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Comparison of Canal Transportation and Remaining Dentin Thickness using Different NiTi Systems with CBCT - An in Vitro Study

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Abstract: ***Context: Controlled, uniformly tapered radicular preparation is a great challenge in endodontics. This study evaluated the shaping ability of three different instrumentation techniques. Aims: The aim of this study was to compare canal transportation and remaining dentin thickness of hand NiTi K files, ProTaper and Wave One rotary systems using CBCT. Settings and Design: This study was conducted in the Department of Conservative Dentistry & Endodontics, Kamineni Institute of Dental Sciences, Narketpally in association with the secunderabad dental imaging, Secunderabad. Methods and Material: 30 mesiobuccal roots of maxillary first molars were taken and assigned to 3 experimental groups (n=10). Pre instrumentation and post instrumentation CBCT images of root cross sections at 3, 5, 7 and 9mm from apex to the canal orifice were obtained. Canal transportation and remaining dentin thickness were evaluated using DICOM software. Statistical analysis used: Data was statistically analyzed using SPSS version 19.0 software, One-way analysis of variance and Post hoc comparison for statistical significance. Results: It was observed that ProTaper has shown significantly more canal transportation when compared to hand NiTi K files and WaveOne at all the sections. Hand NiTi K files has shown significantly more dentin thickness compared to ProTaper and WaveOne at all sections. Conclusions: The WaveOne NiTi system has maintained the canal anatomy with less amount of canal transportation when compared with the ProTaper system and Hand NiTi K flex files in the apical third.***

Keywords: Canal transportation, Cone beam computed tomography, Nickel Titanium, ProTaper, Reciprocating motion, WaveOne

1. Introduction

The goal of root canal treatment is to eliminate microorganisms, to remove infected and necrotic pulpal remnants, and to shape the root canal system in order to facilitate irrigation and the placement of medication and/or filling material[1]. Regardless of the instrumentation technique, cleaning and shaping procedures invariably lead to dentine removal from the canal walls[2].

Transportation is defined by the Glossary of Endodontic Terms of the American Association of Endodontists[3] as ‘‘the removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation.’’ It is usually seen in curved canals when the instrument tends to return to its original shape. As a result of this asymmetrical material removal during shaping, the long axis of the curved root canal will be displaced and the angle of curvature will decrease, resulting in straightening of the original curvature of the root canal.

The introduction of nickel-titanium (NiTi) instruments allowed a safer and easier preparation of canals with complex anatomic characteristics[4, 5]. The rotary techniques of instrumentation significantly improved during the last few years especially with the development of new rotary file designs[6].

ProTaper instruments have a convex triangular cross sectional design with three cutting edges, a negative rake angle and a flute design that combines progressive tapers within the shaft[7]. A unique feature of ProTaper files is that each instrument has varying percentage of tapers over the length of its cutting blades. With this geometry, rotary instruments can cut dentin more effectively and may therefore reduce torsional loads[8, 9].

The WaveOne NiTi single-file is a single-use, single-file system to shape the root canal completely[10]. This system is designed to be used with a dedicated reciprocating motion motor. The reciprocating movement relieves stress on the instrument and therefore, reduces the risk of cyclic fatigue caused by tension and compression .The files are manufactured with M-Wire technology improving strength and resistance to cyclic fatigue.

A number of methodologies have been used to evaluate the efficacy of endodontic instrumentation such as plastic models, histological sections, scanning electron microscopic

studies, serial sectioning, radiographic comparisons, and silicon impressions of instrumented canals. The above mentioned methods are invasive in nature, moreover accurate repositioning of pre and post instrumented specimen is difficult[11].Recently the use of computed tomography has been suggested because it is a non-destructive method that allows measuring the amount of dentin removed from canal walls[12].

Cone-beam computed tomography (CBCT) or digital volume tomography (DVT) is a high-resolution scanning system that has been used clinically and for endodontic investigations when evaluating root canal morphology, fractures, and changes in root canals after instrumentation[13]. One of the major advantages of CBCT over CT is simple to use, less complicated, less expensive hardware than CT scanners and has lower effective radiation dose to which patients are exposed[13].

2. Methodology

Preparation of Specimens

A total of 40 teeth specimens were taken out of which 30 specimens showed mesiobuccal roots with angulations of 20-40 degree according to the criteria described by Schneider[14]were taken. Second mesiobuccal canals were not included. Distobuccal and palatal roots of all teeth were separated by using a diamond disc at the furcation. Access cavities were prepared .The working length was determined with a size 15 K-type file (Dentsply/Maillefer, Ballaigues, Switzerland), which was passively advanced into the canals until the tip of the instrument penetrated and adjusted to the apical foramen. The actual canal length was recorded, and the working length (WL) was calculated by subtracting 1 mm from this measurement.

