Original Article

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Three-dimensional Analysis of the Shaping Characteristics and Ability of a Novel Ni-Ti Rotary File

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Abstract

Purpose: To compare the shaping characteristics and ability of the JIZAI (JZ) Ni-Ti rotary file to two other Ni-Ti files that have a similar operating environment to JZ, HyFlex CM (HCM) and ProTaper Next (PTN).

Methods: Root canal preparation was performed in a J-shaped canal model using the three file systems (n=4), and dental cone-beam computed tomography (CBCT) was performed. The three-dimensional images were superimposed before and after instrumentation at the same position. The X-, Y-, and Z-axes were set 1 mm coronal to the root apex, and the cross-sectional morphology, the extent of transportation, and the volume of the shaped root canal wall were evaluated.

Results: The cross-sectional morphology of the root canal was round, similar to the original root canal morphology with JZ and PTN. The HCM showed an elliptical tendency toward the sagittal direction. The transportation was relatively larger with JZ and smaller with HCM, with no significant difference between the files. The shaped root canal wall volume was greatest with HCM and least with JZ, with no significant difference between the files.

Conclusion: JIZAI had equivalent shaping ability to HyFlex CM and ProTaper Next in terms of transportation and shaped root canal wall volume, and therefore might be useful for safe preparation of root canals.

Key words: Ni-Ti rotary files, root canal preparation, three-dimensional imaging

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Introduction

Ni-Ti alloy files (Ni-Ti files) are commonly used to prepare curved root canals[1]. Compared to conventional stainless-steel files, Ni-Ti files have greater flexibility and closely follow the path of the root canal due to a lower modulus of elasticity. The root canal is often curved in the apical third of the root. A stainless-steel file of size #35 or more does not have sufficient flexibility, and therefore tends to deviate from the original canal pathway, resulting in transportation of the canal center and the formation of a ledge or zip. Conventionally, transportation towards the outer side and inner side of the curvature has been used to evaluate the shaping ability of Ni-Ti files[2–5].

The low elastic modulus and breaking torque of Ni-Ti files lead to instrument separation. Therefore, endodontic files should have flexibility and high fracture resistance. This has been achieved through heat treatment of the austenite phase of conventional Ni-Ti alloys[6,7]. One such file is HyFlex CM (HCM; Coltene, Langenau, Germany). This file comprises the R and martensite phases resulting from heat treatment. When inserted into a curved root canal, the file does not return to its original shape due to its super elasticity, and no load is applied to the file[8,9]. In 2012, the ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) file was introduced; the offset design of the file prevents it from biting into the dentin, thereby preventing separation[10]. The file is fabricated using M-wire, which is martensitic at room or body temperature, austenitic at 43–50℃, and returns to the martensitic phase when cooled, resulting in flexibility[11–13]. Recently, a file with even greater flexibility has been manufactured through electrical discharge machining[5,14]. A new Ni-Ti file, JIZAI (JZ; Mani, Tochigi, Japan), which was recently launched in Japan, comprises the R and/or martensite phase at room or body temperature and is used in a unidirectional rotation mode[15]. Single-length preparation was performed using two files: #25/0.04 and #25/0.06. This file alleviates one of the drawbacks of Ni-Ti files, namely the screw-in-effect due to the cross-sectional shape with a land like an irregular rectangle with a circular arc on one side[16,17].

To date, a wide range of Ni-Ti files have been introduced, and research has chiefly focused on their flexibility and ability to follow the root canal path. Shaping ability is two-dimensionally (2D) evaluated by superimposing radiographs obtained before and after root canal preparation[2–5]. On the other hand, Peters et al.[18] evaluated the surface area of the root canal by three-dimensional (3D) analysis, and observed that the Ni-Ti file did not contact ≥35% of the root canal surface area. Therefore, 2D evaluation is not sufficient to explore the true shaping abilities before and after root canal preparation. In this study, we investigated the shaping characteristics and ability of JZ through a 3D analysis, and compared the findings with those of HCM and PTN, which are similar to JZ in terms of the mode of rotary motion, number of files used, point size, and taper.

