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Shaping ability of different NiTi rotary systems during the preparation of printed mandibular molars

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Abstract

This study aimed to evaluate the shaping ability of XP-endo Shaper, TruNatomy and EdgeFile X3 during the preparation of resin-printed mandibular molar mesial root canals. Thirty-three resin-based mandibular mesial roots with two canals, obtained from extracted tooth cone-beam computed tomography (CBCT) image and printed on a three-dimensional (3D) printer, were divided into three experimental groups according to the different nickel–titanium (NiTi) systems used for root canal preparation. The specimens were scanned using CBCT imaging before and after root canal preparation. Then images were registered using a dedicated software and changes in the canal area, volume, untouched canal surface and the maximum and minimum dentine wall wear were calculated. The XP-endo Shaper instruments showed improved shaping ability with lower untouched root canal surface and better preservation of root canal anatomy during the preparation of resin-printed mandibular mesial root canals compared with TruNatomy and EdgeFile X3 systems.

KEYWORDS

3-D printing, EdgeFile X3, printed resin teeth, TruNatomy, XP-endo Shaper

INTRODUCTION

The development of new generation of nickel–titanium (NiTi) systems relies mainly on changes in instrument alloy and design. These modifications are mainly intended to (i) reduce the fracture rate of NiTi instruments and procedural errors, such as canal transportation and ledging (ii) and to optimise the mechanical debridement of root canals, by reducing the areas of untouched canal walls and accumulated hard-tissue debris [1–3]. The XP-endo Shaper (XPS; FKG Dentaire), TruNatomy (TRN; Dentsply Sirona) and EdgeFile X3 (EF; EdgeEndo) are examples of recently launched NiTi systems.

XP-endo Shaper is manufactured using MaxWire alloy, enabling the instrument to transform from martensitic phase at room temperature to austenitic phase at body temperature [4]. The MaxWire alloy permits the file to contract and expand, reaching areas conventional files cannot access [5]. The file has a tip size of 0.30 mm with a 0.01 taper and a booster tip with six cutting edges. This unique design enables files to enlarge the apical diameter at least 0.30 mm with a 0.04 taper. The TruNatomy rotary system is a set of instruments made of a maximum fluted diameter of 0.8 mm NiTi and proprietary heat treatment. The TruNatomy instruments present an off-centred parallelogram cross-section design and variable taper to provide the benefits of improved performance with increased respect to the tooth anatomy during mechanical preparation [6]. The EdgeFile X3 is manufactured using Fire-Wire and possesses the 'Canal Contouring Technology', which according to the manufacturer, improves instrument strength while making it highly flexible and reducing the shape memory and straightening effects when compared to other NiTi systems [7].

Extracted human teeth are undoubtedly the best substrate to reproduce clinical conditions in laboratory studies [8]. However, there are some disadvantages in using such substrate, such as ethical considerations, the possibility of cross-infection risk and the difficulty of obtaining a good number collection to produce anatomically balanced experimental groups that effectively isolate the variable of interest [8]. Nowadays, it is possible to obtain a model of natural teeth with the same external and internal morphology using cone-beam computed tomography (CBCT) and three-dimensional (3D) printing technology. Printed teeth made from extracted teeth have gained the radiopaque feature using adding barium sulphate powder to evaluate the three-dimensional root canal geometry [9]. Thus, it provides the opportunity to compare the shaping abilities of endodontic instruments by standardising them in terms of samples.

The present study aimed to evaluate the shaping ability of XP-endo Shaper, TruNatomy and EdgeFile X3 during the preparation of resin-printed mandibular mesial root canals. The null hypothesis tested was that there would be no significant difference in root canal preparation among these three NiTi rotary file systems.

MATERIAL AND METHODS

Sample size calculation

A power calculation was performed using G*Power 3.1 (Heinrich Heine University, Dusseldorf, Germany) software with $\alpha = 0.05$ and $ß = 0.96$. The calculation indicated that the sample size for each group should be a minimum of 11 roots [10]. Therefore, 11 mesial roots of mandibular molars (22 mesial canals) were included for each group.

