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THE EFFECTS OF NICKEL TITANIUM ROTARY INSTRUMENT DESIGN ON AN EPOXY RESIN BASED SEALER PENETRATION*

NIKEL TITANYUM DÖNER ALET TASARIMININ BİR EPOKSİ REZİN BAZLI PATIN PENETRASYONU ÜZERİNE ETKİLERİ

Yakup ÜSTÜN[1], Burak SAĞSEN[1]

[1] Erciyes Üniversitesi Diş Hekimliği Fakültesi Endodonti Anabilim Dalı, Kayseri

ABSTRACT In our study it is aimed to evaluate the penetration and adaptation of root canal sealer AH Plus to root canal dentine with usage of Hero 642, ProFile, K3, ProTaper nickel-titanium rotary systems. In this study recently extracted 80 human maxillary central incisor teeth were used. four groups with 20 teeth were generated. Each group was prepared with different Ni-Ti rotary system due to the manufacturer's instructions. Canals were obturated with "Calamus 2 in 1" according to manufacturer instructions with AH Plus sealer. Teeth were divided into two halves and investigated with SEM. Among the comparisons of systems at the coronal thirds ProTaper, Hero 642 and K3 values were significantly higher than ProFile ($p<0.05$). At the comparisons among the middle thirds ProTaper system is significantly higher than Hero 642 and ProFile systems ($p<0.05$). Among the comparisons of apical thirds, ProTaper system was significantly higher than ProFile and Hero 642 systems ($p<0.05$). K3 was significantly superiorer than ProFile and Hero 642 systems ($p<0.05$). There was no statistical difference among the rest of the groups ($p>0.05$).

Key words: Tubule Penetration, AH Plus, Ni-Ti rotary system, SEM

ÖZET Çalışmamızda Hero 642, ProFile, K3, ProTaper Nikel-Titanyum döner sistemleri kullanılarak yapılan preparasyonlarda AH Plus kök kanal patının kök kanal duvarlarına olan penetrasyonu ve adaptasyonunun SEM kullanılarak incelenmesi amaçlandı. Bu çalışmada 80 adet çekilmiş maksiller santral insan dişi kullanıldı. yirmişer dişten oluşan dört grup oluşturuldu. Her bir grup kendi içinde farklı bir Ni-Ti döner sistemle üretici firma talimatları doğrultusunda prepare edildi. Kanallar üretici firma talimatları doğrultusunda "Calamus 2 in 1" sistemiyle AH Plus patı kullanılarak dolduruldu. Dişler ikiye ayrılıp, SEM ile incelenmiştir. Koronal üçlülerde sistemler arasında karşılaştırmalarda ProTaper, Hero 642, K3 sistemlerinin üçü de ProFile'dan anlamlı derecede üstündür ($p<0.05$). Kök orta üçlüsünde ProTaper sistemi Hero 642, ProFile sistemlerinden üstün bulunmuştur ($p<0.05$). Apikal üçlülerinin kıyaslanmasında ProTaper sistemi, ProFile ve Hero 642 sistemlerinden belirgince üstün bulunmuştur ($p<0.05$). K3 sistemi, ProFile ve Hero 642 sistemlerinden anlamlı derecede üstün bulunmuştur ($p<0.05$). Diğer tüm kıyaslamalar arasında istatistiksel fark yoktur ($p>0.05$)

Anahtar kelimeler: Tübül penetrasyonu, AH Plus, Ni-Ti döner sistem, SEM

INTRODUCTION

The aim of a successful root canal treatment is to obturate the root canal space hermetically with an inert, dimensionally stable and biocompatible root canal filling material thus prevention of reinfection of the root canal system. Root canal filling should be adapted to root canals in order to prevent microleakage and reinfection (1).

Chemomechanical preparation is considered as the most important step in the management of the infected root canal system; however, it is difficult or even impossible to eliminate all organisms completely from the canal space (1, 2). Microorganisms in lateral canals and dentinal tubules of the root canal system could survive from the disinfecting actions of irrigants and medicaments (2). These residual microorganisms could be responsible for the persistent periapical disease, in case of incomplete obturation of root canal system (3, 4).