Materials and Methods

1. Ni-Ti files and models

We used the following three types of Ni-Ti files (21 mm): JZ, #25/0.04 and #25/0.06; PTN, #17/0.04–0.075 and #25/0.06–0.07; and HCM, #15/0.04 and #25/0.06. J-shaped epoxy resin transparent root canal models (Dentsply Sirona, York, PA, USA; curvature, 30°; apical foramen diameter, #10; root canal taper, 0.02; root canal length, 17.0 mm; n=4) were used for root canal preparation. A root canal model which did not undergo any instrumentation was used as the control.

2. Root canal preparation

The operator was a dentist with 5 years of experience using Ni-Ti files. The working length of the root canal was determined using a #10 stainless steel K (SSK; Mani) file. After setting the working length to 17 mm and preparing a glide path with #15 and #20 SSK, the root canal was prepared using two types of files in each group. An endodontic motor, Tri Auto ZX 2 (J. Morita Corp., Tokyo, Japan), was used with the auto-reverse setting. Root canal preparation was performed by inserting the file in the root canal three times with light pressure with continuous rotation of the file such that the root length shaped per insertion did not exceed 3 mm. The rotation speed and torque used were 300 rpm and 3 N (JZ), 300 rpm and 2 N (PTN), and 500 rpm and 2.4 N (HCM), respectively, according to the manufacturer's recommendations. The root canal was irrigated with distilled water using a syringe. Recapitulation with a #10 SSK was performed to avoid clogging of the root apex with debris. This cycle was repeated until the sec-

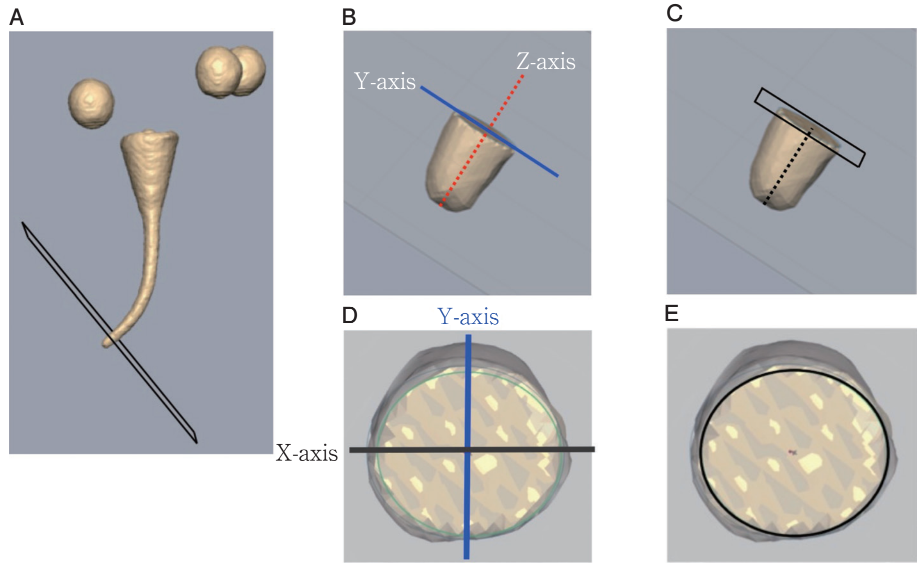
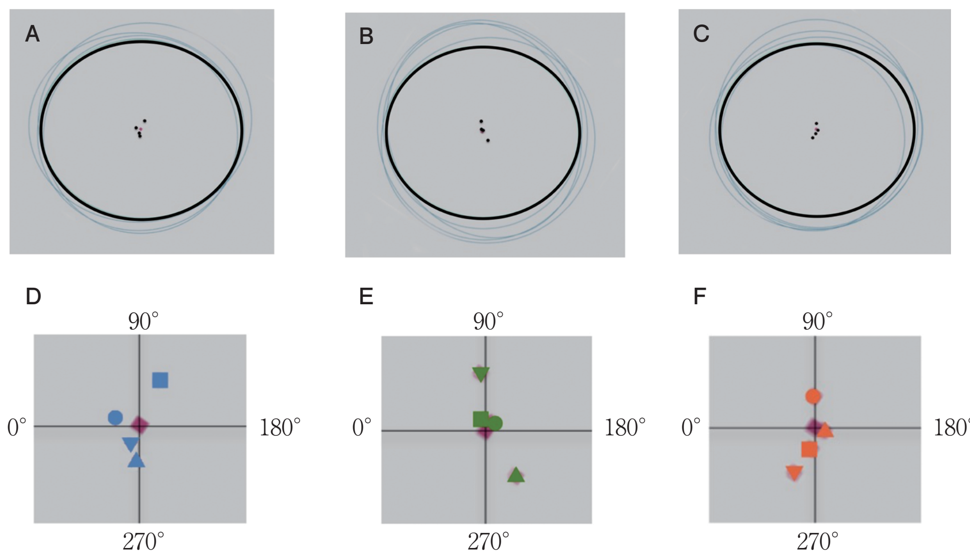


