

# NiTi loss on the dentinal walls and instrument deformation during root canal preparation

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## Abstract

The purpose of this study was to quantify the presence of nickel (Ni) and titanium (Ti) on dentin walls of prepared root canals using Endosequence (ES) and Wave One (WO) systems, the deformation, and fracture of these instruments. Thirty extracted human premolar teeth were selected and prepared with WO, ES, and manually (control group—CG). Each instrument was used in four root canals. The root canals were irrigated with 2.5% sodium hypochlorite solution. After preparation, roots were sectioned longitudinally and the apical third was analyzed by scanning electron microscopy with X-ray microanalysis (SEM-EDS). The percentage of Ni and Ti found on dentin walls was compared using Kruskal–Wallis test and post hoc Dunn. The instruments deformation and fracture was evaluate by SEM before and after use. Spiral distortion, fractures, and surface wear were compared using Mann–Whitney test. The level of significance was set at 5%. Ni and Ti were found on the dentin walls of the apical root canal for ES and WO systems ( $p > .05$ ). No distortion in the spirals and no instrument fracture were observed. Regarding to surface wear, most of the instruments scored as moderate wear ( $p > .05$ ). This study concluded the WO and ES presented Ni and Ti loss. In addition, the preparation of four root canals did not caused irreversible deformation in WO and ES instruments.

## KEYWORDS

endodontics, nickel-titanium, root canal preparation

## 1 | INTRODUCTION

Cleaning and shaping of root canal system is essential for successful endodontic treatment. The use of nickel-titanium (NiTi) rotary instruments has increased the quality of root preparation (Peters, 2004). However, despite improvements in NiTi instrument design and manufacturing methods (Shen, Zhou, Zheng, Peng, & Haapasalo, 2013), there is a potential risk of unexpected fracture (Pruett, Clement, & Carnes, 1997; Sattapan, Nervo, Palamara, & Messer, 2000).

Cyclic flexural fatigue occurs when a metal is subjected to repeated cycles of tension and compression that causes its structure to break down, ultimately leading to fracture (Cheung, Shen, & Darvell, 2007). The variables that contribute for the morphological deformation

of NiTi instruments and consequently fracture include small radius of curvature, diameter and design of the instrument, cross-sectional area, high values of torque and speed of rotation, and the professional experience (Bryant, Thompson, Al-Omari, & Dummer, 1998; Pruett et al., 1997; Yared, Bou Dagher, & Machtou, 2001). Furthermore, the reciprocating motion has a strong influence on the cyclic flexural fatigue resistance and support a lower torsional stress.

Regarding the fatigue of NiTi alloys, formation of microcracks occur primarily along specific crystallographic planes or grain boundaries, followed by crack propagation until reaches the point where the remaining material is overstressed, resulting in typical dimple rupture (Shen et al., 2013). Furthermore, during canal preparation, sodium hypochlorite (NaOCl) has corrosive action on metal (Prasad, Sam,

**TABLE 1** Scores for the instruments conditions according to the instrument's spiral distortion, surface wear and fracture

	Spiral distortion	Surface wear	Fracture
1	No unwinding, reverse winding or shortening of spirals along the shaft examined	No wear along the shaft examined	No fracture
2	Unwinding, reverse winding or shortening of only one spiral along the shaft examined	Small amount of wear: one to three areas with defects along the shaft examined	Fracture
3	Unwinding, reverse winding or shortening of more than one spiral along the shaft examined	Moderate wear: four to five areas with defects along the shaft examined	-
4	-	Severe wear: more than five areas with defects along the shaft examined	-

Kumar, & Kannan, 2014). It also can favor loss of metal mass and reduction of resistance to cyclic stress of the instrument.

EndoSequence (Brasseler USA, Geórgia) is an endodontic rotary system and has electropolished surface and Wave One (Dentsply Maillefer, Ballaigues, Switzerland), a reciprocating instrument, is made of M-Wire alloy that is created by a thermal treatment process. These thermal treatment process and manufacturing technologies can improve resistance to cyclic fatigue, reducing the loss of NiTi during root canal preparation.

The aim of this study was to quantify the nickel (Ni) and titanium (Ti) presence on dentin walls of prepared root canals using ES and WO systems and to evaluate the deformation and fracture of these instruments. The null hypotheses were: (1) there is no difference in the amount of Ni and Ti on dentin walls of prepared root canals using ES or WO systems and (2) there is no difference between ES and WO considering spiral distortion, surface wear and fracture.