For the obturation of the root canals, a core filling material is used in conjunction with a sealer cement (5). As a core material; gutta percha does not bond to dentine regardless of the obturation technique performed (6). Sealer cements adhere both the core material and the root canal wall by filling the discrepancies between the

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Corresponding Author: Dr. Yakup ÜSTÜN
Erciyes Üniversitesi, Diş Hekimliği Fakültesi, Endotonti AD.
Melikgazi, Kayseri, TÜRKİYE Posta kodu: 38039
Tel: +90 (352) 207 66 66 /29139
E-posta: yakupustun33@hotmail.com

root canal wall and the core material (7, 8). The lateral and accessory canals of the root canal system is sealed and disinfected by root canal sealers.

The smear layer is an amorphous structure composed of inorganic and organic substances formed during preparation of the root canals (9, 10). The presence of the smear layer prevents penetration of intracanal medication into the irregularities of the root canal system and the dentinal tubules and also prevents complete adaptation of obturation materials to the prepared root canal surfaces and removal of smear layer may facilitate the opening of dentinal tubules for intracanal medication action and allow better adhesion of the root canal filling material (11-14).

Ni-Ti rotary instruments have been commonly used in endodontics. Manufacturers improved various Ni-Ti instruments with different features such as rake angles, flute designs, taper designs, pitch design, tip design. It is shown that different designs of Ni-Ti rotary instruments have different cutting efficiencies (15-18). Some authors showed that different designs of root canal instruments create different root canal surface profiles with different thickness of smear layer (18-21).

The aim of the present study was to evaluate the effect of root canal preparations performed with four different Ni-Ti rotary systems on dentinal penetration of an epoxy resin based root canal sealer. The systems used were ProFile Ni-Ti Rotary system (Dentsply, Maillefer, Ballaquies, Switzerland), ProTaper Ni-Ti Rotary system (Dentsply, Maillefer, Ballaquies, Switzerland), Hero 642 Ni-Ti Rotary system (MicroMega, Besançon, France), K3 Ni-Ti Rotary system (Sybron Endo, West Collins Orange, CA, USA). The null hypothesis was that no difference occurs among the systems in means of dentinal penetration.

MATERIALS AND METHODS

Eigthy-one freshly extracted human maxillary central incisor teeth with straight root and single canal were used in this study. Following extraction the teeth were stored for eight hours in 5.25% sodium hypochlorite (NaOCl) to remove organic tissue remnants. Subsequently, they were scaled with ultrasonic instruments, washed with distilled water, and immersed in 10% formalin solution until required. The crowns of the teeth were removed and the roots were adjusted to 12 mm to standardize the length of the roots. A #10 K file was introduced through the root canal until it emerged at the apical foramen then the stopper was fixed and working length was established 1 mm short from this length visually. All roots were randomly divided into four groups and the roots in each group was prepared with different Ni-Ti Rotary systems with the aid of X Smart endodontic motor (Dentsply, Maillefer, Ballaquies, Switzerland). The groups were as follows:

Group 1:

Twenty roots were prepared with ProFile Ni-Ti Rotary system (Dentsply, Maillefer, Ballaquies, Switzerland). The instrument sequence, torque / speed adjustment were done according to manufacturer's instructions and master apical file used was ProFile 06/30.

Group 2:

Twenty roots were prepared with ProTaper Ni-Ti Rotary system (Dentsply, Maillefer, Ballaquies, Switzerland). The instrument sequence, torque / speed adjustment were done according to manufacturer's instructions and master apical file used was ProTaper F3.

Group 3:

Twenty roots were prepared with Hero 642 Ni-Ti Rotary system (MicroMega, Besançon, France). The instrument sequence, torque / speed adjustment were done according to manufacturer's instructions and master apical file used was 06/30.

Group 4:

Twenty roots were prepared with K3 Ni-Ti Rotary system (Sybron Endo, West Collins Orange, CA, USA). The instrument sequence, torque / speed adjustment were done according to manufacturer's instructions and master apical file used was K3 06/30.

For each experimental group, four new set of Ni-Ti instruments were used for each five samples. Between each instrument all root canals were irrigated with three ml of 2.5% NaOCl.