Fig. 1 Three-dimensional analysis of the models after root canal preparation
Covers with three spherical reference points were placed on the models, and dental CBCT was performed (A). The Z-axis (axial) was set to pass through the center of the root canal and apex 1 mm coronal to the apex and the corresponding root cross-section was considered the reference plane (B, C). The Y-axis (sagittal) was set along the direction of internal and external curvature perpendicular to the Z-axis (B, D), and the X-axis (coronal) was set perpendicular to the Y-axis (D). The intersection of the X-, Y-, and Z-axes was considered the shaping center (after instrumentation), and the canal center (before instrumentation) (E).

ond file reached the working length.

3. Dental cone-beam computer tomography (CBCT) and 3D analysis

Dental CBCT (3D Accuitomo F17, J. Morita Corp.) was performed to obtain 3D data before and after root canal preparation. A radiopaque material, Calcipex II (Nippon Shika Yakuhin Co., Ltd., Yamaguchi, Japan), was placed in the root canal using a syringe and accessory tip provided by the manufacturers. To prevent dead space in the model, the extrusion of Calcipex II from the apex was confirmed, and the syringe with the accessory tip was tightly inserted into the root canal orifice. The imaging conditions for dental CBCT were as follows: voxel size, 125 μm; 50 kW; 1.0 mA. A cover with three spherical reference points (Fig. 1A) was attached to each model prior to dental CBCT imaging. These covers were made from a room-temperature polymerizing resin (Fixpeed, GC Corp., Tokyo, Japan) and Scanning Resin (Yamahachi Dental Mfg. Co., Aichi, Japan), a radiopaque instant polymerizing resin. The 3D data were reconstructed using ZedView Ver. 9.0 3D planning software (ZedView, LEXI Co. Ltd., Tokyo, Japan) and displayed as images using Geomagic Freeform (3D Systems Inc., Rock Hill, SC, USA) (Fig. 1). The reference plane for evaluation was set 1 mm coronal to the apex, and the Z-axis (axial) was set as that passing through the center of the root canal and apex (Fig. 1B, C). In addition, the Y-axis (sagittal) was set as the direction of internal and external curvature perpendicular to the Z-axis, and the X-axis (coronal) was set perpendicular to the Y-axis (Fig. 1B, D). The intersection of the X-, Y-, and Z-axes was set as the shaping center, and the cross-section was considered the reference plane (Fig. 1E). The top part of Fig. 1E represents the inner curvature, while its bottom part represents the outer curvature. The distance of canal center transportation and the volume of the shaped root canal wall were calculated after superimposing the 3D data before and after root canal preparation using Geomagic Freeform (3D Systems Inc.). In addition, the angle of canal center transportation was measured by setting the internal curvature direction from the X-axis to 0–180°and the external curvature direction to 180–360°.



