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Original Research Article

CBCT assessment of dentin thickness of lower incisors after shaping with NiTi instruments – *in vivo* study

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Abstract: Remaining root dentin thickness plays a key role in the longevity of endodontically treated teeth. ***Purpose:*** The aim of this study was to compare the root canal wall thickness in the danger zones of mandibular incisors before and after their instrumentation with two different NiTi rotary systems by means of CBCT. ***Methodology:*** Thirty lower incisors of patients aged 45 – 55 years underwent primary endodontic treatment with two NiTi files systems: ProTaper Universal and WaveOne Gold. The changes of the root canal thickness in the danger zones of the incisors were investigated by two CBCT scans – one at the beginning of the experiment and the other after the shaping of the root canals. ***Results:*** Shaping of the root canals of lower incisors with the two NiTi systems significantly decreased the mesio-distal root dentin thickness in all root canal levels when compared with the baseline values ($p \leq 0.001$). NiTi files from both experimental groups removed substantially more root dentin in the coronal portion of the root than in the apical ($p < 0.05$). The intergroup comparison between the two tested NiTi systems revealed no statistically significant difference in their performance at the three observation levels ($p > 0.05$). ***Conclusions:*** Both NiTi systems performed equally and removed dentin more aggressively in the coronal portion of the root. Further clinical experiments are necessary to find the minimally invasive endodontic systems for an optimal preservation of root dentin in the danger zones of mandibular incisors.

Keywords: CBCT, danger zone, lower incisors, ProTaper Universal, WaveOne Gold.

INTRODUCTION

Shaping of the root canal system causes an inevitable loss of coronal and radicular dentin (Rajkumar B *et al.*, 2016). Remaining dentin thickness affects the long-term survival of endodontically treated teeth (Rajkumar B *et al.*, 2016; Chaudhary NR *et al.*, 2018; Sai Kiran Reddy P *et al.*, 2020; Suneetha MG *et al.*, 2020; Tamse A, 1988). Despite the wide-spread use of nickel-titanium (NiTi) rotary instruments in the course of a root canal therapy, their effect onto the original root canal anatomy should be further analysed. Several authors claim that their design, mechanical properties and manufacturing technology define to some extent the amount of the removed dentin (Rajkumar B *et al.*, 2016; Bellucci C & Perrini N, 2002). Others state that the geometry of the root canal prior its instrumentation plays a key role in the changes of root canal thickness (Peters OA *et al.*, 2001; Akhlaghi NM *et al.*, 2010).

The danger zone of the root is defined as the one with the least thickness of the root canal wall (Zhou G *et al.*, 2020). Katz *et al.*, claimed that oval roots, exhibiting greater bucco-lingual diameter compared to their proximal thickness, are more susceptible to weakening of the root canal wall after instrumentation. The excessive removal of dentin structure in these areas might initiate dentinal defects and fractures. Such morphology is inherent in upper and lower premolars, mesial roots of lower molars and lower incisors (Katz A & Tamse A, 2003). In their study Versluis *et al.*, (2006) established a relationship between the type of the root canal and stress accumulation after shaping with engine-driven files. The finite element analysis of lower

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incisors showed that the outer mesial and distal root surfaces of oval roots are characterized with a moderate concentration of stress after an endodontic therapy (Versluis A *et al.*, 2006).

Most of the experiments assessing the remaining dentin thickness in the critical zones, analyse the mesial roots of lower first molars (Zhou G *et al.*, 2020; Dhingra A & Parimoo D, 2014; Keles A *et al.*, 2020; Sauáia TS *et al.*, 2010; Tabrizizadeh M *et al.*, 2010; Zuckerman O *et al.*, 2003) and lower premolars (Suneetha MG *et al.*, 2020; Pilo R & Tamse A, 2000; Jain A *et al.*, 2018). Few researchers have investigated the anatomical thickness of root canal wall of lower incisors and traced the changes in this parameter after a regular endodontic treatment (Tamse A, 1988; Katz A & Tamse A, 2003; Akhlaghi NM *et al.*, 2015; Khedmat S *et al.*, 2015). The major deficiency of the previous *in vitro* studies in this field is the inability to resemble the clinical conditions accurately. Tooth inclination and position in the dental arch might result in different amount of removed root canal dentin when compared to that registered in *in vitro* experiments (Singh S *et al.*, 2019). To the best of our knowledge, no other authors have clinically investigated the root canal wall thickness of lower incisors throughout endodontic treatment. Thus, the aim of the current study is to compare the root canal wall thickness in the danger zones of mandibular incisors before and after their instrumentation with two different NiTi rotary systems by means of cone-beam computed tomography (CBCT).

