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SHAPING ABILITY OF A NOVEL ROTARY NICKEL TITANIUM SYSTEM USING CONE BEAM COMPUTED TOMOGRAPHY (AN INVITRO STUDY)

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ABSTRACT

Background: Cleaning & Shaping is the most important aspect of successful endodontic treatment. Root canal curvatures pose a challenge to maintain its curvature with achieving adequate cleaning and shaping.

Aim of the work: Our study was conducted to evaluate the shaping ability of three rotary files: Endo plus files. M-Pro files. Protaper Universal; regarding change in canal curvature, canal transportation and centering ratio.

Materials and Methods: Thirty mesiobuccal canals in thirty mesiobuccal roots of mandibular permanent first molars were divided into 3 groups where each group will be instrumented by a file system; Group (A) shaped by Endo Plus Files, Group (B) shaped by M Pro files, Group (C) shaped by Protaper files. Teeth were scanned using CBCT before and after instrumentation, each group with its respective file system, where both scans are superimposed via software and measurements were extracted at 3 vertical levels and analyzed.

Results: Data : Data was analysed using one-way ANOVA. $P \leq 0.05$ was considered as the level of significance.There was no statistically significant difference between the three file file systems, in terms of evaluation of angle of curvature ($P = 0.120$), Canal Transportation ($P = 0.112$), Centring Ratio ($P = 0.149$).

Conclusion: Under the circumstances of this study, it can be concluded that there is no statistical difference between the overall shaping ability of the three file systems regarding the evaluation of change of angle of curvature, canal transportation and centering ability despite the minor difference in performance at different vertical levels.

KEYWORDS: Shaping Ability, Endo Plus, CBCT

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INTRODUCTION

Shaping of the root canal is an elementary aspect in elevating the rate of success of non-surgical endodontic treatment. The ideal shape of a canal should maintain its original curvature without altering its configuration. Historically, endodontic instruments were made from stainless steel and carbide steel, which were designed for cutting efficiency and canal conformity. However, these materials posed challenges in treating complex canal anatomy with curvatures [1].

Recently, manufacturers have been working towards developing rotary files that are flexible and conform to the original canal anatomy. The goal is to simplify the canal preparation process while minimizing instrumentation errors. The development of rotary files involves various aspects, such as fabrication alloy composition, cutting blade design, taper, helical angle, flute number, cross-sectional shape, tip design, mode of rotation, and surface treatment. These aspects aim to produce a canal shape as close to natural anatomy as possible while ensuring biological objectives of root canal shaping are met.

Stainless steel instruments posed challenges in treating complex canal anatomy due to their rigid nature. They could only shape canals up to a certain point and were limited in moderate canal curvatures. Over-shaping and canal transportation can lead to canal blockage, ledge formation, and weakening of treated roots, resulting in serious complications such as persistent apical periodontitis.

Proper root canal shaping is essential in ensuring the success of endodontic treatment. The use of flexible and conformable rotary files aims to achieve accurate canal preparation and avoid instrumentation errors. Further studies of newly developed Ni-Ti files are necessary to identify their performance capabilities and improve endodontic outcomes. The continued development of Ni-Ti files requires studying their abilities in comparison to high-performing, evidence-based files. This study compares Endo Plus files with M Pro files and Protaper Universal files [2].

Utilizing CBCT (cone beam computed tomography), Pandey et al. [3] evaluated the ability to shape of “2 Shape”, as well as ProTaper Gold (PG). Thirty extracted first mandibular molars were chosen. Before and after chemo-mechanical preparation, pre and post-instrumentation images using CBCT imaging was executed to obtain mesial and distal thickness of dentin walls as well as evaluating of the amount of volume of dentin that has been removed, apical transportation, and centering ratio. A suitable analytical test asserted the statistical analysis. The outcomes demonstrated that both, Protaper Gold, as well as the 2 Shape differ significantly. “2 Shape” performed in a better manner regarding all aspects in comparison to ProTaper Gold. They concluded that (2S) preserved the natural canal morphology better than ProTaper Gold, and that less dentin was lost during cleaning and shaping preparation.

Albuquerque et al.[4] investigated deviation of root canal, ability to stay centered, and amount of dentinal material removed following root preparation using instruments of various rotational as well as reciprocating systems; Protaper next, wave one gold, prodesign logic, and vortex blue utilising micro-computed tomography (micro-CT). They utilised forty curved mesial canals of lower molars, with 10 teeth in each of four experimental groups. The data was statistically examined. At either six millimeter or nine mm away from the canal’s apex, statistically insignificant differences were found among the groups in terms of canal deviation. However, LOG had lesser mesial deviation than PTN apically, namely at the third portion, making it best at centering apically and the worst file at the coronal portion. The researchers determined that the examined systems produced varying results for canal transport, centering ability, and dentin removal at each third.