Sample	Angle
●	18
▲	274
■	111
▼	294

Sample	Angle
●	113
▲	241
■	86
▼	83

Sample	Angle
●	88
▲	193
■	281
▼	294

Fig. 2 Three-dimensional analysis of root canal formation with three types of files (n=4)
Shaping cross-section with JZ (A), HCM (B), and PTN (C). The black line indicates the original root canal before instrumentation, and the blue line indicates the shaped root canal wall after instrumentation (A–C). The canal center transportation with JZ (D), HCM (E), and PTN (F). The angle of canal center transportation was measured by setting the internal curvature direction from the X-axis to 0–180° and the external curvature direction to 180–360°, as shown at the bottom of each figure.
JZ, JIZAI Ni-Ti rotary file ; HCM, HyFlex CM Ni-Ti rotary file ; PTN, ProTaper Next Ni-Ti rotary file

4. Statistics

Median values of transportation of the canal center and volume of the shaped root canal wall for each group were analyzed by the Kruskal-Wallis test (Bell-Curve for Excel, Social Survey Research Information Co., Ltd., Tokyo, Japan) to identify significant differences. A p-value of <0.05 was considered to be statistically significant.

Results

We examined the cross-sectional morphology of the root canal following preparation with JZ, HCM, and PTN as an evaluation of the 3D shaping characteristics. The cross-section of the root canal tended to be circular following preparation with JZ and PTN (Fig. 2A, C), similar to that in the control model. It tended to be elliptical after preparation with HCM, with the major axis along the Y-axis (Fig. 2B).

Next, we investigated the 3D characteristics and ability of the canal center transportation based on the file used. Although none of the files showed a tendency for deviation in a specific direction as shown in Fig. 2D, E, and F, the canal center transportation along the X-axis was the least with PTN (Fig. 2F). There was no characteristic transportation of the canal center along the Y-axis. As shown in Fig. 3A, the median value of transportation of the canal center was the largest with JZ and the least with HCM; however, no significant differences were observed between the files.

Further, we examined the volume of the shaped root canal wall as an evaluation of the shaping ability. As

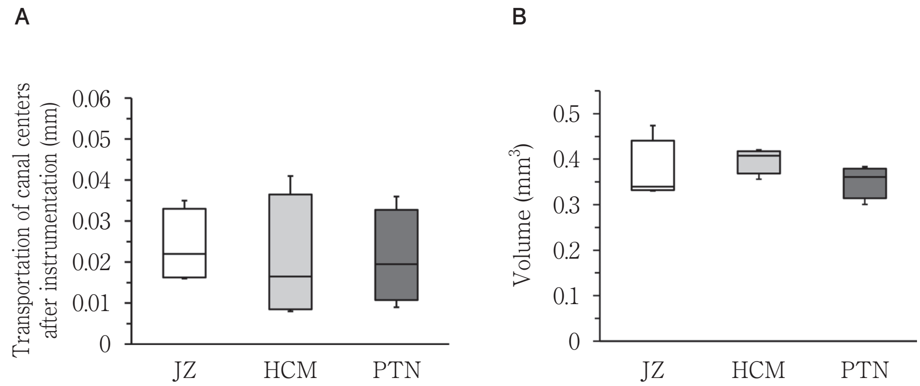


Fig. 3 Three-dimensional analysis of the canal center transportation and the volume of the shaped root canal wall at 1 mm coronal to the apex (n=4)

The distance of canal center transportation (A) and the volume of the shaped root canal wall (B).

JZ, JIZAI Ni-Ti rotary file ; HCM, HyFlex CM Ni-Ti rotary file ; PTN, ProTaper Next Ni-Ti rotary file

shown in Fig. 3B, the median value of volume was the largest with HCM and the least with JZ, with no significant difference between the files.