## 2 | MATERIAL AND METHODS

This study was approved by the Ethics Committee of the Federal University of Rio Grande do Sul (CAAE: 56775714.3.0000.5347). Thirty extracted human premolar teeth with two roots were selected. Initially, a periapical radiograph was performed and the exclusion criteria were observed. Teeth were excluded from this study if they exhibited previous endodontic manipulation, incomplete root formation, calcification, internal or external resorption, or curvature greater than 20 degrees (Schneider, 1971). Before use, the teeth were stored in distilled water at 4 °C.

To standardize the root canal length, the tooth crown was sectioned on the cemento-enamel junction and the roots were separated. Canal length and patency were obtained using #10 until was visible at the apical foramen and after a preflaring with K file #15 and #20. (Dentsply Maillefer, Ballaigues, Switzerland) The working length (WL) was established 1 mm shorter than total length of the root canal. During the exploration of the root canal with K file #10 the operator could feel whether the K file #10 fitted. If it was loose the tooth was excluded.

The samples were randomly assigned into three groups ( $n = 10$ ): manual (control group—CG), Endosequence (ES) and Wave One (WO). The ES group was prepared with #25.04, 30.04, 35.04, and 40.04 instruments (Brasseler USA, Georgia, USA) in a rotary motion. The WO group preparation was performed with the #40.08 instrument

(Dentsply Maillefer, Ballaigues, Switzerland) whose tip size is ISO 40 with an apical taper of 8% which reduces towards the coronal end in reciprocating motion. Each instrument was used in two teeth (four root canals), thus five instruments were used to prepare twenty root canals. After each change of instrument, the root canals were irrigated with 1 ml of 2.5% sodium hypochlorite solution (NaOCl) (Farmácia Marcela, Porto Alegre, Brazil) and the instruments were cleaned with a gauze moistened with 2.5% NaOCl.

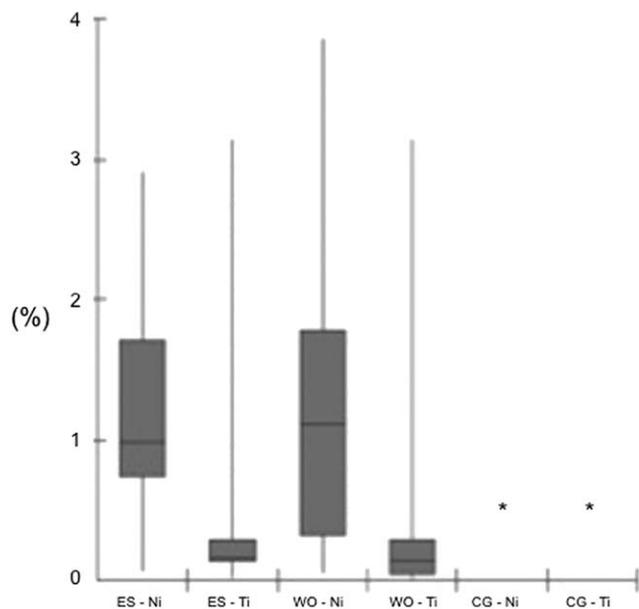
After preparation, roots were sectioned longitudinally to expose root canals. Then, the apical third of the root canal was analyzed by scanning electron microscopy with X-ray microanalysis (SEM-EDS) (JEOL 5800—Tokyo, Japan), at  $\times 85$  magnification within a predetermined area ( $250 \mu\text{m}^2$ ). The identification of Ni and Ti was made within this area using the square tool of the NORAN System SIX software V.1.8 (JEOL 5800—Tokyo, Japan). Therefore, it allowed quantifying the percentage of the Ni and Ti on the dentinal wall.

To evaluate the deformation and fracture of ES and WO instruments (size 40 in both groups), SEM analysis (JEOL 6060—Tokyo, Japan) was performed before and after use. The instruments were fixed on a stub in a standardized position so that about 10 mm from the tip toward handle part of the instrument could be observed at  $\times 100$ –500 magnification. Two blinded and calibrated observers ( $\kappa = 1.00$  for distortion of the instruments' spiral and instrument fracture and 0.90 for instrument surface wear) analyzed 180° of its circumference and two images of each instrument were recorded and classified distortion of the instruments' spiral, instrument surface wear, and instrument fracture, as described by Troian, S6, Figueiredo, and Oliveira (2006) (Table 1).

