EÜ Dişhek Fak Derg 2009; 30: 87-96

Debris and Smear Layer Remained in Oval-Shaped Root Canals Following Rotary and Manual Instrumentations: A Scanning Electron Microscopic Study

Döner ve El Aletleri ile Genişletilen Oval Şekilli Kök Kanallarında Kalan Debris ve Smear Tabakası: Taramalı Elektron Mikroskobu Çalışması

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Abstract

Objectives: *The aim of this scanning electron microscopic study was to investigate remaining debris and smear layer in oval root canals following rotary and manual instrumentation.*

Methods: *Thirty extracted mandibular incisors were used in this study. Root canals were prepared with Quantec LX or HERO 642 instruments in a crown-down technique or with step-back instrumentation with H-files. Teeth were split longitudinally and prepared for scanning electron microscopic evaluation. The presence of debris and smear layer was evaluated in the coronal, middle and apical thirds of the canals blindly by three trained observers. A 5-category established scoring system was used for evaluation. Means were calculated and statistical analysis was performed using non-parametric Kruskal-Wallis and Mann-Whitney U tests.*

Results: *There were unprepared areas in all root canals instrumented with Quantec LX and HERO 642 files. There were no significant differences among the regions with respect to remaining debris and smear layer even though the coronal thirds received the lowest scores. Quantec LX instruments demonstrated lowest debris scores, particularly in the apical third ($p<0.01$). The Quantec system remained less smear layer on root canal walls in comparison to Hero 642 and manual preparation. However, this difference was not significant ($p>0.05$).*

Conclusions: *Quantec LX system performed better particularly in apical part of the root canals with respect to presence of debris. Rotary systems were not very effective in preparing oval-shaped root canals since uninstrumented areas were observed frequently on the root canal walls.*

Keywords: *Root canal preparation smear layer*

Özet

Amaç: Taramalı elektron mikroskobu ile yapılan bu çalışmanın amacı, oval kök kanallarının döner ve el eğeleri kullanılarak şekillendirilmesini takiben kanallarda kalan debris ve smear tabakası miktarının değerlendirilmesidir.

Yöntem: Çalışmada otuz adet alt çene keser diş kullanıldı. Kök kanalları crown-down tekniğinin kullanıldığı Quantec LX veya HERO 642 eğeleri ile veya step-back tekniğinin kullanıldığı H-tipi eğeler ile şekillendirildi. Bütün dişler taramalı elektron mikroskobu incelemesi için hazırlandı. Debris ve smear tabakası varlığı, çalışmada yer almayan üç gözlemci tarafından koroner, orta ve apikal üçte bir bölgelerde, beşli not verme yöntemi kullanılarak değerlendirildi. Verilerin ortalaması alındı ve parametrik olmayan Kruskal-Wallis ve Mann-Whitney U testleri kullanılarak istatistiksel analiz yapıldı.

Bulgular: Quantec LX ve HERO 642 sistemleri kullanılarak gerçekleştirilen bütün şekillendirmelerde prepare edilmemiş bölgeler tespit edildi. Kalan debris ve smear tabakası değerlendirildiğinde, her ne kadar koroner üçte bir bölgede en düşük skorlar elde edilmiş olsa da, bölgeler göz önüne alındığında gruplar arasında anlamlı bir fark saptanmadı. Özellikle apikal üçte bir bölgede, Quantec LX eğeler en düşük debris skorlarına sahip oldular ($p<0,01$). Quantec LX sisteminin Hero 642 ve el eğeleri ile kıyaslandığında en düşük smear tabakası değerlerine sahip olduğu belirlendi, fakat bu fark istatistiksel olarak anlamlı bulunmadı ($p>0,05$).

Sonuç: Debris varlığı değerlendirildiğinde özellikle apikal üçte bir bölgede Quantec LX eğeler diğer sistemlere göre daha başarılı oldu. Oval şekilli kök kanalları döner aletler ile genişletilirken, kök kanal duvarlarında prepare edilmeyen alanlar kalabilmektedir.