MATERIAL AND METHODS

Thirty lower incisors that needed primary endodontic treatment of patients aged 45 – 55 years were included in the experiment. All participants signed informed consent prior the beginning of the therapy. The Research Ethics Committee of Medical University Sofia, Sofia, Bulgaria approved the experiment with a protocol №838/05.03.2020.

The changes in the root dentin thickness were assessed by means of CBCT device Planmeca ProMax 3D Mid *(PLANMECA OY, Helsinki, Finland)*. The first scan was performed prior to the endodontic treatment. Only the segment, containing the teeth of interest, was scanned. Afterwards, the images were collected and analyzed by a dedicated software Planmeca Romexis® Viewer *(PLANMECA OY, Helsinki, Finland)*. Three measurements of the remaining dentin with a step of 1 mm were done at each root canal third – apical, middle and coronal, respectively. The thickness of the root canal wall in the critical zone was measured in mm by calculating the mesio-distal distance from the canal lumen to the outer surface of each proximal wall. The values obtained from each root canal third were averaged.

The negotiation of the root canal and creation of a glide path was performed manually by stainless-steel K-file ISO 10 and 15 (*Dentsply Sirona Endodontics, Ballaigues, Switzerland)* and the working length (WL) was determined by ProPex Pixi Apex Locator (*Dentsply Sirona Endodontics, Ballaigues, Switzerland)*. The shaping was carried out with endo motor X-Smart Plus (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) following the manufacturer's instructions for speed and torque for each of the rotary NiTi file system.

During the endodontic treatment Glyde (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) was used as a chelating agent. Root canals were irrigated with 2% NaOCl and 0.9% NaCl with 27G endodontic irrigation needles. Flutes of the files were cleaned regularly and checked for signs of wear and distortion. Each set of files was used per three root canals.

The teeth were randomly and equally divided into two experimental groups (n=15), according to the NiTi system used for the shaping of the root canal system:

Group 1: ProTaper Universal (Dentsply Sirona Endodontics, Ballaigues, Switzerland) - Sx, S1, S2 and F1 (20/.07)

Group 2: WaveOne Gold Small – 20/.07 (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*)

After the chemo-mechanical treatment of the root canals the teeth were temporarily sealed with Citodur Hard *(DoriDent, Wien, Austria)* and the second CBCT scan was performed. The averaged values were compared to the baseline measurements and statistically analysed.

Root canals were obturated with a single-cone technique by using calibrated gutta-percha cones for each NiTi system and AH Plus (*Dentsply DeTrey, Konstanz, Germany*) sealer. The endodontic access cavities were filled with Ceram X Sphere Tec (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*).

The data were tabulated and statistically analysed by IBM SPSS Statistics 23.0 software (*International Business Machines Corporation, New York, NY, USA*).

RESULTS

The overall number of images after the two CBCT scanning procedures of all 30 lower incisors was 540 (270 after each scan). Three measurements were done in each root canal third and the values were averaged (Fig. 1, Fig. 2). The change of the proximal dentin thickness was assessed by comparison of the pre- and postoperative values.

Table 1 shows the mean and standard deviation of the mesio-distal values for root dentin thickness at the beginning of the experiment and after the endodontic treatment with the tested systems. The measurements were calculated for each root third – apical, middle and coronal, respectively. The change of this parameter was reported in mm and as a percentage (Table 1).

