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Comparative Evaluation Of Apical Transportation and Canal Centering Ability Of Various Nickel-Titanium Rotary Systems In Curved Canals Using Cone-Beam Computed Tomography: An In Vitro Study

Research Article

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Abstract

Aim: The aim of the study was to compare the canal centering ability and canal transportation of SmartTrack (ST), Profit S3 (PS3), and ProTaper Gold (PTG) systems using cone-beam computed tomography (CBCT).
Materials and Methods: Thirty extracted human single-rooted premolars were used in the present study. Using CBCT, pre instrumentation scanning of all the teeth arranged in arch form were taken. The teeth were decoronated to increase standardization and teeth measuring 16mm were only included for the study. The samples were randomly allocated in to three groups with ten samples in each group; Group I was instrumented with ST, Group II was instrumented with PS3, and Group III - PTG. Post Instrumentation CBCT scans were performed with the same parameters, and the two scans were compared to determine canal centering ratio and canal transportation at 3, 6, and 9 mm, from the apex.
Statistical Analysis: One-way-ANOVA and the independent t-test were done for the pairwise comparison. 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: The mean canal centering ratio and canal apical transportation for ST, PS3 and PTG presented with no statistical difference (P> 0.05).
Conclusion: It was evident that ST, PS3, and PTG had no statistically significant difference when analyzed based on canal centering ratio and canal transportation.

Keywords: Canal Transportation; CBCT; Centering Ability; Endodontic Files; Heat-Treated.

Introduction

Endodontic intervention in order to save the teeth from extraction and prolong their survival in the oral cavity cannot be neglected. The purpose of an endodontic intervention is to eliminate microorganisms, their content and by-products. The shaping of all root canals is imperative as it influences the eventual stages of canal irrigation and obturation that mark the success of the endodontic therapy [1]. The objective of canal instrumentation is to produce a continuously tapered conical preparation that simulates the canal anatomy while keeping the foramen as pristine as possible without any variation from the original canal anatomy and curvature [2]. Root canal therapy involves the location of all root canals, hand/machined endodontic instruments and irrigants

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to prepare root canal system chemomechanical such that it is able to receive a three-dimensional filling [3].

Divergence from the original canal curvature often leads to inappropriate and exaggerated dentinal removal, straightening of the canal, creation of ledge, formation of the elbow, stripping, and apical perforation [4]. Over preparation leads to the weakening of the tooth that ultimately may contribute to the fracture of the root.

The centering ability is the ability of an instrument to stay centered in the canal [5]. AAE defines canal transportation 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; may lead to ledge formation and possible perforation [6]. Various parameters that reportedly affect the canal-centering ability of endodontic instruments are the alloys used in manufacturing these instruments and instrument design (cross-section, taper, and tip) [1].

The possible use of NiTi in endodontics was initially proposed by Civijan in 1975. In 1988, Walia et al modified endodontic instrumentation by replacing stainless steel with NiTi alloy [7]. He also reported that NiTi has greater flexibility, shape memory, and fracture resistance when compared to stainless steel files. Before exceeding their elastic limits, Ni-Ti instruments can flex far more than the stainless steel ones. All of the mentioned factors could contribute to a drastic reduction of procedural errors like zipping, ledging, and stripping of the canal [1].

SmartTrack™ (ST) (nikincdental™, Eindhoven, The Netherlands) endodontic files are manufactured by annealed heat treatment of NiTi alloy (Fire Wire). The manufacturers claim that it has extreme strength and flexibility [8]. It is available in multiple tapers (0.04 and 0.06) and in rotary as well as reciprocation systems. It is compatible with most commonly used systems (eg; ProTaper, Vortex, etc). It has a trihelical cross-section with a rounded non-cutting tip that allows the user to follow the root canal shape safely [9].

Profit S3 (PS3) (Kedo Dental, India) is a heat-treated rotary system with titanium oxide coating that was introduced in 2019. It has a rectangular cross-section with variable taper (varying between 0.04 to 0.08) and consists of an orifice opener and three finishing files. PS3 has good shape memory, flexibility, and increased resistance to fracture [10].

ProTaper Gold (PTG) (Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) manufactured through heat treatment of NiTi alloy and is gold coated. It has a convex triangular cross-section, progressive taper, and the main content is of martensite or R-phase of NiTi alloy [9]. PTG has the properties of shape memory, superelasticity combined with increased cyclic fatigue resistance that is useful in curved canals.

Previously our team has a rich experience in working on various research projects across multiple disciplines [11-25]. Now the growing trend in this area motivated us to pursue this project.

The aim of the study was to evaluate the canal centering ability and canal transportation of ST, PS3, and PTG in single-rooted teeth. The null hypothesis was that there was no difference in the canal centering ability and canal transportation between the tested NiTi rotary instruments in single-rooted teeth.