Hatam et al.[5] examined the canal path migration and centricity capacity of the One Shape (OS) in addition to K3 rotational devices regarding the handling of extremely bent lower first molars, at the mesiobuccal section of the molar, in humans (CBCT). They separated 40 extracted mandibular molars due to periodontal pathological etiologies forming binary groups. The first was prepared with One Shape and the second with K3. Precious to, and afterwards to instrumentation, Cone Beam Computed Tomography images were performed to quantify canal transpositioning and the centering ratio at 2mm, 5mm, and 8mm short of the apical opening. Analysis of the produced data demonstrated a negligible difference in canal deviation between both of the groups in the middle and coronal portions of the canal. Nonetheless, in the apical segment which is two millimeter away from the apex, K3 provided considerably inferior levels of canal deviation than the system One Shape. They concluded that the use of k3 system resulted in much lower canal transportation incidence than when the One Shape was used. Additionally, where One Shaps's capacity to centre the canal was inferior to that of K3. However, there were no substantial differences between the canal transporataion coronally and centerally of both systems.

MATERIALS AND METHODS

Thirty human permanent mandibular first molars having mature apices, without any root defects or abnormal morphology and angle of curvature of mesiobuccal canals between 25- 35 degrees from the buccal view (according to **Schneider's method** [6]) were selected to be used in this study. Teeth were cleaned with ultrasonic scalers, kept in 5.25% sodium hypochlorite for 5 minutes to remove any soft and organic debris, and then stored in 0.9% saline solution until they were used.

Three groups of the teeth were formed , containing 10 teeeth each (n = 30) to be shaped by each file system; Group A (Endo Plus (Guilin Woodpecker Medical Instrument Co., Ltd, Guangxi, China, Mainland)), Group B (M Pro(Guangdong, China, Mainland)), Group C (Protaper).

Access cavitie preparations were done utizlizing a high-speed contra-angle handpiece with a small round bur and finished Endo Z bur. The access cavity was performed under the magnification and illumination of the Dental Operating Microscope with a magnification factor of 9x. Cuspal reduction was performed to obtain a reproducible solid flat reference point from which the working length can be measured.

The teeth were placed in three groups, A, B and C, each half submerged in a circular addition silicone mold measuring 9 cm in diameter. This arrangement took into account the maximum field of view of the CBCT machine to include all teeth with high enough resolution. At the direction where all teeth were facing the buccal, a small circular shape was constructed with radio-opaque composite to mark the buccal side of all teeth.

A preoperative CBCT scan was acquired prior to instrumentation. The addition silicone mold fits on the specimen holder provided by the machine manufacturer, where it is centered at the different fields of view of the CBCT machine. Image standardization was reached through adjusting the machine's patient positioning guide lights so that the region of interest (ROI) is vertically within the machine's field of view (FOV).

For determining patency and tooth length, we used manual files #10 and #15 Manni (DENTSPLY, Maillefer, Ballaigues, Suisse) was used. Shaping for respective groups using Endo Plus System (W0, W1, W2, W3, W4), (17/12, 18/5, 20/4, 20/6, 25/6) respectively. M Pro System (18/4. 20/4, 25/6) respectively, and Protaper Universal System (SX, S1, S2, F1, F2) (19/progressive taper, 17/ progressive taper, 20/ progressive taper, 20/7, 25/8) respectively using rotary endo motor (Endogold woodpecker).

The irrigation protocol applied was with 5ml sodium hypochlorite (NaOCl) (2.5%) for 5 minutes using a 27-gauge needle and a plastic syringe, followed by copious amounts of intermediate saline solution (0.9%) for another 5 minutes, and finally, 17% ethylenediaminetetraacetic acid (EDTA) gel was utilized as a lubricant.

A post-operative CBCT scan was acquired after instrumentation after each group of teeth were put back into their respective mold. Pre and post-operative scans were superimposed using image analysis software to determine the change in measurements before and after instrumentation.

