on the testing platform of an Instron testing machine (Model 4206, Instron Corp., Canton, MA) which is running at a cross head speed of 1-mm/min. A D11 hand spreader tip (Hu-Friedy) was attached to the machine and was inserted into the root canal for fracture testing. Once the test started, the hand spreader tip gradually applied a force within the canal and stopped immediately after fracture was detected. The load at fracture was recorded in kilogram force. The roots were subsequently examined under a stereomicroscope with 10X magnification to determine the location and direction of fracture lines.

Statistical analysis:

To compare the statistical significance among the scores of the two groups, paired t-test was used at 95% level of confidence.

Results

Load at fracture:

The comparison of Mean fracture load between the two groups using paired t-test showed that the canals prepared with rotary instrumentation were stronger than the canals prepared with hand instrumentation. However the differences were not statistically significant at the 95% confidence level ($p=0.353$) (Table 1).

Direction of fracture lines:

Most of the fracture lines observed in the two groups were in bucco-lingual direction (14/20), followed by roots fracturing in the proximal direction (4/20) and then compound fractures (2/20) (Table 2).

Discussion

The technique used in this study for producing root fracture involved the generation of forces within the canal space by means of a spreader inserted into canal, which is in accordance with several studies [5, 6, 18 – 21]. This method was chosen because it produces force distribution from inside the root canal wall. This resembles root fracture of endodontic origin or from a post [5].

The load required to fracture the root provides an indication of fracture susceptibility of the root when subjected to forces encountered during obturation, post placement, or subsequent clinical function. The mean fracture load obtained by Lertchirakarn et al [5] for mandibular premolars was 9.7 kg. This value is closest to the hand preparation group in this study (10.420 kg), but considerably lower than the fracture loads in the ProTaper group (12.4).

The fracture loads ranged from as low as 5.6 kg to a high of 21.1 kg across the two instrumentation groups. The minimum load required to fracture a mandibular premolar was 5.6 kg and 5.9 kg for K-files and ProTaper respectively. These values are similar to that found by Lertchirakarn et al. (minimum load 4.8 kg) [5]. Holocomb et al [18] found that the minimum force required to fracture a mandibular incisor was 1.5 kg. As in previous studies, there was wide variability in the fracture load of the roots, This is presumably because of the variation in root morphology, dentin thickness, calcification, and canal preparation techniques. Despite larger preparations by ProTaper files compared to K-files, no statistically significant differences were observed with regard to fracture load. This finding is contrary to the study by Wilcox et al [20] and Zandbiglari et al [22] which concluded that the more root dentin was removed, the more likely a root was to fracture. This may be a result of the effect of the rounder canal shapes prepared by ProTaper files, leading to reduced areas of stress concentration which may counteract the effect of increased dentin removed. This study also observed that most fracture lines were in a bucco-lingual direction, and the second most common direction was proximal fracture. This is in agreement with that reported in other studies [18, 21]. No major differences in fracture patterns were noted between the two groups. Most vertical root fractures occur in the buccolingual direction, even in mandibular incisors [18] and molars [5, 21] where the dentin thickness in the buccolingual direction is almost twice that in the mesiodistal direction. The mechanism of bucco-lingual fracture was proposed by Lertchirakarn et al [23] who stated that when pressure is applied in a thick-walled vessel, stresses are of two types: tensile stress in a circumferential direction and compressive stress in the radial direction. The thin (proximal) part of the wall will be forced to expand more readily than the thick (bucco-lingual) part of the wall in a radial direction.

The asymmetrical expansion creates additional circumferential tensile stresses on the inner surface of the thicker areas, resulting from the outward bending of the thinner part of the dentin wall. In the present study, the mechanism of resultant bucco-lingual fracture could be explained due to the following reason: When an apical pressure is applied with a round instrument (D11 Hand spreader) inserted into an elliptical canal, it will bind at its narrowest width, which is typically from mesial to distal. The initial forces will be directed towards the mesio-distal direction leading to a strain on the bucco-lingual surface. Hence the resulting fracture lines will orient in the bucco-lingual direction.

Conclusion

Within the parameters of this in-vitro study the following conclusions may be drawn:

1- Increased taper as advocated by ProTaper rotary files do not weaken roots any more than the conventional step-back K file preparations and may even increase the fracture resistance of mandibular premolars.

2- Most of the fracture lines observed in mandibular premolars were in bucco-lingual direction, followed by roots fracturing in the proximal direction and then compound fractures.

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Table 1: Comparison of Mean fracture load between the two groups using paired t-test.

Groups	Mean	SD	Minimum loud (kg)	Maximum loud (kg)	p-value	Level of significance
Group 1	10.420	3.451	5.6	12.7	0.3532	Non significant
Group 2	12.40	4.064	5.9	21.1		

SD = standard deviation

Table 2: Direction of fracture lines in the tested groups.

Groups	Direction	Frequency
Group 1	Bucco-lingual	8
	Proximal	1
	compound	1
Group 2	Bucco-lingual	6
	Proximal	3
	compound	1