Sample preparation

One human mandibular molar was selected after the local ethics committee approval (Ethics Committee of the Dicle University, School of Dentistry Protocol no: 2021-20). After decoronation and resection of the distal root, a size #10 K-file (VDW GmbH) was inserted into the canal until the instrument's tip was just visible at the apical foramen. The root had uncalcified, type IV Vertucci canals (2 separated canals) [11]. The working length (WL) was established 1 mm shorter than that point. After the determination of WL, the root canals were manually prepared with hand files up to size 20 [12], rinsed with distilled water and dried with paper points. The root was scanned using a CBCT (GXDP-700; Gendex Dental Systems) with the following parameters: 90 kVp, 13 mA, exposure time 12 s, a field of view 6 × 8 cm.

The CBCT data (DICOM file) were segmented with the 'Tooth Segmentation' option in RealGUIDE 5.0 software (3diemme Software Corp) and turned into a 3D model. The acquired CBCT scan data were converted into .stl files to use the 3D printer (Ackuretta FreeShape 120, Ackuretta Technologies). 12.5% of barium sulphate powder was mixed with resin (KeyVest, Keystone Ind.) to achieve radiopacity.

Root canal preparation

The roots were inserted into the CBCT by designing cylindrical bases that are precisely compatible with the produced models. Due to the cascading design, the models were not confused during CBCT scan. The apical foramen was blocked using modelling wax. All instrumentation was performed by a single experienced endodontist.

The instruments were used according to the manufacturers' instructions for each system. A new instrument was used for four root canal preparations. All instruments were operated using an endodontic motor (VDW Gold, VDW, Munich, Germany). During root canal preparation, in all the samples, instruments and distilled water for irrigation were kept in a water bath at 37 ± 1°C to simulate the clinical conditions while also allowing the XP-endo Shaper instrument shape transformation. A total of 20 ml of distilled water was used for irrigation with a 30-G TruNatomy irrigation needle (Dentsply Sirona) taken up to 2 mm short of the WL between the use of each instrument in all groups. Apical patency with a size #15 K-file was also performed between the use of each instrument.

XP-endo Shaper group

The XP-endo Shaper instrument was operated at 1000 rpm and 1 Ncm torque. The instrument was used performing a pecking motion movement with a 4-mm amplitude until the WL was reached. Once it reached the WL, the instrument was removed from the canal, cleaned with sterile gauze and reintroduced. This procedure was repeated, totalising three cycles. A gutta-percha cone size 30, 0.04 taper was placed to WL to confirm the completion of canal instrumentation.

TruNatomy group

After the enlargement of the coronal third with the TruNatomy Orifice Modifier (size 20, 0.08v taper), root canals were prepared with Glider (size 17, 0.02v taper) and Prime (size 26, 0.04v taper) instruments taken up to the WL. All instruments were used at 500 rpm and 1.5 N.cm torque.

EdgeFile X3 group

Root canals were prepared with EdgeFile X3 C1 (size 20, 0.06 taper) and C2 (size 25, 0.06 taper) taken up to the WL. Instruments were used at 300 rpm and 2 N.cm torque.

3D modelling and evaluation

After root canal preparation, the root canals were dried with absorbent paper points and the teeth were submitted to a new CBCT scanning. Then, DICOM images were rendered 3D in RealGuide software again. Finally, the 3D rendered models were overlaid with the .stl file of the unprepared model in Rapidform software (INUS Technology, Inc.). After superpose, only the 3D version of the canals was obtained, and the differences between root canals before and after preparation were evaluated (Figure 1). The changing canal area (Δ canal area), changing canal volume (Δ canal volume), untouched canal surface area and maximum–minimum dentine wall wear parameters were calculated with Rapidform software by an experienced operator (Figure 2).

Statistical analysis

The normality of the data was tested with Shapiro–Wilk. Mean and standard deviations were calculated for each group. The Δ canal area, Δ canal volume, maximum dentine wall wear and untouched canal surface area parameters were compared using one-way ANOVA and Tukey test, while the minimum dentine wall wear parameter was analysed with the Kruskal–Wallis *H*-test. The level of significance was set at $p < 0.05$.