For the removal of the smear layer, final irrigation was performed with five ml of 17% EDTA (WERAX, SDD, Izmir, Turkey), five ml of 2.5%NaOCl and five ml of distilled water. Root canals were dried with paper points. One sample was used for Scanning Electron Microscope (SEM) investigation to clarify the smear layer removal.

AH Plus root canal sealer was mixed according to manufacturer's instructions and the root canal walls were covered using a medium size gutta percha (Autofit gutta percha, SybronEndo, Orange, CA, USA) coated with the sealer.

Obturation of root canals

Root canals were filled with vertical condensation of warm gutta percha with the aid of Calamus 2 in 1 system (Densply, Tulsa, OK). This system consists of two apparatus: Calamus pack and Calamus flow. A medium size gutta percha that fits apically to root canal was chosen as master apical gutta percha. A 40/03 electric heat plugger (EHP) (four mm short from the working length) was inserted to Calamus pack unit, system was activated and utilized to sear off the master cone at the level of orifice. EHP was activated for 5 seconds and moved vertically about eight mm. The apical gutta percha was laterally and vertically condensed, the EHP was deactivated and left for ten seconds to cool down then the EHP was activated again for one second and moved laterally to left and right direction to sear of the gutta percha. The EHP was deactivated again and withdrawn from the canal. Coronal part of the master gutta percha was removed together with the EHP. Apical part was vertically condensed with hand pluggers. A 23 gauged gutta percha cartridge was inserted into Calamus flow apparatus and the device was set to 200 °C. The tip of the warm canula is positioned against the down packed gutta percha for five seconds to resoften its most coronal extent. The Calamus Flow handpiece is activated and a three mm segment of warm gutta per-

cha is dispensed into the most apical region of the empty canal. The dispensed gutta percha was vertically condensed with hand plugger. This action was repeated again for the rest of the canal. The orifices were sealed with a temporary filling material (Cavit G, ESPE, Dental AG Norristown, PA, USA) and the teeth were then stored at 37 °C and 100% humidity for seven days to allow the sealer cement to set.

All roots were sectioned longitudinally by means of intentional fracture and were prepared for a SEM observation (Leica-Leo S440, Cambridge, UK). Fractured halves of each root were mounted on aluminium stubs, vacuum-dried, coated with 20 nm of gold and then examined under SEM. Energy dispersive spectroscopy (EDS) was performed at selected sites, and the maximum penetration depth of the sealers into the dentinal tubules was examined in the coronal, middle, and apical levels. The penetration depth of sealers were measured with Image ProPlus 6.0 programme (Media Cybernetics, Inc., SilverSpring, MD, USA).

All statistical analyses were performed with Sigmastat 3.5 (Systat Software, San Jose, CA, USA) programme. The Shapiro Wilk test was used to test the assumption of normality of the data. The distribution of data was not normal. Non-parametric Kruskal-Wallis test was applied to data and non-parametric Tukey test was used for multiple comparisons with a confidence level of 95%.

RESULTS

The coronal, middle and apical thirds of each specimen were examined under the SEM observation. Intergroup comparisons, in means of root thirds were done for each group. In the ProFile group, the penetration scores of the middle thirds were significantly higher than the apical and coronal thirds ($p<0.05$). The penetration scores of the coronal thirds were significantly higher than apical thirds ($p<0.05$). In the ProTaper, Hero 642 and K3 groups, the penetration scores of the middle thirds were significantly higher than the apical thirds' scores ($p<0.05$) and the penetration scores of the coronal thirds were significantly higher than the apical thirds ($p<0.05$). There were no significant difference between the coronal and middle thirds ($p>0.05$). (Table 1).

Table 1: Intergroup comparisons of experimental groups according to the root canal thirds in µm. (In each group same superscript letters shows no significant difference)

Group	N	Standard Error	Median	25%	75%
ProFile Coronal^{A}	20	7.394	51.500	44.000	89.500
ProTaper Coronal^{B}	20	16.278	103.500	78.000	138.500
Hero Coronal^{B}	20	4.288	91.500	80.500	102.000
K3 Coronal^{B}	20	8.109	104.000	82.000	135.000
ProFile Middle^{A}	20	9.063	94.000	77.500	121.000
ProTaper Middle^{B}	20	9.172	147.000	110.000	172.500
Hero Middle^{A}	20	5.785	97.000	85.000	117.500
K3 Middle^{AB}	20	7.337	112.000	95.500	138.000
ProFile Apical^{A}	20	2.778	28.500	13.500	36.500
Protaper Apical^{B}	20	3.689	50.500	43.500	59.500
Hero Apical^{A}	20	3.378	23.000	12.000	41.500
K3 Apical^{B}	20	4.519	40.000	34.000	65.000