Evaluation of change of degre of curvature angle was done following to **Schneider's methodology** [(6)] which involved making a point, which is horizontally situated at canal orifice level, extending a uniform line which connects point A and point B, point C, considered the third of the points, is allocated at the apical level, and a line is then dragged from point C to point B, allowing for the measurement of the canal curvature. The formed angle at which the lines connecting B and C intersected was quantified and subsequently compared between the pre-instrumentation and post-instrumentation images.

The capacity of the instrument to maintain its position within the canal can be assessed by utilizing the mean centering ratio, as explained by Gambill et al. (7). This ratio is determined for each group at various levels using the subsequent equations:

D=(m1 - m'1) / (d1 - d'1), Where D is the mesiodistal measurement and

The variables m1, m'1, d1, and d'1 correspond to the shortest distances from the mesial and distal aspects of the root to the periphery of the uninstrumented and prepared canals, respectively.

Examining this equation, when the calculated result is "1", it is indicated that perfect centering is achieved. Results greater than "1" indicates a more mesial shift of the file, while results less than "1" indicates more distal movement for the mesiodistal measurement (MD).

Evaluation of canal shift away from centricity, required superimposing the images scanned advanced to canal instrumentation as well as the ones acquired afterwards, the double set of scans were being reconstructed at the same layer. For measuring the dentin thickness, the apex of the tooth was identified. Using it as a reference point, three vertical lines of lengths 3, 5, and 7 mm were extended from the reference point coronally. The measurement level was set to be at the end of the vertical lines. After overlaying both pre and post-instrumentation layers, the dentin thickness was measured at the three levels through the above-mentioned allocation method. At each axial cut, the dentin breadth at all aspects of the canal lumen were measured at both scans simultaneously. The procedures were repeated at the each vertica axial level of all teeth.

RESULTS

The evaluation of changes in canal curvature involved a sequential analysis. First, a one-way ANOVA was conducted to assess the overall differences among groups. Subsequently, Tukey's post hoc test was applied to compare different groups and identify specific intergroup variations. Additionally, a Bonferroni post hoc test was employed to examine intragroup differences. This two-step analysis allowed for a comprehensive evaluation of the changes in canal curvature. Transportation and centering ratio) were analyzed using the Krusakl-Wallis test followed by Dunn's post hoc test. $P \leq 0.05$ was considered as the level of significance. Regarding the evaluation of change of angle of curvature, there was no statistically significant difference between the three file systems ($P = 0.120$). Regarding the evaluation of canal curvature, there was no statistically significant difference between the three file systems ($P = 0.112$). As for the centering ratio,The statistical analysis revealed that no significant difference was observed among the three file systems (P = 0.149). This indicates that, in terms of canal curvature, the choice of file system did not have a statistically significant impact or influence on the measured outcomes.

TABLE (1) Mean and standard deviation (SD) values of change in canal curvature (%) for different files

Change in canal curvature (%) (mean±SD)			p-value
Group A	Group B	Group C	
3.51±1.44[A]	3.98±1.73[A]	2.59±1.19[A]	**0.120ns**

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

DISCUSSION

The cleaning and shaping of the root canal are widely recognized as the crucial stages in endodontic treatment. The primary objective of root canal preparation is to create and sustain a consistently tapered canal, with the smallest diameter at the apical foramen and the widest diameter at the orifice. This facilitates effective irrigation and ensures proper filling, while preserving the original anatomical structure without any deviations.

An ideal instrumentation technique aims to achieve uniform dentinal material removal from the canal walls while avoiding excessive thinning of the root structure. Additionally, the presence of curved canals can present challenges during root canal instrumentation, potentially resulting in complications such as ledges, blockages, perforations, and apical transportation (8).

Cleaning and shaping of the root canal were carried out by various instruments. Stainless steel, which was used previously for root canal instrumentation, has the drawback of susceptibility to fracture, tarnish, and corrosion. To overcome these failures, stainless steel has been introduced in the field of endodontics, and it had a long clinical success rate but had the disadvantage of lesser flexibility. Various studies have shown that the incidence of transportation and straightening of the root canal was common with the use of stainless steel [(6)].

The relativly new discovery of Ni-Ti rotartional instruments has brought about a significant transformation in root canal preparation. The Ni-Ti alloy, used in the development of Ni-Ti rotary files, was initially created by Buehler et al. (10) in 1963 at the Naval Ordnance Lab. This significant breakthrough in material science paved the way for the production of Ni-Ti rotary instruments and played a pivotal role in revolutionizing root canal preparation techniques. Ni-Ti rotary files possess a unique characteristic known as elastic memory, which allows the file to regain its original shape without undergoing deformation. This property enables the Ni-Ti files to maintain better centering within the canal during the instrumentation process, in comparison to stainless steel files. As a result, the utilization of Ni-Ti rotary files minimizes the occurrence of canal straightening, ultimately enhancing the precision and effectiveness of the root canal preparation procedure.