RESULTS

Table 1 shows the mean and standard deviations regarding the parameters in each group. The Δ canal area and Δ canal volume were significantly higher in the XP-endo Shaper group than in the TruNatomy and EdgeFile X3 groups ($p < 0.001$). Moreover, the untouched canal surface area was significantly lower in the XP-endo Shaper when compared to the TruNatomy and EdgeFile X3 groups ($p < 0.05$). However, no differences in the Δ canal area, Δ canal volume and untouched canal surface area were observed between TruNatomy and EdgeFile X3 groups ($p > 0.05$). While the minimum dentine wall wear was significantly higher in the XP-endo Shaper group than in the TruNatomy and EdgeFile X3 groups ($p < 0.05$), no difference was observed regarding maximum dentine wall wear values between the three tested groups ($p > 0.05$).

DISCUSSION

The present study aimed to compare the shaping ability of 3 NiTi rotary files with a different design, taper, cross-section and NiTi alloy. Despite striking differences, TruNatomy and EdgeFile X3 showed an overall similar shaping ability as no differences were observed among them, for all evaluated parameters. However, XP-endo Shaper showed major differences in almost all outcomes when compared to the other groups. Therefore, the null hypothesis tested was rejected in the present study.

In the present study, the XP-endo Shaper instrument led to lower unprepared area (36 ± 5%) after instrumentation of mesial canals of mandibular molars. Similar values were also observed in previously published studies using micro-CT technology [4, 13]: De-Deus et al. [4] showed 31.82% of untouched surface area when the XP-endo Shaper was used as recommended by the manufacturer, and Pérez-Morales showed 42% of untouched surfaces after preparing mandibular mesial root canals. The XP-endo Shaper instrument has an adaptive core and an extra-flexible non-tapered structure, which creates a preparation according to the anatomy of the root canal during preparation [14]. Previous studies pointed out to a non-standard taper ranging from 0.04 to 0.08, in different canal thirds after XP-endo Shaper preparation [14, 15]. These differences are probably due to the properties of the XP-endo Shaper in expanding and contracting according to canal anatomy, which allows for more significant contact with root canal walls [14]. These properties also explain the higher Δ canal area and volume observed for XP-Endo Shaper. Interestingly, while no differences were observed among the instruments for the maximum dentine wall wear, the minimum dentine wall wear was higher in the XP-Endo Shaper group. Taken together, these results clearly demonstrates that while XP-Endo Shaper reduced the untouched surface area and increased root canal area and volume, its intrinsic properties did not generate an exaggerated wear, respecting better the root canal anatomy. No differences were observed between TruNatomy and EdgeFile X3 systems. While some differences are present in the NiTi alloy, design and taper, the similarity between both systems may be explained by the off-centred cross-sectional design of the TruNatomy, which, unlike the conventional concentric design as in the EdgeFile, creates a snake-like motion that

