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Original Article

Comparative Evaluation of Apical Transportation of three Rotary File Systems Using Cone-Beam Computed Tomography: An In-Vitro Study

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Abstract

Background: The goal of root canal preparation is to develop a shape that tapers from apical to coronal, maintaining the original canal shape. Emergence of nickel‑titanium (NiTi) instruments, was a significant improvement in the quality of root canal shaping, with predictable results and less iatrogenic damage. **Aim:** The aim of the study was to evaluate the apical transportation of three NiTi file system in root canal using cone‑beam computed tomography (CBCT). **Materials and Methods:** Root canal of thirty extracted human permanent teeth with mature root apices with a of curvature 20°-40° were collected and divided into three groups after initial bio‑mechanical preparation: Group 1: canal prepared using Mani silk system; Group 2: canal prepared using V‑taper file system and Group 3: canal prepared using ProTaperNext (PTN) file system. All samples were scanned before and after biomechanical preparation using CBCT. The data collected were evaluated using the Kruskal–Wallis analysis of variance test and Mann-Whitney U‑test. **Results:** It was observed that in apical region Group 3 (PTN) showed significantly lower mean apical transportation ability as compared to Group 1 (Mani Silk) and Group 2 (V‑taper). **Conclusion**: It was concluded that PTN rotary system has no canal transportation in comparison to Mani and V‑taper rotary file system in apical region of curved root canal.

Keywords: Apical transportation, cone‑beam computed tomography, rotary instruments

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INTRODUCTION

In the modern‑day endodontic literature, there are numerous concepts, strategies, and techniques for preparing root canals and one among the objectives in root canal preparation is to develop a shape that tapers from apical to coronal, maintaining canal shape.[1]

The design of the file, the amount of instruments required and multitude of techniques advocated, endodontic treatment has typically been approached with optimism for probable success especially in curved root canals. During shaping of curved root canals, several procedural errors can occur including apical transportation, zips, ledges, root perforations, loss of working length, straightening of root canals, or deviation from original path.[2] The breakthrough in clinical endodontics progressed from utilizing an extended series of stainless steel (SS) hand files and a number of other rotary gates‑glidden drills to nickel‑titanium (NiTi) files for shaping canals.

Since 1993, 30 new NiTi instrument systems within the market are classified consistent with their design, shaping characteristics, breakage potential, and clinical performance from generation 1st to generation 5th.[3]

Apical transportation of various rotary NiTi files are compared by different methods. Cone‑beam computed tomography (CBCT) imaging provides three‑dimensional evaluation without destructing the tooth, is a noninvasive technique for analysis of canal geometry and efficiency of shaping techniques.[4] It becomes possible to match the anatomic structure of canal before and after passage preparation through CBCT.

Investigations of the shaping effect of those new NiTi systems with different design features and kinematics are important for understanding how the differences affect their performance. The present study was conducted to compare the apical transportation of three different newer rotary NiTi file system, i.e., Silk from Mani, V taper from SS White and Protaper Next (PTN) Densply in curved root canal.

MATERIAL AND METHODS

Thirty human permanent mandibular 1st and 2nd molars (compromised periodontal condition) were collected and stored in a 2% thymol solution until use[5] and teeth with mature apices, curved canals (20°–40° of curvature) were selected. The canal curvature of each tooth was determined using Schneider’s method.[6] Teeth with immature apices, root resorption, calcified canals, fractured teeth, and teeth with curvature above 40° were excluded from the study. The Ethical clearance was obtained from the Ethical Committee of Dawani Dental College & Research Centre, Kota.

The crowns of selected teeth were removed at the level of the cementum enamel junction using a diamond disc and 12 mm mesiobuccal length root canal was obtained. The specimens were then embedded in acrylic resin employing an endodontic cube.[5]

Before instrumentation images were taken by CBCT machine (Alphard VEGA, Asahi Roentgen Ind., Kyoto, Japan) with following settings: 80 kV, 4 mA, and 51 mm × 51 mm field of view and 0.1/voxel (mm) size. All samples were scanned with roots perpendicular to the beam of CBCT device starting from the apical end of the root.

A glide path was determined using a size 10 K‑file (Dentsply Maillefer, Ballaigues, Switzerland). The working lengthwas determined. RC Help (Prime Dental Products Pvt. Ltd.) was used during canal preparations, and 2 ml 2.5% sodium hypochlorite solution was used as an irrigant after each instrumentation.

After initial biomechanical preparation till 20# K‑file 30 mesiobuccal roots were divided into three groups-

• Group 1 ‑ The canals were prepared using Mani Silk file system with 0.08/25 (Orifice opener) followed by, 0.06/20 and 0.06/25 file at the rotational speed of 500 rpm with a torque of 300 g/cm

• Group 2 ‑ The canals were prepared using V Taper SS White file system with the coronal shaping sequence 25 (V08), 30 (V10) and apical shaping sequence 30 (V10), 25 (V08) files at the rotational speed of 250 rpm with a torque of 455 g/cm.