Materials and Methods

The teeth that were included in the study were thirty extracted human mandibular premolar teeth with fully formed apices due to periodontal or orthodontic reasons. Only the teeth that exhibited no defects were included. Calcified root canals, teeth with internal or external resorption, previously root canal treated teeth with obturating material or post, teeth with prosthetic crowns, and aberrant morphology were strictly excluded from the study. All the included teeth presented with a single canal and a single apical foramen, as analyzed through radiographic examinations. In order to increase standardization, the teeth were de-coronated using diamond discs, and only teeth measuring 16 mm were included in the current study [26]. Only the mandibular premolars that presented with angles of curvature within 0°-10° were selected applying Schneider's technique [27, 28]. The access cavity preparation was done using Endo Access bur with specifications of 21 mm size 2 (DentsplyMaillefer) and #10 K-file (Mani, Utsunomiya, Tochigi, Japan) was used for the initial patency of the canal till working length was achieved (WL), visible at the apical foramen. The WL was established 1 mm short of this length.

The teeth were randomly divided into three groups and embedded in modeling wax in mandibular arch form, Group I - ST, Group II - PS3, and Group III - PTG. All the teeth were scanned with CBCT (CS 9600, Care Stream Dental, Atlanta, GA) with slice thickness of 75 microns to determine the morphology of the canals before instrumentation at an exposure parameter of 80kV, 3, 2mA and 20.0 seconds . The centering ability and canal transportation were evaluated at 3, 6, and 9 mm from the root apex [29]. After the cleaning and shaping process, post instrumentation scans were taken at the same exposure parameters as mentioned. Pre- and post-instrumentation scans were analyzed using CBCT, and the values obtained on axial view were analysed.

The formula used for measuring the degree of canal transportation [5].

$([a_1–a_2] - [b_1–b_2])$

Where a_1 and b_1 the shortest distance from the mesial edge of the root to the mesial edge and the distal edge of the root to the distal edge of the uninstrumented canal respectively. Similarly, a_2 and b_2 the shortest distance from the mesial edge of the root to the mesial edge and distal edge of the root to the distal edge of the instrumented canal respectively. The result of "0" indicates no canal transportation and other than "0" means that transportation has occurred.

The following formula is used to calculate the canal centering ability.

$(a_1–a_2)/(b_1–b_2)$ or $(b_1–b_2)/(a_1–a_2)$

In the case of unequal numbers, the lower figure was considered as the numerator. A result of "1" indicates perfect centering.

The variation in the canal centering ratio and canal transportation

were analyzed using one-way ANOVA and the independent t-test for the pairwise comparison. 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 and Discussion

Our institution is passionate about high quality evidence based research and has excelled in various fields [30-40].

The mean canal centering ratio and apical transportation for ST, PS3 and PTG show no statistical difference (P> 0.05) at 3 mm,6 mm and 9 mm from the apex.

Schilder introduced the concept and phrase 'cleaning and shaping' almost 6 decades ago [41]. The process of shaping the root canal can be classified in to five phases which are as follows; Negotiating the canal- "patency filing", coronal pre enlargement, working length measurement, root canal shaping techniques, and establishment of root canal working width.

Five mechanical objectives of the shaping of the root canals as given by Schilder are to develop a continuously tapering conical form in the root canal preparation, to make the canal narrower apically, with the narrowest cross-sectional diameter at its terminus, to make the preparation in multiple planes, never transport the foramen and to keep the apical foramen as small as is practical [2].

Amongst the most common endodontic mishaps are ledging, transportation of the canal, and apical stripping. The management of curved canals and prevention of its deviation while canal preparation is a challenge [42, 43]. They can be serious as well as challenging to be managed. Insufficient flexibility and uncontrolled preparation or overzealous use of endodontic files' contribution to straightening of the root canal cannot be denied [44].

Figure 1. Cone-beam computed tomography cross section. (a) Preoperative SmartTrack, (b) Postoperative SmartTrack, (c) Preoperative Profit S3, (d) Postoperative Profit S3, (e) Preoperative ProTaper Gold, and (f) Postoperative ProTaper Gold.

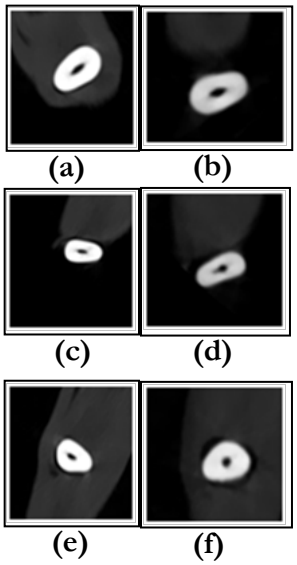


Figure 2. The graph shows the mean canal centering ratio at 3mm (blue bar), 6mm (green bar), and 9 mm (grey bar) from the root apex of the teeth. There was no statistically significant difference between the 3 groups (P > 0.05).