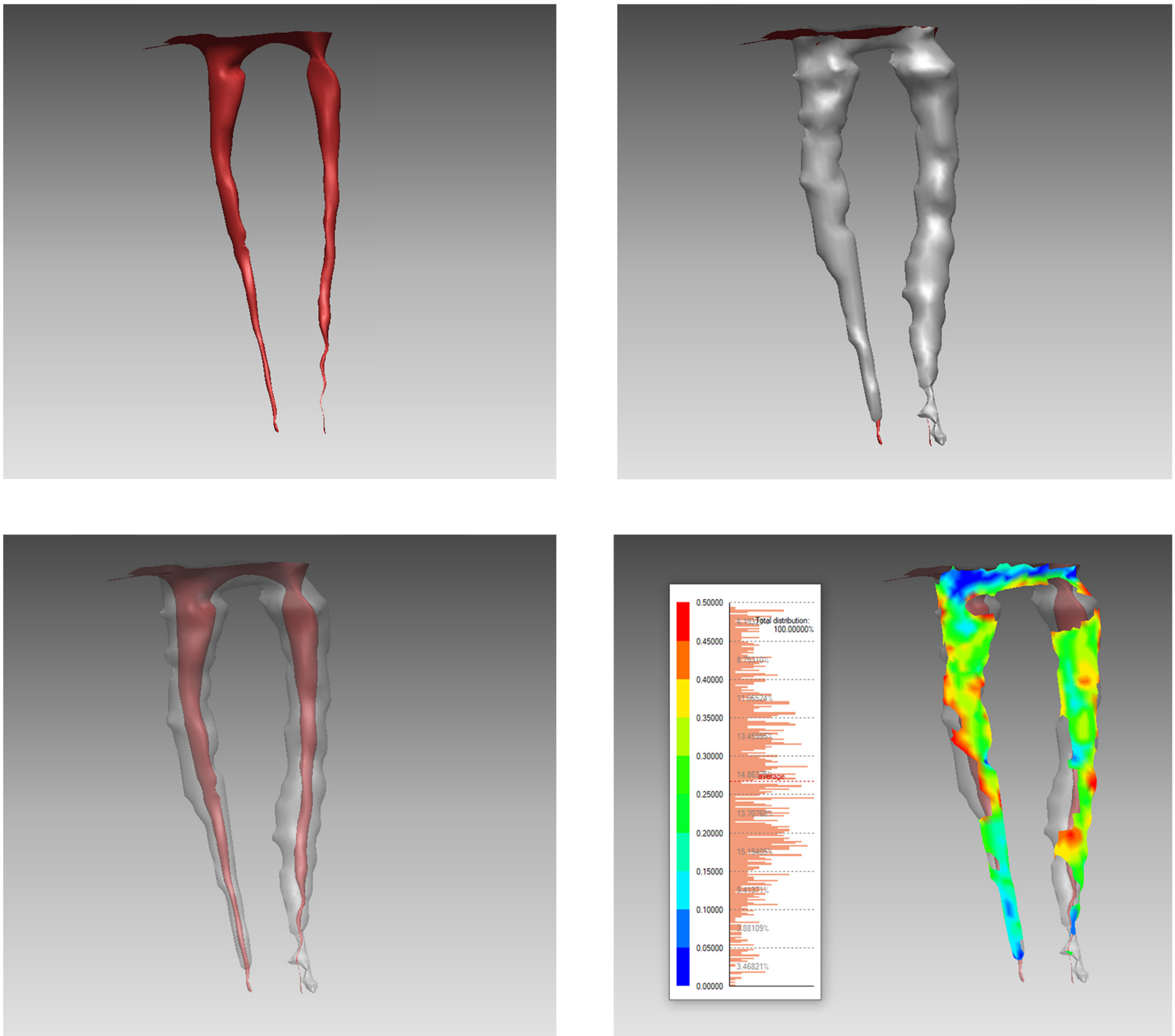

FIGURE 1 Root canal preparation analysis in the superposition of the pre-and post-preparation of the root canals. The coloured map shows the dentine wall wear (minimum blue, maximum red)

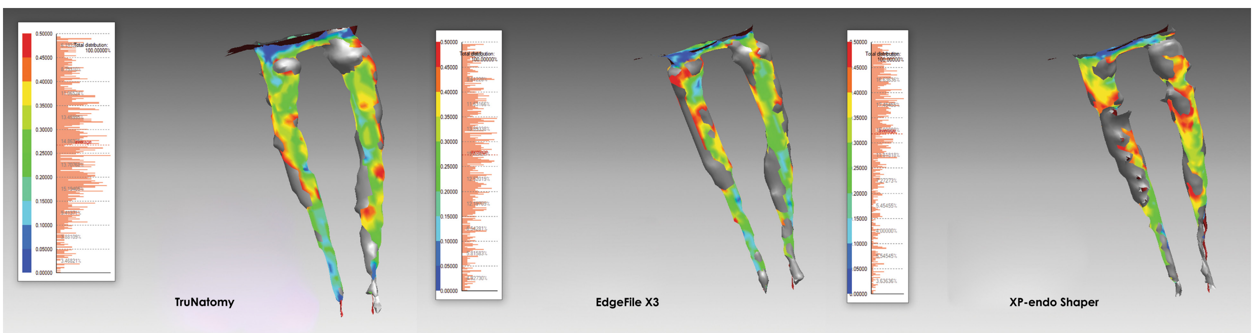

FIGURE 2 Software superpose images of root canals before and after preparation; TruNatomy, EdgeFile X3, XP-endo shaper

allows the instrument to touch in more canal walls even having smaller dimensions. It is important to emphasise that, regardless of the improvements in the metallurgical characteristics and design of these instruments, none of the tested NiTi systems tested was able to touch all surface of the canal walls [10, 15]. The potential impact of unprepared canal walls on endodontic prognosis is a main concern and further developments should try to solve this problem.