• Group 3 ‑ The canals were prepared using PTN Densply file system of sequence SX, PTN X1, and X2 at a rotational speed- 350 rpm with torque- 200 g/cm

After canal preparation CBCT scans were taken with similar values and position as before instrumentation scans.

Pre‑and post‑operative CBCT scans were superimposed, and the transportation in the mesiodistal direction was calculated.

Transportation at each level was calculated using the formula:[4]

Transportation = $(X1 - X2) - (Y1 - Y2)$

i.e - X1 was the shortest mesial distances from the exterior of the curved root to the periphery of the un‑instrumented canal.

X2 was the shortest mesial distances from the exterior of the curved root to the periphery of the instrumented canal.

Y1 was the shortest distal distances from the exterior of the curved root to the periphery of the un‑instrumented canal.

Y2 was the shortest distal distances from the exterior of the curved root to the periphery of the instrumented canal.

Canal transportation data were analyzed using the Kruskal–Wallis analysis of variance test and pairwise comparison was done by Mann– Whitney U‑test. The significance level was set at $P = 0.05$. Statistical analysis was performed with SPSS statistics version 20.0 (SPSS Inc., Chicago, IL, USA).

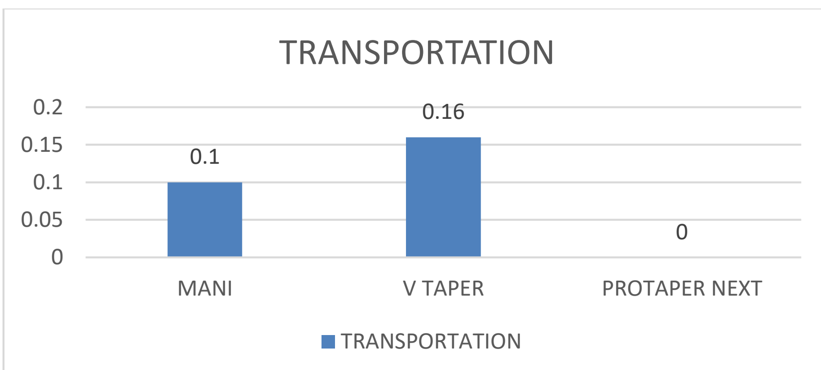
RESULTS

Mean and standard deviation values of canal transportation in apical region for three groups [Table 1 and 2]. The mean apical transportation for PTN file showed statistically significant result when compared with Mani Silk and V taper file system. Mann Whitney test was used to assess pair wise correlation in which a significant correlation was noticed between V taper and PTN (P < 0.05) and a non-significant correlation was observed with V taper and Mani and Mani and PTN (P > 0.05). In pairwise comparison, V Taper–PTN combination is highly significant.

Table 1- CANAL TRANSPORTATION OF CURVED CANALS IN APICAL REGION

GROUPS	TRANSPORTATION	
	MEAN	SD
MANI	0.10	0.18
V TAPER	0.16	0.12
PROTAPER NEXT	00	00
H	5.208	
P	0.050	
**Significant*		

Table 2 GRAPHICAL COMPARISION OF THREE GROUPS



DISCUSSION

Proper root canal shaping and effective debridement of the root canal system are the key factors responsible for successful endodontic treatment. The aim of mechanical instrumentation is to get rid of the infected soft and hard tissues from the root canal and to make a sufficient taper for the further placement of root filling materials.[7]

Cleaning and shaping procedures invariably lead to dentine removal from the canal walls regardless of the instrumentation technique used. However, excessive dentine removal in a single direction rather than in all directions equidistantly from the main tooth axis causes "canal transportation."[8] The occurrence of up to 0.15 mm of root canal transportation has been considered to be acceptable whereas the canal transportation above 0.30 mm may have negative impact on apical seal after obturation of canal.[2] During this study, the effects of three newly developed file systems that have different designs, metallurgies, manufacturing process on the parameter of canal transportation using CBCT imaging was evaluated.

Mani Silk is marketed into simple pack configuration containing a 0.08/25 OO, 0.06/25, and 0.06/30 instruments (mostly used for straight canals). Standard pack configuration contains a 0.08/25 OO, 0.06/20, and 0.06/25 instruments (for moderate curvature of the canals). Complex anatomy pack configuration contains a 0.08/25 OO, 0.04/20, and 0.04/25 instruments (For moderate‑to‑severe canal curvature). All pack configurations and individual sizes are available in 21 and 25 mm.[9] NiTi alloy of martensitic type makes the file more flexible to accommodate the stress. They're rotated at 500 rpm and 300 g/cm. Files are heat treated from D1 to D10 of the cutting flutes providing increased fracture resistance and flexibility. The Teardrop shaped cross section design channels debris out of the canal efficiently and centers the file thus minimizing transportation. This also decreases the "screwing‑in" effect and simultaneously improves tactile sensation. The Mani Silk files has a constant taper throughout the file length with noncutting tip.[9]