The samples were randomly divided into three groups of 10 samples in each group and pre instrumentation canal morphological scan was taken using CBCT and subjected to cleaning and shaping:

Group 1: The MB canals were instrumented using the hand NiTi K flex files using balanced force technique suggested by **Roane et al.**[15]'Balanced force' technique. Coronal preflaring was completed using size 1-3 Gates Glidden drills. The root canal was irrigated with 2 ml of 3% NaOCl between instrumentation. Each sequentially larger file was worked in a similar fashion until the apical preparation was completed with a size 25 NiTi flex file. After the size 25 NiTi flex K-file had been used to full length, the procedure was continued upto 40 NiTi flex K-file keeping each file 1 mm short of WL. Recapitulation with a size 25 NiTi flex K-file was carried out to avoid ledge formation.

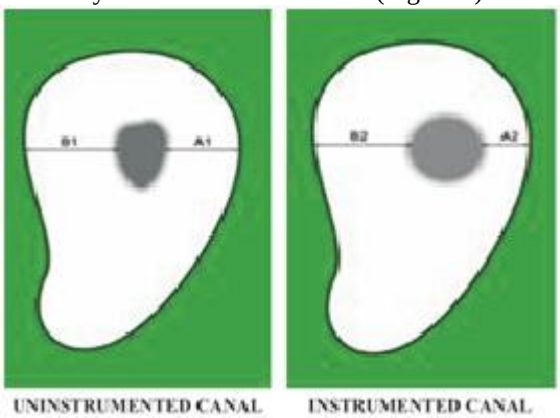
Group 2: The MB canals were prepared by using the ProTaper Nickel-Titanium Rotary System. The X-Smart plus motor (Dentsply, Maillefer) was used at 300 rpm and 5-Ncm torque with a 6:1 contra angle handpiece. Sx was used in brushing motion till the resistance was felt followed by S1 which was used to improve the radicular access. After this, S1 was used till 1mm short of the working length followed by S2 which was used till working length. The finishing of the canals was done using F1, F2, F3 till the working length.

Group 3: In this group the MB canals were prepared using single reciprocating WaveOne file having a size 25 and a taper of 0.08 was used. The X-Smart plus motor (Dentsply, Maillefer) setup at Wave One file configuration (170^o counterclockwise, then 50^o clockwise rotation) was used. Instrumentation of the coronal 2/3 rd was done using WaveOne primary file till the resistance was felt. The working length was determined using 15K file and canal patency was checked. Final instrumentation was done using WaveOne primary file till the definitive working length.

The teeth were coded and mounted on a thermocol, and were horizontally fitted to a chin support with its occlusal plane parallel to the plate. Three-dimensional CBCT images were acquired before and after instrumentation from root cross sections located 3, 5, 7 and 9mm above the apical foramen at 74KV and 10 mA 76×76×76 pixels matrix, 200µm thick cross sections, 4 X 6 and 6 X 12 display field of view, and beam incidence at the central portion on the device used to fix the specimens.. The sections were 200µm thick from apical to the canal orifice. The images were stored in the computer's hard disk for further measurement and comparison between these scans was done by using the DICOM Software.

Individual cross sectional image at each level was taken and zoomed to 100%, then using the calibration tool the mesiodistal measurement was done.

For the canal transportation extent and direction was determined by **Gambill et al**[16] formula (Figure 1):



(A1-A2)-(B1-B2)

Figure 1: Gambill et al[16] formula

For the measurement of remaining dentin thickness shortest distance from the canal outline to the closest adjacent root surface was measured at each level.

3. Results

Data was statistically analyzed using SPSS version 19.0 software, One-way analysis of variance and Post hoc comparison for statistical significance.

In this present study, the ProTaper rotary system has shown more amount of canal transportation when compared to WaveOne and Hand NiTi K flex files at all the levels ($P < 0.05$). (Table 1, Figure 2)

Figure 2: Comparison of canal transportation between the three groups at 3mm, 5mm, 7mm and 9mm by anova

Levels	Group I (Mean±SD)	Group II (Mean±SD)	Group III (Mean±SD)
3mm	0.0248 ±0.0075	0.0365±0.0087	0.0207±0.00691
5mm	0.0205 ±0.0042	0.0368±0.00842	0.0196±0.00542
7mm	0.0281±0.0057	0.0364±0.0053	0.0244±0.0056
9mm	0.0471±0.011	0.0739±.0155	0.0479±0.011