Anahtar sözcükler: Kök kanal genişletmesi, smear tabakası

Kabul Tarihi: 04.05.2010

Introduction

Use of nickel-titanium (NiTi) alloy in endodontics has allowed the creation of newer instruments and preparation techniques that shortens the working time and lead the clinician to less iatrogenic errors such as ledging, zipping, canal transportation and apical blockage.[1] Handpiece-driven systems have been reported to rotate tapered instruments to efficiently create smooth and funnel-shaped preparations, with minimal iatrogenic errors.[2-6] The ability of these new instruments to remove debris and smear layer has also been examined by several researchers. using different evaluation techniques with varying root canal systems.[7,8] With regard of these techniques available up to date, complete debridement of the root canal system was not provided due to the geometrical dissymmetry between the preparation instruments and root canals.[9] Especially, the efficacy of instrumentation in long oval root canals such as mandibular incisors and distal canals of mandibular molars has been a major concern since the rotary NiTi instruments were reported to prepare a circular bulge similar with their designs, leaving unprepared buccal and lingual extensions with debris and smear layer.[8-15]

Circumferential filing with hand files or pressing the instrument against the root canal wall are the most common techniques in preparation and shaping of oval root canals.[13] Hybrid techniques combining hand and rotary instrumentation are also suggested to use to handle insufficient debridement.[10]

Quantec LX (Tycom, Irvine, CA, USA) instruments have a noncutting tip with a slightly positive cutting angle with radial lands and are helical in cross-section.[16] Taper sizes differ from 0.02 to 0.06 with flare series of 0.8 to 0.12. Hero 642 (Micro-Mega, Besancon, France) instruments have a noncutting tip with a negative cutting angle with three cutting edges without radial lands and are triangular in cross-section.[14] Taper sizes differ from 0.02 to 0.06. Instruments with taper greater than 0.04 are reported to be rigid and contribute to more lateral cutting in dentine walls.[9] Therefore, the increased taper might result in a better preparation of oval root canals.

The purpose of this study was to investigate the effects of rotary (Quantec LX & HERO 642) and manual (H-files, Thomas-Endo, France) instrumentations in oval root canals of mandibular incisors with respect to remaining debris and smear layer.

Materials and Methods

Thirty freshly extracted single-rooted, mandibular incisors having single canal were used in this study. The teeth had been extracted due to periodontal reasons and none of the teeth had previous restorative or endodontic therapy. Following extraction, the teeth were rinsed in tap water in order to remove blood and cleaned using a rubber cup and pumice. Then, they were stored in 0.1% thymol solution at 4°C until use. No fixative solution was used to avoid any effect that the fixative might have on the dissolution of organic tissue.

Standardized endodontic access cavities were prepared using a high-speed handpiece (Kavo, Super-torque 625-D, Germany), with diamond bur (801-020 ML Diatech) under copious water irrigation. To determine working length, a size 10 K-file was inserted until it reached the apical foramen and one millimeter subtracted from this length. Teeth having more than one canal were excluded from the study. Specimens were divided randomly into three groups for preparation with Quantec LX, HERO 642 or stainless steel Hedstroem files. One experienced-operator performed all instrumentation procedures. Rotary instruments were used according to the manufacturers' instructions. One set of instruments was used for the preparation of five canals in the Hero 642 and Quantec LX group to prevent file breakage as previously described by Mahran & AboEl-Fotouh.[17]

Canal Instrumentation

Groups I and II: The Quantec LX (Tycom, Irvine, CA, USA) was used to prepare the root canals of

Group I and Hero 642 (Micro-Mega, Besancon, France) was used for Group II with an electrically-powered handpiece Tri-Auto ZX (J. Morita, Kyoto, Japan) at a constant speed of 330 rpm. The manufacturer-recommended sequences used for each rotary NiTi system are given in Table 1.All canal preparations were limited to #30 apically to achieve apical standardization. Visual examinations were done to examine whether the files were deformed or not. In both systems, circumferential filing was done with the last file.

Group III (Hand Instrumentation): In hand-prepared specimens, step-back instrumentation with initial coronal flaring was used. The coronal thirds were shaped using Gates-Glidden drills from sizes #3 to#4. The root canals were then instrumented with sizes 15, 20, 25 and 30 H-files. Each file was passively placed to working length, and then filed circumferentially until loose. The apical patency was established by periodic passage of a size 10 H-file through the apical foramen. After reaching an apical matrix of a size at #30, step-back was performed to a size of #50, in 1 mm increments (Table 1).