Discussion

In this study, we analyzed the shaping characteristics and ability of three types of Ni-Ti files, including a new file. It has been observed that approximately ≥35% of the root canal surface area does not contact the Ni-Ti file during preparation[18]. This fact prompted us to think of using 3D analysis to evaluate the shaping characteristics and ability. Therefore, we performed 3D analysis using highly accurate CBCT images.

A previous 3D analysis[19] showed that the extent of sagittal deviation was greatest at 1 mm coronal to the apex. Therefore, in this study, we analyzed the canal center transportation, the cross-sectional morphology, and the volume of the shaped root canal wall 1 mm coronal to the root apex. There was no significant difference in the median value of transportation of the canal center between the files, but JZ was the largest among all files. However, a 2D evaluation by Nakatsukasa et al.[15] at 1 mm coronal to the root apex showed that the extent of deviation with JZ was slightly smaller but not significantly different from that with PTN. This discrepancy might be explained by the fact that the evaluation equivalent to the Y-axis (sagittal) transportation in this study was carried out by 2D analysis. In our 3D analysis, we evaluated both the X-axis (coronal) transportation and the Y-axis transportation. We found that the Y-axis transportation was similar between the two files, whereas the X-axis transportation tended to be larger with JZ than with PTN.

On the other hand, HCM showed the least average transportation of the canal center but the largest amount of root canal wall removal. Compared to the other two files, the cross-section of HCM is slightly elliptical, with the long axis in the Y-axis direction of the inner and outer curvature. A previous micro-computed tomography study on the extent of transportation in the direction of the internal and external curvature found smaller deviation with HCM than with PTN[19], which is consistent with the present results. The cross-section of the blade of HCM is triangular, that of PTN is rectangular, and that of JZ is irregularly rectangular. PTN and JZ have an offset design in which the rotation axis is away from the center of their cross-section[10,16,17]. On rotation, this creates a wave-like motion that enables shaping of the root canal wall in three dimensions. HCM is not a land type, and the rake angle of the file is large[8,9]. The present results do not clarify whether there is a relationship between the movement of the file during shaping and the morphology of the shaping surface. However, in clinical settings, the canals should be carefully shaped when there is a risk of perforating the side of the inner curvature, which is considered a danger zone. Therefore, clarifying the shaping characteristics of the file through a 3D analysis can help prevent endodontic procedural accidents. Regarding the morphology of the shaping cross-section, we believe that the ideal shape is that of the control model, which resembles the original root canal morphology. JZ and PTN showed similar X- and Y-axes deviations and shaping cross-sections as those of the original root canal. However, relatively less shaping along the X-axis was observed with HCM, which showed a large deviation along the Y-axis. In the case of such a shape, for example, in cases requiring endodontic retreatment, residual infected dentin may be present due to inadequate canal preparation during the initial treatment. Therefore, selecting the Ni-Ti file based on each case may be necessary. Specifically, in buccolingually compressed root canals, selecting JZ or PTN may be helpful for adequate canal preparation.

The manufacturer recommends using a brushing motion for PTN and a light pecking motion for JZ and HCM. In this study, all three groups were operated with a light pecking motion, and the shaping characteristics were analyzed under conditions that excluded the possibility of the difference in motion affecting the results. Therefore, if the PTN is operated using the motion recommended by the manufacturer, it is possible that the results of this experiment may not match.

The shaping characteristics of Ni-Ti files have been evaluated with dental CBCT and micro-computed tomography with high resolution[20,21]. Placement of reference points is necessary for 3D superposition; however, no well-defined method has been reported yet. In this study, we fabricated a cover to standardize the spheres made of radiopaque Scanning Resin that serve as three reference points, and used it during CBCT imaging.

Conclusions

In this study, we examined the 3D extent of canal center transportation and the morphology of the shaping cross-section, and the volume of shaped root canal wall following preparation with JZ, a Ni-Ti file recently introduced in Japan. The results of 3D analysis revealed that JZ had equivalent shaping ability to HCM and PTN. Therefore, JZ might be useful for safe preparation of root canals.

Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest related to this manuscript.

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