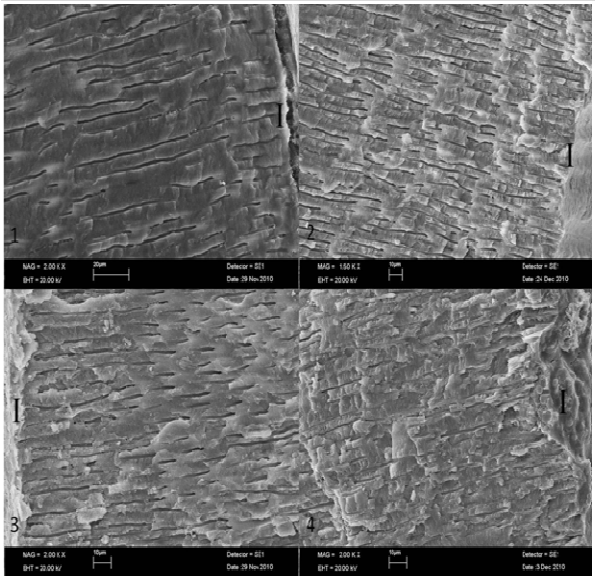

Figure 1 : Figure represents the penetration photographs of each system for coronal root thirds. (1: ProTaper, 2: Hero 642, 3: K3, 4:Profile, I: Root canal space).

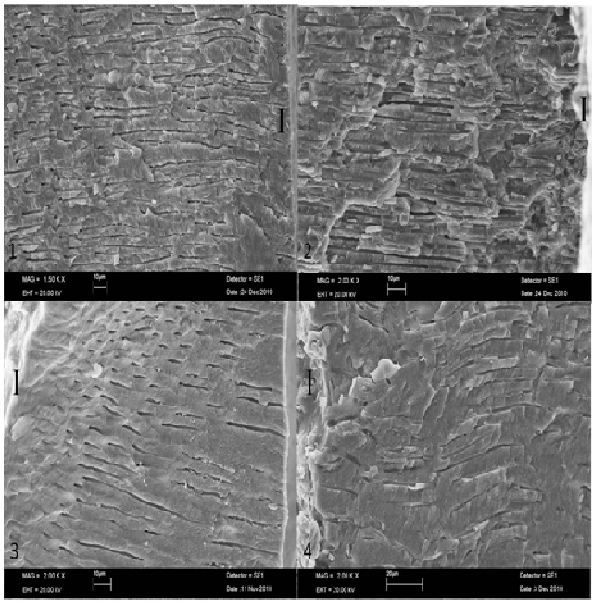

Figure 2: Figure represents the penetration photographs of each system for middle root thirds. (1: ProTaper, 2: Hero 642, 3: K3, 4:Profile, I: Root canal space).

Comparisons among the coronal thirds of the groups in terms of sealer penetration revealed that ProTaper, Hero 642 and K3 groups showed no significant differences among each other (p>0.05). However, ProTaper, Hero 642 and K3 groups were significantly superior to ProFile group in means of sealer penetration in the coronal thirds (p<0.05). (Table 1) (Figure 1).

Sealer penetration results among the middle thirds of the groups showed that ProFile and Hero 642 groups had no significant difference (p>0.05). Also, K3 and ProTaper, K3 and Hero 642 and, K3 and ProFile groups had no significant difference (p>0.05) but ProTaper group significantly resulted in deeper sealer penetration compared to ProFile and Hero 642 groups (p<0.05).(Table 1) (Figure 2).