In this experiment, Pro Taper Universal was chosen as it has been used for years (conventional Ni-Ti alloy). Its structure consists of a convex triangular U-shaped outline when cross-sectioned. Shaping files possess multiple tapers that ensure flexibility [(11)(12)].

The incorporation of Nickel-Titanium (Ni-Ti) rotary instruments, known for their enhanced flexibility and reduced aggressiveness, has become a necessity in the field of endodontics. In this study, the Endo Plus instrument was specifically chosen to fulfill this requirement. With the development of the exclusive Martensite alloy, two key properties were emphasized: super elasticity and shape memory. These remarkable attributes paved the way for a revolutionary generation of instruments [13], offering unprecedented capabilities and advancements in endodontic instrument design. By harnessing the power of super elasticity and shape memory, Ni-Ti rotary instruments, exemplified by the Endo Plus, bring forth an innovative era in root canal treatment, facilitating superior performance and outcomes.

In most cases, the simulators were made from low-viscosity epoxy resin [14]. When instruments enlarge canals in this type of material, they generate sticky flakes that might interfere with the progression of the file instrument along the simulated canal [15].

The angle of curvature of the mesiobuccal canals was measured using Schneider's method [6]. Many previous studies have used Schneider's method for the determination of root canal curvature as it showed reliability and accuracy.

In this study, human mandibular permanent teeth were preferred over the simulated resin acrylic blocks, as the latter do not reproduce the anatomic variations and the micro hardness of the dentinal walls inside the root canals [17,12].

Mesial roots of mandibular molars were selected for the reason that canals are often curved in two planes which allows them to become an ideal model to compare mechanical alteration promoted by two different instrumentations [7]. The mesiobuccal canals were selected for the purpose of standardization and owning to their curvature [18].

The Mesiobuccal canals were prepared till F2 in the group (Protaper universal). The F2 prepared the apical one-third a further enlarged the middle one-third of root canals. F3 was not used to avoid over-instrumentation in MB tight canals.

Historically, a range of techniques were employed to assess canal's amount of transportaion, the remainder of remaining thickness of dentinal material, and centering ability. These included the utilization of radiographic methods [9], the meticulous process of serial sectioning [19], visual evaluations through photography [20], intricate observations using scanning electron microscopy [21], and the application of computer manipulation techniques [22]. However, these methods had inherent invasiveness and posed challenges in accurately repositioning specimens before and after instrumentation. Furthermore, the radiographic approach, while valuable, was limited to providing two-dimensional images of three-dimensional objects [9], restricting a comprehensive understanding of the analyzed structures.

In more recent times, a non-invasive technology has gained recognition for its effectiveness in evaluating canal anatomy ahead of and subsequent to instrumentation. This technology, known as cone beam computed tomography (CBCT), utilizes an X-ray beam that has a cone-shap and detector with a difinitive area that enables the capture a comprehensive cylindrical volume of data in a single dose acquisition. The implementation of machine offers several notable advantages. It enables the generation of highly accurate and finely detailed cross-sectional in addition to three-dimensional images, which exhibit exceptional resolution. Furthermore, CBCT provides fully quantifiable data and delivers consistent and replicable results [23]. This innovative approach in imaging has revolutionized the assessment of canal anatomy, allowing for non-destructive evaluation with unparalleled precision and reliability.

Taking into account the aforementioned considerations, this research endeavor was undertaken to assess and juxtapose the centering ability and remaining dentin thickness following instrumentation with the Endo Plus M pro and ProTaper rotary systems, utilizing the cutting-edge technology of cone beam computed tomography (CBCT). By employing this technology, the study aimed to evaluate and compare these crucial parameters with remarkable precision and accuracy. This investigation sought to shed light on the performance and outcomes of the Endo Plus M pro and ProTaper rotary systems in terms of their impact on centering ability and remaining dentin thickness, presenting a comprehensive analysis enabled by the advanced capabilities of cone-beam imaging device.

The teeth had been put in addition silicon mold[24] so that the teeth were in identical position during scanning for pre-instrumentation and post-instrumentation records; also, radio density of the addition silicon would not obscure the details of the root canals[25].