Spiral distortion, fractures, and surface wear were compared using Mann-Whitney test. The percentage of Ni and Ti was summarized by median, minimum, and maximum values and compared using Kruskal-Wallis test and post hoc Dunn. Data were analyzed using the SPSS 11.0 software (V.11.0; SPSS, Chicago, IL). The level of significance was set at 5%.

## 3 | RESULTS

All teeth prepared with the ES and WO systems, Ni and Ti were found on the dentin walls of the apical root canal (Figure 1). No significant differences were observed between ES and WO systems ( $p > .05$ ), and both showed differences compared to CG, in which Ni and Ti were absent ( $p < .05$ ).



**FIGURE 1** Box-plot comparing percentage of Ni and Ti in the dentinal wall of the apical third after the preparation of root canals. \*Indicates statistically significant differences

No distortion in the spirals and no fracture were observed for ES and WO systems. With regard to surface wear, most of instruments scored 3 (moderate wear: four to five areas with defects along the shaft examined) without statistical differences between the systems ( $p > .05$ ) (Figure 2).

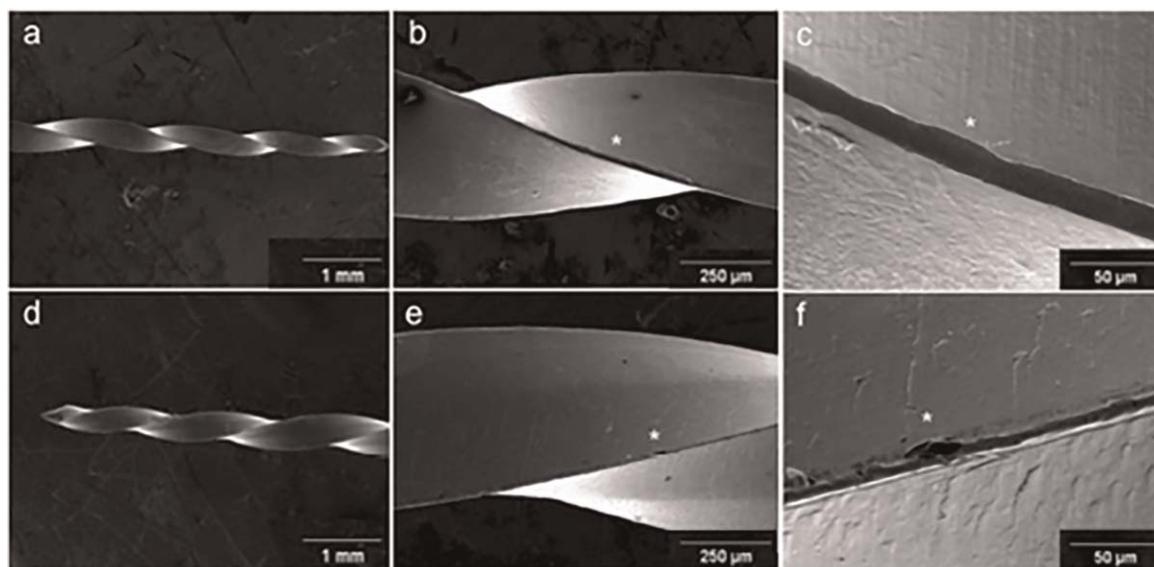
## 4 | DISCUSSION

The manufacturers have developed new NiTi systems with different design features to improve the flexibility, cutting efficiency and safety

during root canal shaping. However, instrument fracture has been recognized as a potential risk.

The results of this study showed the presence of Ni and Ti on the canal walls only in reciprocating and rotary system groups. Therefore, the first null hypothesis was rejected. Kim et al. (Kim et al., 2012) evaluated Reciproc, WaveOne, and ProTaper instruments, and the SEM analysis showed typical fractographic appearances of cyclic flexural and torsional fatigue for both systems. After the cyclic flexural fatigue test, those instruments showed the presence of crack initiation areas and overload fast fracture zones. The overload fast fracture zone is the portion of the piece where the final catastrophic failure occurs. Usually, this zone is macroscopically brittle and the ductility is present. In this area, the crack propagates at approximately 1/2 the speed of sound in the material (Sachs & Sachs, 2005). After torsional fatigue test, those fragments demonstrated typical fractographic appearances of shear failure, including concentric abrasion marks and fibrous microscopic dimples at the center of rotation. So, in this study, the loss of Ni and Ti probably occurred as consequence of these cracks and shear failure (Kim et al., 2012).