All root canals were irrigated with 1 mL of 2.5% sodium hypochlorite (NaOCl) between each instrument and kept flooded with irrigant during the instrumentation phase. The irrigant was delivered with an endodontic syringe (Max-I-probe; Hawe Neos, Bioggio, Switzerland) that had been placed down the canal until slight resistance was felt. At the end of instrumentation, final flush was achieved by 2 mL of 2.5% NaOCl. Since the effectiveness of the systems was being examined, irrigation was performed only with 2.5% NaOCl and any other chelating agents were not used in the study. The teeth were stored in distilled water at 4°C until they were prepared for scanning electron microscopy (SEM) examination.

Preparation for SEM

The crowns of the teeth were removed at the cemento-enamel junction. All roots were grooved longitudinally on the buccal and lingual external surfaces with a diamond disk, avoiding penetration into the root canals. The teeth were then carefully split with a hammer and a chisel. The half of each specimen having the most visible part of the apex was selected. The roots were coded and mixed; hence the groups and specimens could not be identified during SEM observation. The specimens were dehydrated in graded concentrations of ethanol (30%, 50%, 70%, 90% and 100% twice, 30 minutes each) and dried overnight in a desiccator containing phosphorous pentoxide. Sections were mounted on brass stubs and sputter-coated with 200 Å gold and observed under a scanning electron microscope (JEOL, JSM-5200, Tokyo, Japan).

Specimen Grading

Separate blind evaluations were made by three trained observers on-site. A rating system previously described by Hülsmann et al.[18] was used with a set of reference photographs. All root canal walls were constantly scanned through buccal fracture surface to the lingual one in each third. At x200 magnification, the presence of macro- and microscopic debris or other residues were evaluated using a qualitative scale from 1 to 5. A similar scale was used to evaluate the x1000 images for the presence of smear layer. In addition, the presence of uninstrumented walls was noted in each third of the canal.

Scoring of the debris

Debris was defined as dentin chips, pulp remnants, and particles loosely attached to the root canal.[18]

Score 1: Clean root canal wall, only few small debris particles.

Score 2: Few small agglomerations of debris.

Score 3: Many agglomerations of debris covering less than 50% of the root canal wall.

Score 4: More than 50% of the root canal wall covered by debris.

Score 5: Complete or nearly complete root canal wall covered by debris.

Scoring of the smear layer

Smear layer was defined as a surface film of debris retained on dentine or other surfaces after instrumentation with either rotary instruments or endodontic files consisting of dentine particles, remnants of vital or necrotic pulp tissue, bacterial components and retained irrigant.[18]

Score 1: No smear layer, dentinal tubules open.

Score 2: Small amount of smear layer, some dentinal tubules open.

Score 3: Homogenous smear layer covering the root canal wall, only a few dentinal tubules open.

Score 4: Complete root wall covered by homogenous smear layer, no open dentinal tubules.

Score 5: Heavy, non-homogenous smear layer covering the complete root canal wall.

The final result for each section of the canals was obtained by calculating the mean of the scores given by three observers. Mean debris and smear layer scores were evaluated statistically using the Kruskal-Wallis test. For pairwise comparisons, Mann- Whitney U test was used. Significance was set at the 95% level.

Results

All systems including Quantec LX, HERO 642 and hand instrumentation with H-files proved to be safe techniques with no instrument fracture, apical blockage and perforation.

Uninstrumented areas

There were uninstrumented areas in coronal thirds of buccal or lingual extensions in all Quantec LX (Fig.1) and Hero 642 specimens (Fig.2)(Table 2). These areas were extended to the middle thirds in most of the root canals. Quantec LX instruments were not able to clean buccal or lingual extensions even in apical thirds of 4 root canals. Due to the action of NaOCl, calcospherites were clearly visible and dentinal tubules were open in these uninstrumented areas (Fig.1). In root canals prepared by manual instrumentation, all dentinal walls had been contacted and instrumented by H-files.