By mounting them in that way, teeth of each group can be ensured to be removed and secured back in the exact same position after instrumentation for post-instrumentation imaging.

Lubrication of the instruments during insertion inside the root canals was achieved using EDTA [25] to reduce the stresses from the friction between the dentinal walls and the instrument during preparation, enhancing the instrument efficiency and minimizing the incidence of instrument failure or fracture.

The outcomes derived from the study revealed the absence of any statistically significant distinction observed among the various systems in terms of the change in angle of curvature when different files were utilized. The study demonstrated that all groups exhibited similar performance in regard to minimizing canal straightening. These results underscored the comparable effectiveness of the different systems in maintaining the original curvature of the canal, further emphasizing the significance of this evaluation.

Regarding canal transportation, there was no statistical difference between the three file systems (P=0.112), where all files performed similarly. The Endo Group system showed no statistical difference at between all vertical distances, where the M-Pro system, showed a significant difference where the highest value was at 3mm, and the lowest at 7mm. The Protaper showed a significant difference where the highest value was found at 5mm, and the lowest value was found at 7mm.

Regarding the centering ability, there was no statistical difference between all groups at 3mm, where at 5mm, the Endo Plus group performed better than the ProTaper Group. At 7mm, there was a significant statistical difference where Protaper performed better than Endo Plus files.

The Endo Plus files are Martensite phase heat-treated Ni-Ti golden files with shape memory allowing them to be pre-curved and return to their original straight Shape upon exposure to heat. The unique file structure increases its flexibility while maintaining good cutting efficiency, minimal risk of creating ledges and transportation, and maintaining the original canal anatomy. The kit consists of two (W0) files used as orifice opener with tip size ISO 17 and taper 12 percent. While W1 file is size ISO 18 and taper 5 percent, followed by the W2 files are size ISO 20 with a taper of 4 percent, W3 files with size ISO 20 with a taper of 6 percent, and finally, the W4 file with tip size ISO 25 and taper 6 percent.

The M-pro files are crafted from X-wire, a specially engineered material renowned for its capability of being pre-bent, heightened flexibility, and exceptional resistance to cyclic fatigue. These files are designed with a cross-section of a convex triangle shape, strategically minimizing contact with the canal wall. Additionally, they feature a rounded non-cutting tip, effectively preventing excessive cutting[27]. These unique characteristics enable the M-pro files to navigate various canal curvatures precisely and securely. The file configuration, combined with the specialized fabrication material, ensures a tight fit within the canal, averting any risk of transportation, ledge formation, or perforations. Each M-pro file kit is packaged in a card, comprising two sets, with each set including three files. The file sizes provided are ISO 18 taper 4%, ISO 20 taper 4%, and ISO 25 taper 6%. This comprehensive design and manufacturing approach emphasize the manufacturer's commitment to delivering superior performance while maintaining the integrity and safety of the canal structure.

The ProTaper Universal system distinguishes itself with a uniquely designed convex triangular cross-section, which is purported to enhance dentin cutting efficiency. This Austenitic Ni-Ti system encompasses shaping files that follow a progressive taper sequence, gradually increasing in taper from the tip towards the coronal portion. Conversely, the finishing files exhibit a taper profile that decreases in size. The progressive taper sequence aims to enhance the flexibility of the files in the middle and tip regions, while the decreasing taper sequence focuses on strengthening the files [28]. These design characteristics align with the findings of a prior study by Luo et al. [29], which concluded that the shaping ability of the ProTaper Universal system surpasses that of stainless steel K files. However, caution should be exercised, as noted in a study by Nagaraja et al. [25], particularly when employing the ProTaper Universal system in severely curved canals. The study cautioned that its use may lead to increased canal transportation and thinning of root dentin at the middle and coronal levels. These collective insights emphasize the significance of employing the ProTaper Universal system judiciously, taking into account the specific characteristics and conditions of the treated canals.

The null hypothesis is accepted as the results showed there is no statistically significant difference between the shaping ability of the three groups, although some groups have performed slightly better than others.

CONCLUSION

Considering the specific conditions of this study, it can be deduced that there exists no statistical contrast in the overall shaping ability among the three file systems when evaluating the change of angle of curvature, canal transportation, and centering ability. Despite minor variations in performance observed at different vertical levels, the statistical analysis revealed no significant differences among the file systems. This conclusion underscores the comparable effectiveness of the file systems in achieving the desired outcomes, particularly in terms of shaping ability. These results emphasize the importance of selecting the appropriate file system based on individual case requirements and considerations.

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