TABLE 1 Mean and standard deviations of canal area, canal volume, maximum dentin wall wear and untouched canal surface; and median, minimum and maximum values of minimum dentin wall wear in the different experimental groups

Parameters	XP-endo Shaper	TruNatomy	EdgeFile X3
Canal area (mm^2)			
Initial	51.51	51.51	51.51
After instrumentation	108.43 ± 4.98	90.81 ± 8.14	93.88 ± 7.52
Δ[a]	56.91 ± 4.98[a]	39.29 ± 8.14[b]	42.37 ± 7.52[b]
Canal volume (mm^3)			
Initial	13.63	13.63	13.63
After instrumentation	31.92 ± 3.55	21.73 ± 4.72	22.16 ± 2.01
Δ[a]	18.29 ± 3.55[a]	8.1 ± 4.72[b]	8.53 ± 2.01[b]
Dentin wall wear (mm)			
Minimum[b]	0.0009 (0.0002–0.0049)[a]	0.0002 (0.0001–0.0008)[b]	0 (0–0.0007)[b]
Maximum[a]	0.2740 ± 0.0054[a]	0.2675 ± 0.0095[a]	0.2709 ± 0.0096[a]
Untouched canal surface (%)[a]	36 ± 5[a]	52 ± 5[b]	48 ± 2[b]

Note: Different superscript letters in a row indicate statistical significance ($p < 0.05$). Δ: The changing amount of parameter.

[a]One-way ANOVA.

[b]Kruskal–Wallis *H*-test.

One of the most critical limitations of the shaping ability studies in the literature is that it is impossible to standardise natural teeth. To provide standardisation in this study, a resin model was obtained from a CBCT scan image obtained from natural human teeth. Thus, the length of the root canal, its apical diameter and thickness could be standardised. Furthermore, standardisation of canal morphology in each sample increases validity and eliminates potential biases that could confuse between-group results [16]. Reymus et al. [9] reported that the significant benefits of 3D-printed teeth are good standardisation of tooth and canal shape and dimensions before preparation, especially those with complex and rare anatomy way [8].

Researchers preferred using lower molars due the anatomy of the mesial root canals and the concave and convex irregularities in the canal surface [17]. In the present study, all the instrumentation was performed by one experienced operator to minimise confounding factors. Moreover, all procedures were performed at 37 ± 1°C as heat-treated NiTi instruments mechanical properties, especially those of XP-Endo Shaper, can be affected by temperature changes [14]. Due to the standard dentine thickness of all resin models, the temperature was equalised in all groups. This is an additional advantaged of the current methodological design as differences in dentine thickness along the root canal wall can cause uneven temperature absorption within the canal [18]. It is almost impossible to standardise the dentine thickness in studies with extracted human teeth. However, it is important to emphasise that temperature changes are different in dentine and resin substrate, and this can be a disadvantage of the present setup.

Since the resolution of the resin layers used in the 3D printer is between 16 and 32 µm, the initial diameter of the root should not be less than ISO 15 size [19]. Therefore, in the present study root canals were prepared with a size 20 K-file before the CBCT scan. There are discussions in the literature about the difference in radiopacity and hardness between resin and human dentine [19, 20]. However, Reymus et al. reported that none commercially available ones could mimic human dentine in hardness and radiopacity.

CONCLUSIONS

The XP-endo Shaper instruments showed improved shaping ability with lower untouched root canal surface and better preservation of root canal anatomy during the preparation of resin-printed mandibular mesial root canals when compared to TruNatomy and EdgeFile X3 systems.

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The authors deny any conflicts of interest related to this study.

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