Debris

In 38% of all thirds, the scores given by three observers were identical. In an additional 58% of the scores, there was only one-score deviation among the observers. The total percentage of Score 1 (Fig.3A) and 2 was 64.4% for Quantec LX, 26.6% for HERO 642 and 24.4% for manual instrumentation. Score 5 (Fig.3B) was not given to any third of the root canals preapared using Quantec LX. When the debris scores were evaluated according to the regions of the root canal, ,coronal thirds demonstrated the lowest scores (Table 3). This difference, however, was not statistically significant ($p>0.05$). With respect to the root canal preparation systems (Table 3), the Quantec LX group had lowest debris scores ($p<0.01$). This statistical difference was mainly originating from the scores in the apical third ($p<0.01$).

Smear layer

In 47% of all thirds, the scores given by three observers were identical. In an additional 51% of the scores, there was only one-score deviation among the observers. The total percentages of Score 1 (Fig.4A) and 2 were very low for all instrumentation groups. These were 17.7%, 6.6% and 4.4% for Quantec LX, HERO 642 and hand instrumentation, respectively. Dentinal tubules were completely opened with little smear layer on instrumented areas. With respect to smear layer formation, best results were achieved in coronal third (Table 4) however no significant differences were found among the coronal, middle and apical thirds ($p>0.05$) When smear layer was evaluated according to the root canal preparation systems, the Quantec LX group showed the lowest scores in comparison to Hero 642 and hand preparation. However, this difference was not significant ($p>0.05$) (Table 4).

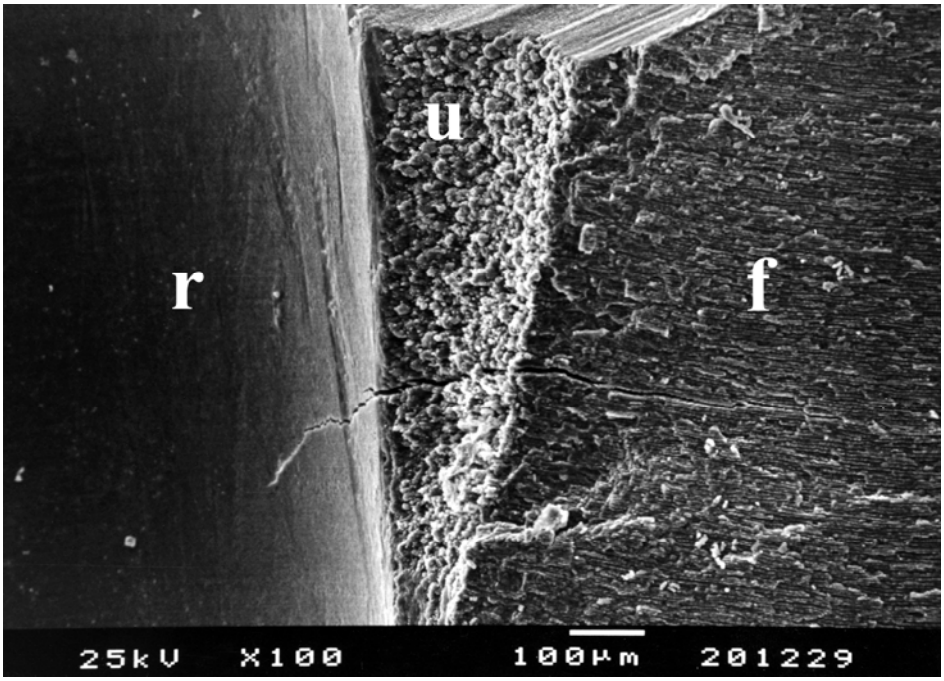

Figure 1. A view from the fractured side of coronal third of a Quantec LX specimen. Note the presence of dense calcospherites in the uninstrumented area (f = fractured side; r = instrumented root canal; u = uninstrumented area) (original magnification x100).