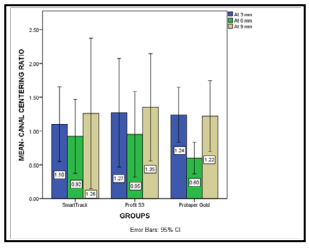
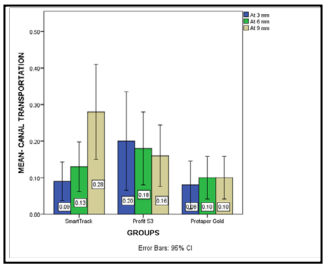


Figure 3. The graph shows the mean of canal transportation at 3mm (blue bar), 6mm (green bar), and 9 mm (grey bar) from the root apex of the teeth. There was no statistically significant difference between the 3 groups (P > 0.05).



One of the age-old tricks to negotiate a curved canal is pre-curving instruments depending on the nature of curvature as anticipated from preoperative radiographs. When these instruments are not precurved, they tend to generate more stresses with in the canal while negotiating. These stresses are greater for stainless steel instruments when compared to Ni-Ti instruments. Eccentricity occurs due to the amount of force that is required to bend the instrument and contribute to its cutting action. More cutting is seen on the outer curvature of the canal. Ni-Ti instruments need less forces to bend and are less aggressive in their cutting action when compared to the stainless steel files. Ni-Ti has been reported to be 2-3 times more elastic than stainless steel. Stainless steel is reportedly observed to cut a lot extra on either side leading to overzealous preparation especially of one wall than the other.

The tendency of endodontic files to straighten and restore their original form during the canal preparation while in the root canal leads to the straightening and skewing of the preparation towards one wall. This in turn results in the altered root canal pathway [28, 45].

In the current study, it can be seen that there is no statistically significant difference in the canal centering ability and canal transportation amongst the three groups (ST, PS3 and PTG) at 3, 6 and 9 mm levels. This indicates the fact that the tested endodontic files tend to have similar centering ability and canal transportation within the root canal at the coronal, middle and apical third of the root canal. Similar deviations from the natural canal pathway was observed in all the tested root canals irrespective of the endodontic file used. The ability of the tested files to remain centered and cause less transportation is critical to prevent iatrogenic errors like apical transportation, ledging and apical stripping. Inadequate shaping contributes to poor cleaning and prevents elimination of microorganisms while excessive shaping escalates the chances of weakening of radicular dentin and leads to vertical root fracture. Iatrogenic errors are difficult to be managed and pose trouble for both the clinician as well as the patient. It implies the fact that heat treatment of the files improves flexibility, bendability, and strength of the endodontic files. PTG and ST files are to be used sequentially while PS3 is a single file system.

Similar results have been reported with no statistically significant difference among PS3, PTG, and OneCurve (OC) files when canal centering ability and canal transportation was evaluated [28]. The systems tested in the above study are all heat-treated and hence these are flexible causing less straightening of the root canals.

The current study is the first study where ST files have been used to study their canal centering ability and canal transportation. No previous studies were found in the literature that compared at least two of the tested file systems. However, two studies have been found that studied ST files. These evaluated the cyclic fatigue resistance and dentin crack propagation of ST files. The cyclic fatigue resistance (CFR) at 45° amongst ST, Reciproc Blue (RB), and Wave One Gold WOG) is not statistically significant. However, at 60°, RB and ST files exhibited better CFR compared to WOG (statistically significant) [46]. Dentin crack formation is reportedly high by ST files when compared to ProTaper Next and HyFlex CM files [47].

Cone-beam computed tomography (CBCT) is an alteration of the concept of computed tomography (CT) and usually involves a single rotation of an X-ray source with the object being stationary. The use of CT in endodontics was first reported in 1990 by Tachibana and Matsumoto [48]. The data is reconstructed using an algorithm that evaluates the volume of the subject and presents it in three conventional (axial, sagittal, and coronal) planes as well as multiple alternative planes. The use of CBCT to evaluate canal preparation has been advocated as it gives clear three-dimensional images of preoperative and postoperative intervention and allows superimposition for effective analysis of the same [49]. Hence, the use of CBCT in this study is validated as it provides accurate, reproducible, and error-free results.

Conclusion

With in the limitations of the study, it was evident that ST, PS3, and PTG presented with no statistically significant difference when examined for canal centering ability and canal transportation aspects of endodontic files. However, the limitation of the study was that it was performed in vitro. Further studies are essential to be able to extrapolate these results in a clinical setup.

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