Although the results showed no statistical difference regarding Ni and Ti loss, which confirmed the null hypothesis, an extended lifespan was recorded for instruments used in reciprocating motion (Ferreira et al., 2017; Karataş, Arslan, Bükler, Seçkin, & Çapar, 2016). The increased fatigue resistance and the reduction of torsional stress of NiTi instruments have been postulated to be due to the release of reaction stresses built up in the material by reversing the rotational direction (De-Deus, Moreira, Lopes, & Elias, 2010; Ferreira et al., 2017; Karatas et al., 2016; Yared, 2008). A recent systematic review confirmed this finding. Ferreira et al. (2017) evaluated 20 papers that described the effects of reciprocating and continuous movements on cyclic fatigue of the instruments. The authors found that the majority of the studies reported that reciprocating motion improves the fatigue



**FIGURE 2** (a, b, c) SEM images at 19, 100, and 500 $\times$  magnification of ES instrument, respectively. (d, e, f) SEM images at 19, 100, and 500 $\times$  magnification of WO instrument, respectively. \*Represents defect areas on the surface of the instruments

resistance of endodontic instruments when compared to continuous rotation, independent of other variables such as the angle or radius of curvature of simulated canals, the surface characteristics of the NiTi instruments, the speed of rotation, or geometry and taper of the instruments.

Conversely, corrosion of the instruments may also have been generated by the presence of NaOCl in the root canal and contact of the instruments with the dentin walls. Prasad et al. (2014) evaluated the action of 5% NaOCl and 17% EDTA in NiTi systems by using an atomic force microscope, and observed surface deterioration in a short period of time. Ni-Ti instruments immersed in EDTA and NaOCl showed highly surface roughness than those that were not immersed in those solutions. Conversely, some authors stated that Ni-Ti instruments are not affected by short-time immersion, compatible with the time required for clinical procedures, in NaOCl (Bulem, Kecici, & Guldass, 2013; Cavalleri et al., 2009).

Furthermore, the presence of metal on the dentinal walls could have influenced the penetration of the irrigating solution and sealers in the dentinal tubules. Additionally, Ni and Ti particles could apically be extruded to the periapical tissues and their consequences still remains unclear. Several papers have reported that dentin chips, microorganisms and their by-products, pulp tissue and irrigants may extrude to the periapical tissues during canal preparation (Mittal, Singla, Garg, & Dhawan, 2015; Silva et al., 2016; Uzunoglu, Turker, & Görduysus, 2015). Apical extrusion of debris may lead to postoperative symptoms and impair the treatment outcome (Silva et al., 2016). However, previous researches did not investigate the apical extrusion of Ni-Ti. Thus, future investigations which aim to evaluate the amount of Ni-Ti extrusion and its repercussion to the periapical tissues must be performed.

Despite Ni and Ti loss, no fracture occurred and little defects along the examined surface were observed. No differences were observed between ES and WO groups ( $P < 0.05$ ), thus the second null hypothesis was accepted. So, it could be suggested that the ES and WO systems are secure to prepare up to four narrow root canals with moderate curvature. Ni-Ti instruments may fail because incorrect or excessive use; however, other factors have been linked to the propensity for defects on Ni-Ti instruments (Shen, Haapasalo, Cheung, & Peng, 2009). Cross-section area and instrument design may influence the fracture resistance of Ni-Ti instruments. Increasing the instrument diameter and its cross-section area, the risk of torsional fracture decrease but the cyclic flexural fatigue resistance is compromised (Ullmann & Peters, 2005). Additionally, deterioration and microcrack formation on the instrument surface can be visualized at SEM, but such deterioration cannot be detectable clinically. Shen et al. (2009) observed that 0.5% of the Ni-Ti instruments can fail at the first use and the majority of fractures and deformations occurred after multiple uses. Deformation of Ni-Ti rotary instruments may range between 1 and 28% according previous studies, while fractures have occurred in a range of 0.2–23% (Plotino, Grande, & Porciani, 2015).

Under the conditions of this study, it may be concluded that the WO and ES presented Ni and Ti loss. In addition, the preparation of four root canals did not caused irreversible deformation in WO and ES instruments.

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