PTN is marketed as pack of five files (X1, X2, X3, X4, and X5) with color coded identification ring of yellow, red, blue, double black, and double yellow on their handles, respectively.[10] PTN files sequence is PU SX followed by X1 (17/0.04) and X2 (25/0.06). The X1 and X2 are the shaping and finishing files and X3, X4, and X5 which are optional.[11] Both X1 and X2 file system uses both increasing and decreasing percentage tapered design on a single file. This design feature serves to minimize the contact between a file and dentin, which reduces dangerous taper lock and the screw effect while increasing efficiency.[10] M‑Wire incorporation in the mechanical design of PTN file system improved the resistance to cyclic fatigue, decreased the potential for broken instrumentation, and increased its flexibility. The unique asymmetrical rotary motion enables only two edges to contact with the canal wall at time, leading to an efficient canal preparation.[12] It has a rectangular cross‑section, except at apical 3 mm it has square cross‑section with radial land and noncutting tip. The rotation of the off‑centered cross section enlarges the space for debris removal, optimizes the canal tracking, and reduces binding. The shaft size of the PTN is also small, providing better access to the posterior teeth. Its use is recommended at 350 rpm with a torque of 2.5 N/cm.[11] Clinically, PTN has three advantages (a) Reduced engagement due to swaggering effect which limits undesirable taper lock (b) Affords more cross‑sectional space for enhanced cutting, loading, and augering debris and (c) Allows files to cut a bigger envelope of motion compared to a similarly‑sized file with a symmetrical mass and axis of rotation.[12]

Schäfer E et al in 2004, used two experimental models: Simulated canals versus extracted teeth. The advantage of using extracted teeth over resin blocks was that they provided conditions closer to clinical situations.[13] Even the hardness and abrasion behavior of acrylic resin and root dentin differed,[14] and the heat generated soften the resin material.[15] Therefore, extracted teeth were used in this study to compare different file systems.

Schneider's method was used to measure canal curvature. In this technique, the angle is obtained by two straight lines. The first line is parallel to the long axis of the root canal and the second line crosses the apical foramen until it's intersection with the first line at the point where the curvature starts.[6]Inclusion criteria for canal curvature was 20°–40° in this study.

Various methods have been employed to evaluate the quality of root canal preparations, such as serial sectioning and microscopic evaluation, simulated canals, true tooth training replicas radiographic evaluation and CBCT.[16] To evaluate the final shape of root canal preparations, Serial sectioning technique and optical microscopy have been used. However, when using these methods, part of the specimen is lost because there is a need to cut the tooth before the postoperative evaluation.[17] More complex simulated canals, True Tooth training replicas have been introduced recently.[18] These models have five difficulty scales that many factors (i.e., pulp chamber size, canal curvature, apical branching, etc.) determine their difficulty, but these models also have drawbacks such as different hardness of dentin. Radiographic evaluation only allows for two‑dimensional evaluation of the root canal[19] CT allows a noninvasive and reproducible three dimensional evaluation of external and internal morphology of the tooth with little radiation. Although the cost is more, we used CBCT in this study as it leads to increased precision, resolution, and the time of exposure of radiation is less.

According to the results of the present study, PTN caused no apical transportation as compared to Mani silk file and V‑taper file system. One of the reason for this may be the reducing taper of PTN file in coronal portion leading to more flexibility in the apical region[20] causing less apical transportation. The apical 3 mm of the PTN instrument has square cross‑section which gives more core strength in narrow apical part.[21]

Shenoi et al.[20] concluded that PTN and V‑taper had no significant transportation in apical region. According to López et al.[22] Canal transportation in the apical region is directly propotional to the taper. Similar results to our study was also concluded by Wu et al.[23] showing that PTN caused the least apical transportation in severely curved canals and had better shaping ability than Protaper universal and Wave‑one. He also attributed this to the progressive taper of PTN which making it more flexible at the apical section. The microstructure of Ni‑Ti alloy of PTN file mostly consisted of martensite phase which adds to its advantage of being flexible and ductile.

In our study, Mani Silk showed more canal transportation than PTN. The contributing factor may be the constant taper of the Mani Silk rotary file system which adds more material to the overall body, leading to an increase in stiffness. Kunert et al.[24] and Gundappa et al.[25] suggested that taper is one of the main factors responsible for canal transportation.

CONCLUSION

In agreement with the results we may conclude that PTN (Dentsply Maillefer, Ballaigues, Switzerland) rotary system has no canal transportation in comparison to Mani and V taper rotary file system. It is among one of the few rotary systems that provide quick and safe endodontic preparation. With the constraints of low sample size, all the file system used showed acceptable apical transportation. Hence, further studies with larger sample size are needed to get the more accurate data.

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