Our results showed that the shaping of the root canals of lower incisors with the two NiTi systems significantly decreased the mesio-distal root dentin thickness at all root canal levels when compared with the baseline values (Paired samples T-test, $p \leq 0.001$).

We noticed a statistically significant difference in the change of the root dentin thickness in the different root canal thirds. NiTi files from both experimental groups removed substantially more root dentin in the coronal portion of the root than in the apical ($p<0.05$). Instrumentation with WaveOne Gold preserved the root dentin in the middle third to a greater extent than in the coronal level (Table 1).

The intergroup comparison between the two tested NiTi systems revealed no statistically significant difference in their performance at the three observation levels (Independent Sample T-test, $p>0.05$) (Table 2).

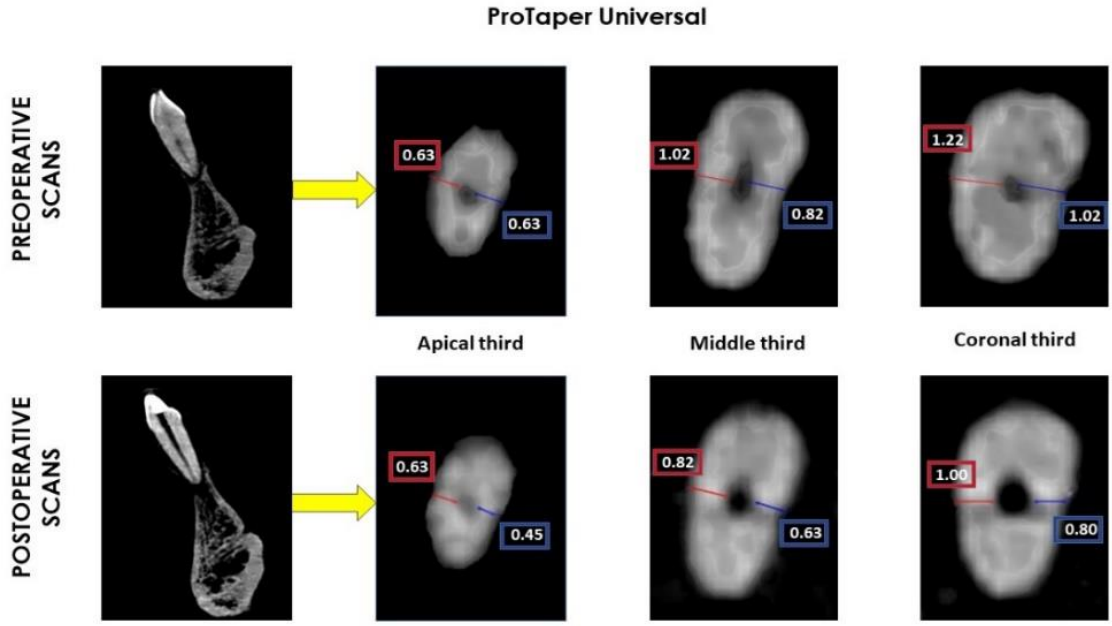

Fig. 1: CBCT assessment of the remaining root dentin thickness in the danger zone of lower incisors after shaping with ProTaper Universal

