

# Effectiveness of Nickel-Titanium Endodontic Instruments on Smear Layer Removal from Radicular Dentin

## A Scanning Electron Microscopy Study

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*The aim of our study was to evaluate the cleaning effect of nickel-titanium (Ni-Ti) rotary files on the smear layer formed on the radicular dentine walls during endodontic procedures. We used 50 freshly extracted maxillary permanent teeth divided in two study groups according to the instruments used for cleaning: Group 1 with ProTaper Ni-Ti rotary files, Group 2 with manual Ni-Ti files. Longitudinal sections of root canals from each group were evaluated by scanning electron microscopy (SEM) in the apical, middle and coronal sections. Representative microphotographs were taken and double blind scoring was performed by calibrated examiners. The amount of smear layer was measured according to Hulsmann scoring system and the data were statistically analyzed. There were statistically significant differences between instruments in the apical root canal sections ( $p < 0.05$ ), where the manual Ni-Ti files gave the best cleaning scores. There were no differences between groups for the middle and coronal thirds. In conclusion, the best approach for an effective removal of smear layer is to combine manual files with rotary Ni-Ti instruments during the endodontic treatment.*

**Keywords:** ProTaper rotary system, nickel-titanium files, smear layer removal, endodontic debridement

For dental medicine, the last decade was characterized by many changes regarding materials, techniques, instrument design and types of metal alloys used to manufacture endodontic files. The root canal treatment of necrotic teeth is accompanied by the development of a layer containing organic and inorganic material, bacteria and their by-products, called smear layer, which not permit the penetration of endodontic medicaments into dentinal tubules and has a negative effect on the adhesion of root filling materials to the dentin walls [1-3].

A thorough cleaning of the root canal is considered to be the most important step towards endodontic success and therefore numerous Ni-Ti instruments had been developed during the last decades.

Titanium alloys are widely used in different fields of medicine for many biomedical applications due to their low density, excellent biocompatibility, corrosion resistance and mechanical properties [4-6].

The Ni-Ti alloys (Nitinol, 55% nickel and 45% titanium) (table 1) endodontic files are suitable for preparing curved canals due to their elastic behavior. This allows the returning to the original shape after deformation and gives the instruments the ability to maintain a memory of their initial shape, if deformed.

The surface treatment of Ni-Ti instruments by thermal nitridation process, deposition of titanium nitride by physical vapor, cryogenic, argon and nitrogen treatment may increase their cutting performances. Nitinol's

		Austenite	Martensite
<b>Physical properties</b>	Density (g/cm <sup>3</sup> )	6.45	
	Melting point (°C)	1310	
	Magnetic permeability	< 1.002	
	Coefficient of thermal expansion (X10 <sup>6</sup> /°C)	11.0	6.6
<b>Mechanical properties</b>	Young's modulus (Gpa)	120	50
	Yield strength (Mpa)	195-690	70-140
	Elongation	13-40%	
<b>Shape memory</b>	Transformation temperature	-50°C up to 100°C	
	Recoverable strain	6.5% – 8.5%	
	Superelastic recoverable strain	Up to 8%	

**Table 1**  
PROPERTIES OF NICKEL-TITANIUM (NITINOL) ALLOY

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properties derive from a reversible solid-state process known as martensitic transformation: at high temperatures the alloy has a cubic structure called austenite and at low temperatures it spontaneously transforms to a tetragonal crystal structure known as martensite (fig.1).

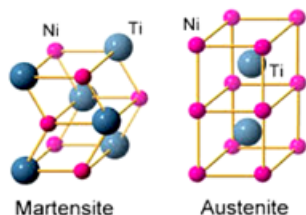


Fig. 1. Tri-dimensional graphic representation of austenite and martensite structure of the Ni-Ti compound [7]

This has the unique ability to undergo limited deformation and when it is reverted to austenite by heating, the original structure is restored (fig.2) [7].

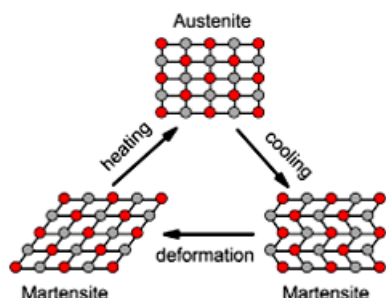


Fig. 2. Bi-dimensional graphic representation of Nitinol's crystalline structure during cooling/heating cycle [7]

The basic design of endodontic files changed very little, except for minor modifications regarding new materials, improved cutting properties and better flexibility. Among these, the Ni-Ti instruments are up to three times more elastic and more fracture resistant compared to stainless steel files [8-11]. Furthermore, the manual and rotary Ni-Ti instruments improved the final quality of root canal preparation and offer a continuous tapered shape which favors a tridimensional root filling.