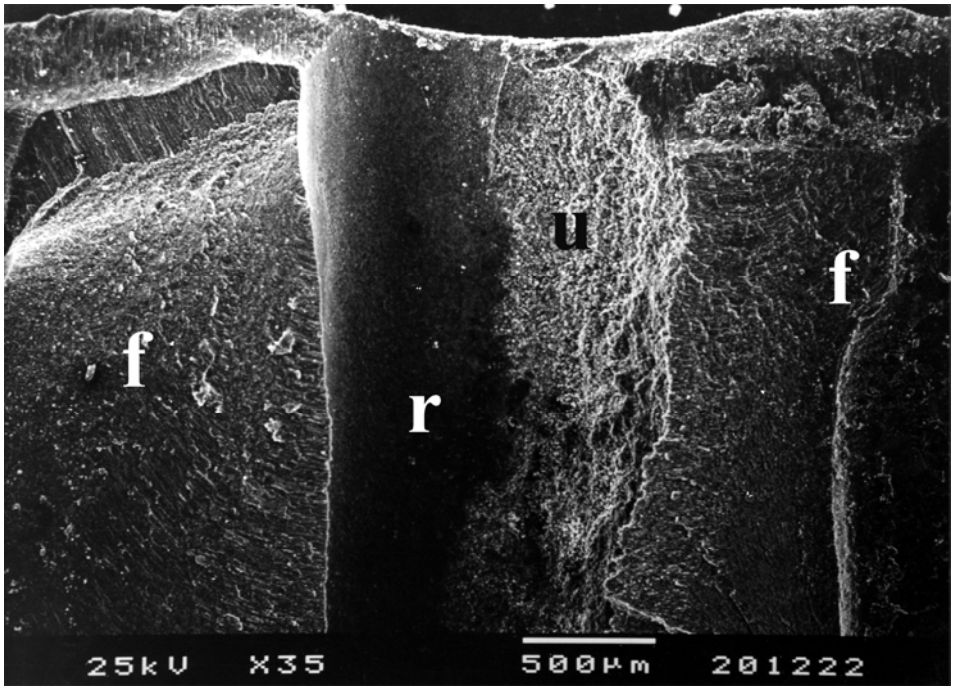

Figure 2. Root canal view from the fractured side of a HERO specimen. There is a wide and long uninstrumented area in the coronal third. This area was extending to middle third (f = fractured side; r = instrumented root canal; u = uninstrumented area) (original magnification x35).

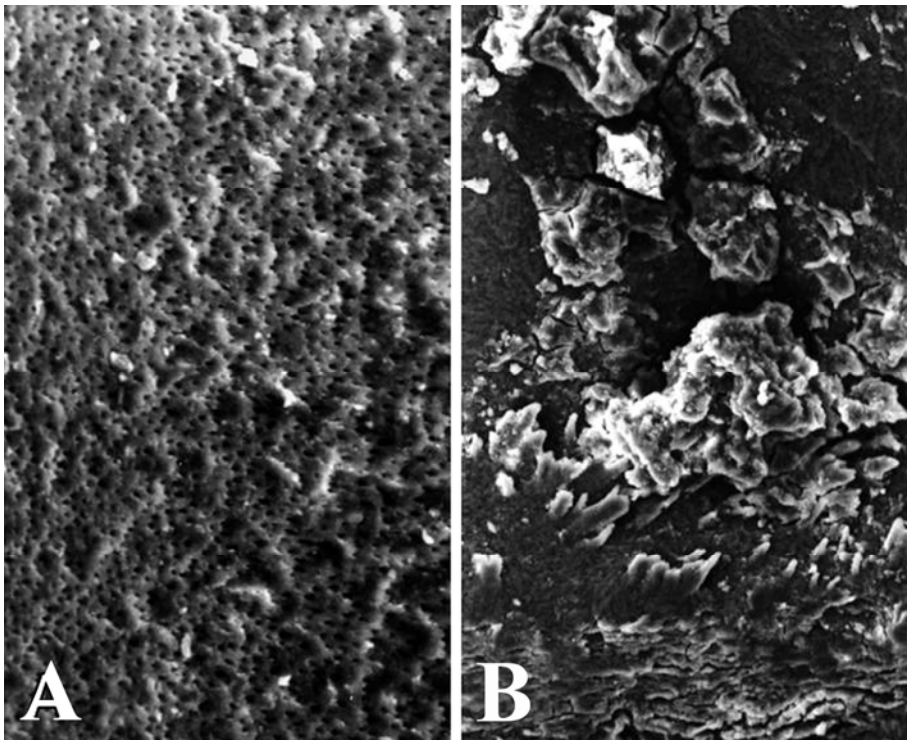

Figure 3. Standardized evaluation of debris: **A.** Score 1 **B.** Score 5 (original magnification x200).