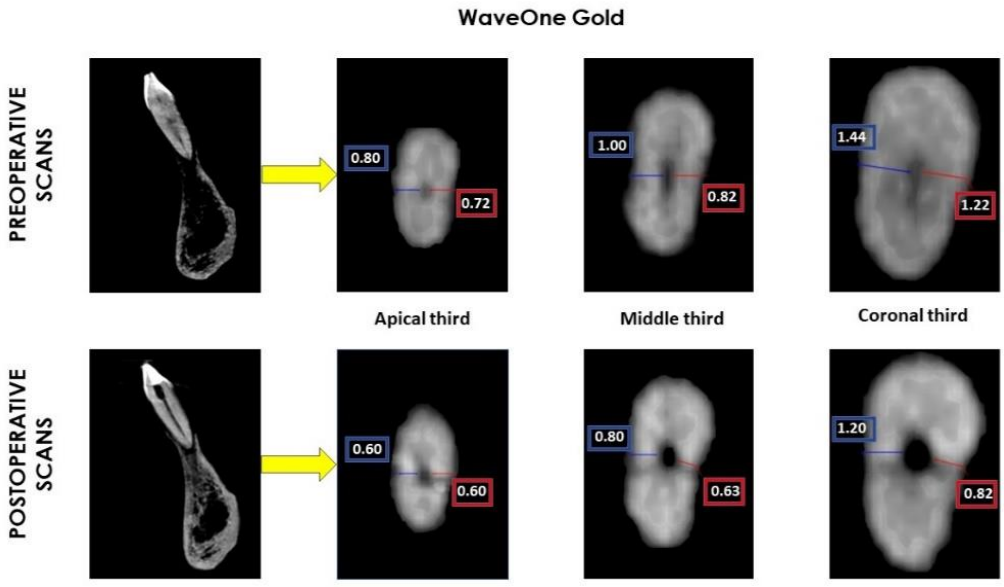

Fig. 2: CBCT assessment of the remaining root dentin thickness in the danger zone of lower incisors after shaping with WaveOne Gold

Table 1: Changes in the mesio-distal root dentin thickness (mm, %) of the lower incisors after shaping with ProTaper Universal and WaveOne Gold *(Statistically significant differences are marked with different superscript letters*)

NiTi system	*Root canal third*	*Preoperative (mm)*	*Postoperative (mm)*	*Δ root dentin thickness (mm)*	*Δ root dentin thickness (%)*
ProTaper Universal	Apical	1.37±0.14	1.14±0.12	0.23±0.15[a]	16.33±9.48
	Middle	1.89±0.35	1.51±0.12	0.38±0.34[a,b]	18.13±11.40
	Coronal	2.69±0.22	2.16±0.34	0.53±0.24[b]	19.83±9.04
WaveOne Gold	Apical	1.63±0.47	1.27±0.24	0.36±0.42[a]	19.17±14.85
	Middle	1.93±0.27	1.68±0.33	0.25±0.12[a]	13.49±7.09
	Coronal	2.77±0.45	2.11±0.45	0.66±0.20[b]	24.16±7.64

Table 2: Intergroup comparison of the removed dentin tissue after shaping with ProTaper Universal and WaveOne Gold

Root canal third	*N*	*Δ root dentin thickness ProTaper Universal*	*Δ root dentin thickness WaveOne Gold*	*t*	*P*
Apical	15	0.23±0.15	0.34±0.42	- 1.136	0.266
Middle	15	0.38±0.34	0.25±0.12	1.312	0.200
Coronal	15	0.53±0.24	0.66±0.20	- 1.607	0.119
Total	45	0.38±0.28	0.42±0.32	- 0.722	0.472

DISCUSSION

The results from the current experiment support earlier findings that shaping of the root canal system with NiTi rotary files substantially reduces the thickness of dentin in the danger zones of the roots (Sharma N *et al.*, 2017; Mangal S *et al.*, 2018).