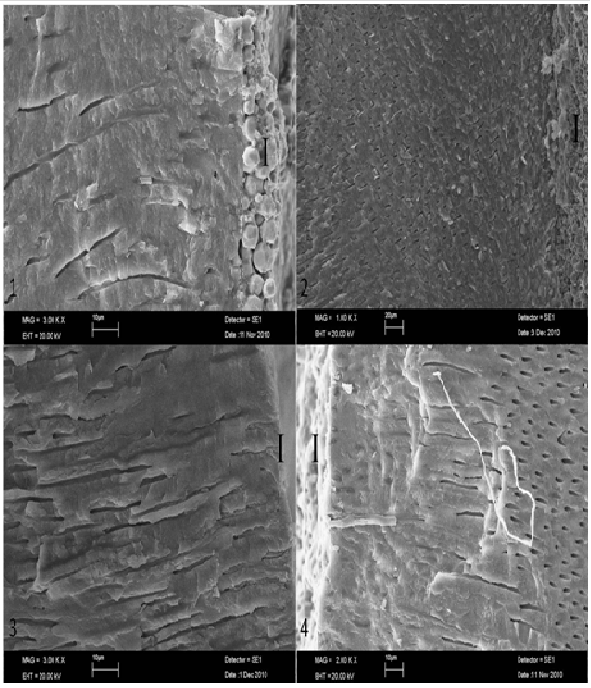

Figure 3: Figure represents the penetration photographs of each system for apical root thirds. (1: ProTaper, 2: Hero 642, 3: K3, 4:Profile, I: Root canal space).

Comparisons among the apical thirds of the groups showed that ProTaper group was significantly superior to Hero 642 and ProFile groups (p<0.05). There was no significant difference between ProTaper and K3 groups (p>0.05). K3 group was significantly superior to ProFile and Hero 642 groups (p<0.05). No significant difference was found between Hero 642 and ProFile groups (p>0.05).(Table 1) (Figure 3)

DISCUSSION

Root canal instrumentation should provide a tapered canal form with adequate shape to allow optimum disinfection and three dimensional obturation of the root canal system (22) Chemomechanical preparation is considered to be one of the most important part of the endodontic therapy. Various type of root canal preparation techniques and instruments were improved in endodontics. Ni-Ti instruments represent many advantages like rapid endodontic preparation, less canal transportation, better centering ability than stainless steel hand files (23-25). Several studies showed that different Ni-Ti Rotary files created different root dentine surface profiles (18-21). In the current literature, there is no study concerning the relation between sealer penetration and different Ni-Ti file designs.

There are some factors such as smear layer removal, dentine permeability, the surface activity of the sealers, the contact angle between the sealer and the dentinal

walls, the diameter of the opened dental tubules, the obturation technique employed, the physical and chemical properties of the sealers which effect the penetration of root canal sealers into dentin tubules (26, 27). The penetration of sealer cements into dentinal tubules will increase the interface between sealer and dentine improving the sealing ability and a mechanical locking activity will be obtained by retention of the material (27). Also any residual bacteria in dentin tubules may be entombed by the chemical components and antibacterial activity of root canal sealers (28).

Several authors concluded that smear layer prevents the penetration of root canal sealers into dentin tubules (5, 12, 13, 26, 27). The influence of smear layer removal on the penetration of sealer cements has been investigated by a number of authors with general agreement that smear layer removal results in deeper and more consistent sealer penetration (12, 13, 29, 30). Gutta percha is the most commonly used core material in root canal obturation. Several studies evaluated the quality of root canal fillings performed with cold or warm obturation of gutta percha in different parameters such as clinical success (31), density of gutta percha (22), void formations (32), film thickness of root canal sealers (33), core material / sealer ratio (34), sealer penetration (26), apical leakage (35) in obturated root canals. It is shown that warm techniques were found to be more successful in clinically, have greater density of gutta percha, showed less void formation and deeper sealer penetration and less apical leakage in obturated root canals. With regard to these results, in the present study we preferred to use a recently introduced obturation system ''Calamus Dual 3D Obturation System (Dentsply Tulsa Dental Specialties)''.

In several SEM studies that investigated the penetration of root canal sealers into the dentinal tubules, obturated roots were split along buccolingual direction (12, 29, 36-38). Mamootil & Messer (27) evaluated root canal sealer penetration at the middle third's by horizontal split method. In this method, it is possible to view both buccolingual and mesiodistal direction but only in a restricted part of the roots can be seen so we chose to split the samples in buccolingual direction to have a complete view of the root surface.