In the present study, second parameter is the remaining root dentin thickness which was calculated and it was observed that ProTaper has more amount of dentin removal compared to hand NiTi K flex and WaveOne. (Table 2, Figure 3)

Levels	Group I (Mean±SD)	Group II (Mean±SD)	Group III (Mean±SD)
3mm	0.0759 ±0.0059	0.0735±0.0105	0.0579±0.0036
5mm	0.1032±0.0061	0.0842±0.0059	0.0896±0.0038
7mm	0.1141±0.0049	0.0940±0.0063	0.0961±0.0032
9mm	0.0856±0.0061	0.0933±0.0055	0.0762±0.0011

4. Discussion

Mechanical root canal preparation can be considered the most important step that influences the success of endodontic treatment. It enhances adequate chemical and mechanical debridement, while preserving the radicular anatomy[1]. A variety of instruments and techniques have been developed and described for this crucial phase of cleaning and shaping of root canal space [17, 18, 19]. Unfortunately, a number of procedural errors such as canal transportation, ledges, perforations and apical zips can occur while shaping the curved canals[20].

During cleaning and shaping, the removal of excessive dentin in a single direction rather than in all directions equidistantly from the main tooth axis, causes what is known as canal transportation, jeopardizing the centering ratio and canal curvature[21].

Instrumentation changes in the canal can be assessed using natural teeth or simulated canal resin blocks. In our study natural teeth were selected as there are certain drawbacks of using rotary instrument in resin blocks.

Mesiobuccal root canals of extracted human maxillary molars were used in the present study because they usually present an accentuated curvature and mesiodistal flattening.[22] The crowns were maintained to simulate, as closely as possible, the clinical endodontic practice, in which the interference of cervical dentin projections creates tensions on the files during root canal instrumentation. Angle of curvature was assessed according to the criteria described by **Schneider** method[14].

In this present study the cross sections of root located at 3, 5, 7 and 9mm above the apical foramen were taken because they represent the apical and middle thirds of the root canal where curvature exist and mishaps are more likely to occur. The cross sections of 200µm thick are taken for better and more detailed image definition.

In this present study, the ProTaper rotary system has shown more amount of canal transportation when compared to WaveOne and Hand NiTi K flex files at all the level. The results of this study are in accordance with study done by **Javaheri and Javaheri**[23] which shows that files of decreasing taper size to prepare the apical third of the root canal to prevent apical transportation.

WaveOne instruments resulted in significantly less canal transportation when compared to canal instrumentation with ProTaper and Hand NiTi K flex files ($P < 0.05$). This can be attributed due to several reasons as the WaveOne instrument system is made from M-wire alloy characterized by superior flexibility compared with conventional NiTi . WaveOne was used in a reciprocal motion. This working motion has been associated with well-centred preparations and reduced incidence of procedural errors[24]. WaveOne instruments have variable cross-sections along the working part that change from a concave triangular cross-section with radial land at the tip to a neutral rake angle with a triangular convex cross section in the middle part and near the shaft[25]. The radial lands in combination with the reciprocating working motion are claimed to keep the WaveOne instrument centred whilst advancing apically into the root canal[10, 29] .

At the middle and coronal levels, ProTaper showed higher transportation which can be mainly attributed to progressive taper along the cutting surface in combination with the sharp cutting edges.

Hand Ni-Ti K flex files used in balanced force technique caused significantly less canal transportation ($P < 0.05$) and removed significantly less volume of root dentin ($P < 0.05$) than ProTaper and WaveOne rotary systems. Its performance indicates that the balanced force technique produced less deviation from the center of original curved canal [26].

No statistical difference in remaining root dentin thickness at apical levels between the groups could be attributed to the non cutting modified safety tip of the ProTaper and WaveOne, blunt transition angle at the tip of Hand NiTi K flex-file. But the remaining root dentin was significantly thinner at the mid-root and coronal level sections following ProTaper instrumentation. Progressively tapered design along with triangular convex cross sectional design could have led to aggressive cutting[27].

The present study found that the remaining root dentin was significantly thinner at the mid root sections following ProTaper instrumentation which is in accordance with the study by **Nagaraj S et al** [28]. This may be because of the difference in taper and cross sectional design between the instruments. The use of CBCT is increasing rapidly worldwide and is a desirable aid in diagnosis and management of complex endodontic problems [30].

In conclusion, within the limits of this study, the new WaveOne NiTi Primary reciprocating single-file better maintained the original canal anatomy, with less amount of canal transportation when compared with the ProTaper system and Hand NiTi K flex files.

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