Various techniques and methods are utilized for the assessment of the residual dentin thickness in the critical zones of the roots such as radiography, sectioning, micro-CT, etc. (Sauáia TS *et al*., 2010; Tabrizizadeh M *et al*., 2010; De-Deus G *et al*., 2019; Harris SP *et al*., 2013). Despite being the most commonly used diagnostic tool in the field of endodontics, X-ray provides only a two-dimensional image of the examined object. A major flaw of this methodology is the fact that the wall is measured to be thicker than the it's actual size (Raiden G *et al*., 2001). Due to its destructive nature, sectioning can only be applied in *in vitro* studies and the results cannot be compared with the baseline values. Micro-CT scanning ensures a detailed observation of the dentinal wall throughout the course of the endodontic procedures. Nevertheless, this method is not clinically approved because of its higher radiation dose (Keles A *et al*., 2020; Harris SP *et al*., 2013; Lee JK *et al*., 2015). CBCT is used as an alternative in the daily endodontic practice. Recently, CBCT is widely-preferred for diagnostics, treatment planning and evaluation of the outcomes after endodontic treatment (Jain A *et al*., 2018; Harandi A *et al*., 2017; Patel S *et al*., 2015; Tomer AK *et al*., 2017). This type of tomographic investigation enables a precise, three-dimensional view of the internal anatomy of the teeth. The non-invasiveness of this method allows for the scanning of one and the same root canal before and after its instrumentation. Thus, the changes in the thickness of the root dentin wall could be repeatedly and precisely observed (Mangal S *et al*., 2018; Gu Y *et al*., 2018). The comparisons made in our study are performed on horizontal slices, on the basis of the laboratory CBCT and sectional techniques. The tomograph used in the current experiment offers a possibility of scanning a certain fragment of the lower jaw which results in lower radiation for the patient.

Mandibular incisors are the smallest teeth in the human permanent dentition (Akhlaghi NM *et al*., 2015). The thickness of their proximal root walls is considerably smaller than their bucco-lingual size (Bellucci C & Perrini N, 2002; Akhlaghi NM *et al*., 2015; Khedmat S *et al*., 2015). Our results corroborate with the statement that the thinnest dentin in mesio-distal direction is observed at the apical root third. In the study of Akhlaghi *et al.*, (2015) on histological slices, the mesio-distal thickness of teeth from the same group was found to be less than 1 mm and about 1.2 mm upon measuring at 1 mm and 4 mm level from the apex, respectively (Akhlaghi NM *et al*., 2015). We registered statistically significant thinning of the root wall in the danger zones in the apical area of the root in both experimental groups ($p \leq 0.001$). The instrumentation with ProTaper Universal led to 16% change in the dentinal wall thickness, whilst in the WaveOne Gold group the percentage was slightly higher – 19%. Nonetheless, these differences remained statistically insignificant. The weakening of the dentinal wall requires a minimal preparation of the root canal in that zone. The apical enlargement should only ensure the elimination of necrotic tissue and bacteria (Zuckerman O *et al.*, 2003; Pilo R & Tamse A, 2000; Khedmat S *et al.*, 2015).

Despite the differences in their design, number and type of rotation, both tested NiTi systems performed almost equally in all of the tested root levels. The files were significantly more aggressive in the coronal portions of the root which might be due to their increased taper at that level.

Literature is inconclusive regarding the requirements of root dentin thickness that could guarantee the strength of the root. Lim and Stock (1987) reported that 0.3 mm remaining dentin is thick enough to withstand the occlusal and lateral forces, generated during the root canal filling (Lim SS & Stock CJ, 1987). Based on the results from their study on mesial roots of lower molars, Zhou *et al.,* (2020) defined that the minimum dentin thickness in the danger zones should be 0.5 mm (Zhou G *et al.*, 2020). Other research teams claimed that 1 mm dentin thickness could preserve the root from fracture (Tomer AK *et al.*, 2016; Caputo AA & Standlee JP, 1976). In their investigation Dhingra *et al.*, suggested higher values –3 mm (Dhingra A & Parimoo D, 2014). We did not register mesio-distal dentin thickness less than 1 mm in none of the root levels.

Knowledge of the initial thickness of root canal wall of lower incisors as well as its expected change after endodontic treatment with certain NiTi files could help dental practitioners choose a minimally invasive shaping system (Chaudhary NR *et al.*, 2018).

CONCLUSION

Within the limitations of the current clinical study, it could be concluded that shaping of the root canals of lower incisors with ProTaper Universal and WaveOne Gold files resulted in a significant decrease of dentin thickness in the danger zones of the roots in all root canal thirds. Both NiTi systems performed equally and were more aggressive in the coronal level of the root. Further clinical studies are necessary to find the minimally invasive endodontic systems for an optimal preservation of root dentin in the danger zones of mandibular incisors.

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