Saleh et al.(39) investigated the adhesion of endodontic sealers and investigated the samples with EDS to determine the type of sealer. Guigand et al.(40) also used EDS to determine the sealer in the dentin tubules. In the present study, we also evaluated the penetration images with EDS analyses.

Gonzalez et al.(41) investigated Hero 642, K3, ProTaper systems in means of root canal instrumentation and stated that Hero 642 system removed much more dentin from the root canal space than the other systems. Ersev et al. (42) compared the shaping effects of 5 Ni-Ti rotary system (K3, ProFile, NiTi-TEE, EndoWave, HeroShaper) on simulated S shaped canals. The same researchers found K3 system as the most effective system in preparation of S shaped canals. de Deus et al. (43) evaluated the effects of different Ni-Ti rotary systems (K3, ProTaper, Hero 642) with regard to canal debridement quality and found no significant differences among the systems. In the present study in comparisons among the coronal thirds of the groups there were no significant difference among ProTaper, Hero 642, K3 systems ($p>0.05$) however these three systems were significantly superior to ProFile system ($p<0.05$). Similar results of K3, Hero 642, ProTaper systems could be related to similar root canal debridement as showed by study of de Deus et al. (43) and similar smear layer profile of ProTaper, Hero 642, K3 systems as it was mentioned by Prati et al. (20). ProFile system's results could be related to low cutting efficiency of ProFile instruments (20, 25) and more smear layer formation of the Profile system due to the design of the system.

There are several studies concerning progressive and constant tapered shaft designs of Ni-Ti Rotary instruments (44-47). Guelzow et al. (44), showed that progressive tapered ProTaper system created more regular canal diameter than constant tapered Ni-Ti rotary files. Yun et al. (24), stated that ProTaper system removed more dentin from root canal space in all root canal thirds than ProFile and Quantec instruments. Yoshimine et al. (48) also stated that ProTaper system removed more dentin than K3 and RaCe systems and related this result to ProTaper convex triangle cross section design. In the present study ProTaper system was superior to ProFile system in means of penetration at middle thirds of the roots. Many investigators stated that the progressive design of the ProTaper system removed more dentin from middle third's of the root canal space (24, 44, 47-50) and as a result of this, irrigation procedure could be facilitated and became more efficient by the increased root canal volume. The results of ProTaper & ProFile could be related to these factors. However, there were no significant differences among K3 & Hero 642, K3 & ProFile, K3 & ProTaper and Hero 642 & ProFile systems. The results between K3 and Hero 642 systems could be related to the studies of Prati et al. (20) and De Deus et al. (43) who showed no difference in means of root canal surface profile and root canal debridement, also could be related to similar shaft designs and cutting efficiencies of the systems. The results between ProTaper and K3 systems could be related to the study of Sonntag et al. (51) that shows no significant difference between K3 and ProTaper systems in means of root canal geometry preservation and De Deus et al. (43); also, the success of irrigation protocol could be effective in the results. The similarity of the results of K3 & ProFile systems could be related to efficient and successful irrigation protocol and also Gonzales et al. (41), showed no difference between K3 and ProFile systems in amount of dentin removed from root canals. The success of irrigation procedure could be effective in results of ProFile & Hero 642 systems.

O'Connel et al. (52), stated that 17% EDTA with 5.25% NaOCl removed the smear layer in the middle and coronal thirds of canal preparations, however this combination is less effective in the apical third. The inadequate volume and/or penetration of the solution into the apical third of the canal during irrigation could be reason for less effective results of smear removal (53).

The amount of material removed from the root canal depends on the shape of the rotary files and the penetration depth in the canal. The taper of the ProTaper files has been found to be 0.02 to 0.19% (54) and is greater than the other files at the same level of the root canal, which resulted in the greatest increase in canal width (24). In the present study, at the apical thirds ProTaper system was superior to Hero 642 and ProFile systems. Progressive taper formation and efficient (superior) cutting behaviour of ProTaper system could be effective on the results.

Conclusion

The results of the present study showed that the use of Ni-Ti rotary systems with variable helical angle design, and/or progressive taper design could result more effectively penetration of resin-based root canal sealers into the dentinal tubules.

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