As the literature on Ni-Ti endodontic instruments is still controversial, more studies are needed in order to evaluate the efficacy of manual and rotary endodontic systems in cleaning and shaping the root canals.

The aim of our study was to compare, by scanning electron microscopy, the efficiency of two types of endodontic files on smear layer removal from the radicular dentine walls during endodontic procedures.

## Experimental part

### Material and methods

Our study was approved by the Ethics Committee for Scientific Research from our university, based on the Declaration of Helsinki.

We used manual Ni-Ti files and ProTaper rotary system and a unique irrigating protocol with 3% sodium hypochlorite (NaOCl) and 5 mL of saline solution as final rinse.

We used 50 freshly extracted permanent teeth lost due to periodontal disease. The teeth were divided in two groups of 25 teeth. After storage in saline solution for 1-2 days the endodontic instrumentation in Group 1 was performed according to the step-back technique using



Fig. 3. Selection of teeth with larger root canals and the endodontic tray used for manual instrumentation using Ni-Ti files according to step-back technique (Group 1)



Fig. 4. The endodontic files of the rotary ProTaper system and the technical parameters used during mechanical instrumentation of teeth from Group 2

manual Ni-Ti files (Dentsply-Maillefer, Ballaigues, Switzerland) (fig.3).

In both groups the irrigating protocol included the use of 5 mL of NaOCl 3% after each instrument, followed by 5 mL of saline solution as final irrigation. For the SEM evaluation, longitudinal grooves were made on the buccal and oral surfaces of the roots using a diamond disk at low speed, without penetrating the canal. The roots were split in half with a sharp blade and were coded according to the protocol used. The specimens were dehydrated with increasing concentrations of ethyl alcohol, mounted on coded stubs and sputter-coated with 300 Angstrom gold layer. The specimens were examined using a SEM (Cam scan MV 2300, Oxford Instrument, UK) at x1000 and x750 magnification at the coronal, middle and apical thirds, based on a numeric scale from introduced by Hulsmann et al [12]: 1- no smear layer, open dentinal tubules, 2- small amount of smear layer, some opened dentinal tubules, 3- homogenous smear layer covering the root canal wall, few dentinal tubules opened, 4- complete root canal covered by a homogenous smear layer, no dentinal tubules opened, 5- heavy non-homogenous smear layer covering completely the root canal.

Photomicrographs of the examined areas were taken and evaluated by two independent observers in a double-blind manner. Statistical analysis was carried out with the Statistical Package for Social Sciences (SPSS) version 16.0 for Windows. Chi square test was used to identify the significance of smear layer accumulation in the coronal, middle and apical part of the root canal. The level of significance was set at  $p < 0.05$ .

## Results and discussions

Statistically significant differences ( $p < 0.05$ ) were observed between the study groups in the cleaning of apical parts of the root canal, as the group of teeth instrumented with manual Ni-Ti files revealed the least amount of smear layer accumulation, especially in the apical sections of the dentin walls (table 2).

Score	Group 1 Apical	Group 2 Apical	Group 1 middle	Group 2 middle	Group 1 coronal	Group 2 Coronal
1	19 (76 %)	3 (12 %)	12 (48 %)	4 (16 %)	9 (36 %)	3 (12 %)
2	4 (16 %)	9 (36 %)	10 (40 %)	11 (44 %)	9 (36%)	8 (32 %)
3	2 (8 %)	7 (28 %)	1 (4 %)	6 (24%)	5 (20 %)	8 (32 %)
4	-	6 (24 %)	2 (8 %)	2 (8 %)	2 (8 %)	4 (16%)
5	-	-	-	2 (8%)	-	2 (8 %)

Table 2  
SMEAR LAYER  
EVALUATION  
BETWEEN  
STUDY  
GROUPS

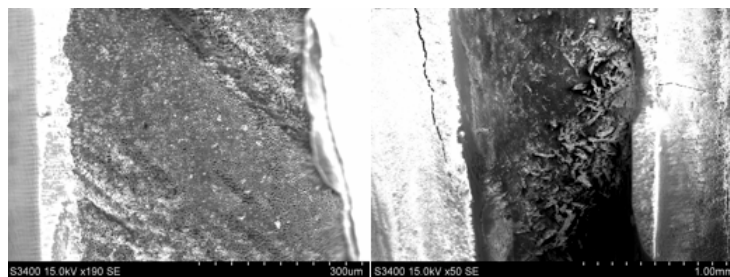


Fig. 5. Apical thirds of the root canal instrumented with manual Ni-Ti instruments: Presence of smear layer recorded as scores 1 and 3

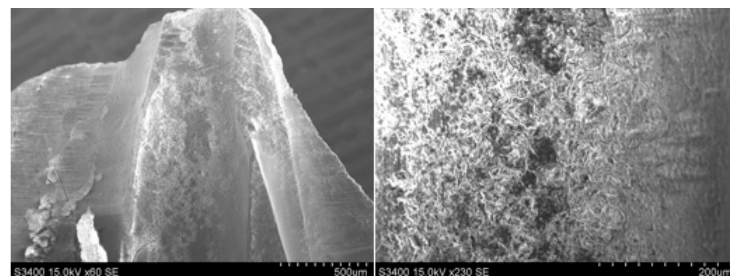


Fig. 6. Apical and middle thirds of the root canal instrumented with rotary ProTaper system: There was a greater amount of smear layer accumulated on dentin walls, recorded as score 4 and 5 respectively

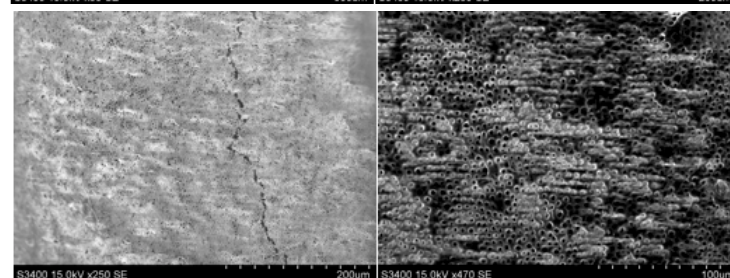


Fig. 7. Coronal sections of root canal, instrumented with manual and rotary ProTaper system: Showed proper cleaning, with adequate smear layer removal, recorded as score 1 for both systems

For the middle and coronal parts no statistically significant differences were recorded, with values of  $p=0.05$  and  $p=0.135$  respectively. Despite the fact that the manual instruments were used in accordance to the step-back technique that implies a gradual retraction of 1 mm along the apical part of the root canal with each consecutive file, the canals were better cleaned and the amount of smear layer was reduced. The SEM microphotographs obtained from the apical, middle and coronal part of root canals in the study groups are presented in figure 5-7.

The success of endodontic treatment depends on the microbial reduction in the root canals, through a careful cleaning and shaping performed traditionally with manual instruments.

Classical stainless steel instruments have a high stiffness that increases with instrument size and might cause lateral forces resulting in transportation of the root canal. As consequence, a significant portion of the canal will remain untouched along with a consecutive development of an irregular cross-section of the endodontic space that is very difficult to fill. During the last decade, endodontic procedures have been revolutionized by the introduction of Ni-Ti rotary systems, which proved to be efficient especially in curved canals [13,14].

Numerous studies had reported on the effectiveness of endodontic techniques and instruments, using various methods of evaluation of the root canal debridement, but SEM proved to be more valuable in measuring and comparing different systems regarding the smear layer removal from radicular dentin [15-17].

As intra-canal irrigating solutions we used only NaOCl and saline, as our purpose was to evaluate only the effect of instrumentation on smear layer removal from root canals; under clinical conditions, the irrigating protocols that include chelating agents as EDTA or citric acid remove more easily debris and smear layer, therefore we avoided them during our experiment. In our study, two endodontic instrumentation techniques were compared, based on

separate numerical evaluation calculated for the coronal, middle and apical section of the root canals. Our results showed that both methods generate smear layer along the radicular dentin wall, but the manual instruments were more efficient in cleaning the apical parts. Both methods used produced smooth prepared surfaces, relatively clean and debris-free dentin in the coronal and middle thirds of the root. The better cleaning properties of manual files has been attributed to their 0.02 taper, compared to a greater taper of rotary files that might create a false sensation of tightness in the middle and coronal section, even if at apical level the instrument is laying passively [18,19].

In the apical part, more smear layer and remnants on Ni-Ti alloy were detected in Group 2, where ProTaper rotary system was used. A review article that compared Ni-Ti instruments used with different motion regimens showed that those with reciprocating motion seemed to have better resistance to cyclic fatigue and less canal transportation tendency, compared to the instruments used in a continuous rotation motion, such as the ProTaper system [20-22].

However, nitinol files have a high fatigue tolerance and flexibility, which greatly decreases the possibility of fracture, thus improving safety medical procedures. It has been emphasized that root canal lubrication during preparation ensue easy contact between the cutting blade of the file and radicular dentin, which decreases friction. On the other hand, NaOCl has a negative impact on dentin, as it attacks the organic matrix and reduces the micro-hardness of the tissue, making biomechanical preparation easier.

## Conclusions

Based on the results of our study, the use of rotary Ni-Ti systems alone in the cleaning of the root canals could not significantly reduce the amount of smear layer formed on the radicular dentin walls during endodontic instrumentation. The use of hand files after engine driven instruments could result in better cleaning, which might have an important clinical impact, by improving the success



rate of endodontic therapy. This is sustained by the excellent cleaning ability of the manual Ni-Ti instruments demonstrated in the apical part of the root canals.

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