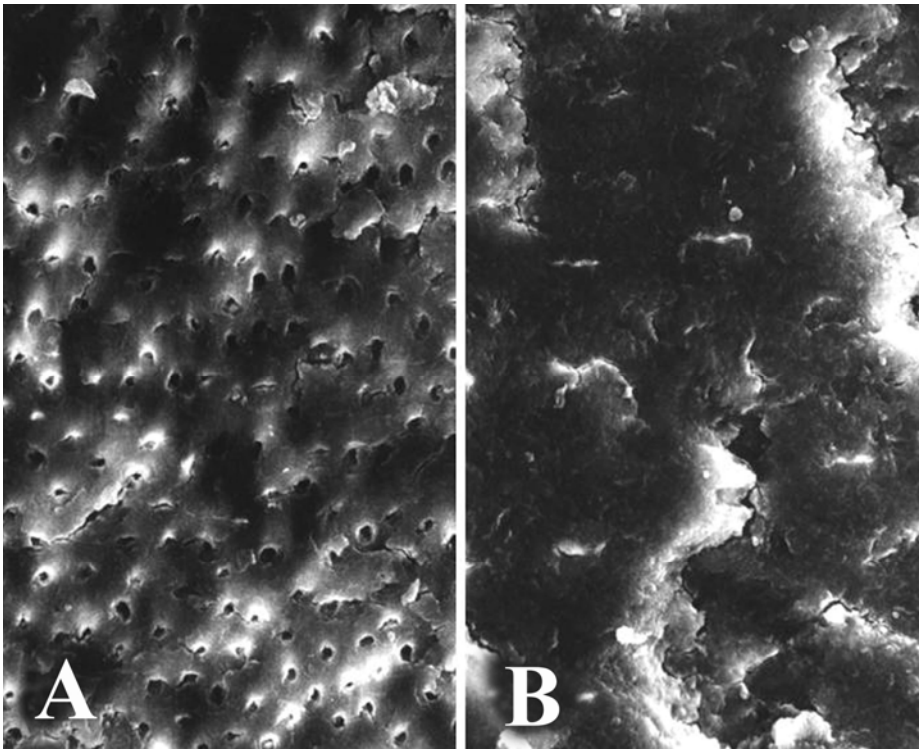

Figure 4. Standardized evaluation of smear layer: **A.** Score 1 **B.** Score 5 (original magnification x1000).

Table 1. Instruments used, sequence of preparation, taper, size and working length

QUANTEC LX			HERO 642			MANUAL	
Taper*	Size	WL	Taper	Size	WL	Size	WL
12**	15**	17 mm**	6	20	2/3 WL	GG#3	WL-10 mm
6	25	WL	4	20	WL-2 mm	GG#4	WL-10 mm
2	15	WL	2	20	WL	15	WL
2	20	WL	4	25	WL-2 mm	20	WL
2	25	WL	2	25	WL	25	WL
3	25	WL	4	30	WL-2 mm	**30**	**WL**
4	25	WL	**2**	**30**	**WL**	35	WL-1mm
5	25	WL				40	WL-2 mm
6	25	WL				45	WL-3 mm
2	**30**	**WL**				50	WL-4 mm

WL: Working length, GG: Gates Glidden

* Taper values are given as (%)

** Quantec Flare Series™

Table 2. Distribution of uninstrumented areas in buccal and lingual extensions of root canals.

Groups	Coronal	Middle	Apical
Quantec LX	10	4	4
Hero 642	10	8	0
Manual	0	0	0
Total	20	12	4

Table 3. Mean debris scores (±SD)

Groups	Coronal	Middle	Apical	Mean
Quantec LX	2.00 ± 1.05	2.40 ± 0.72	2.27 ±0. 98	2.22 ± 0.88
Hero 642	2.67 ± 1.56	3.27 ± 1.14	4.73 ± 0.43	3.56 ± 1.39
Manual	3.07 ± 1.79	3.80 ± 1.43	3.67 ± 0.91	3.51 ± 1.36
Mean	2.58 ± 1.47	3.16 ± 1.10	3.56 ± 0.78	

Table 4. Mean smear layer scores (±SD)

Groups	Coronal	Middle	Apical	Mean
Quantec LX	2.80 ± 0.77	3.47 ± 1.04	3.80 ± 0.61	3.36 ± 0.88
Hero 642	3.27 ± 1.40	4.27 ± 0.72	4.27 ± 0.80	3.93 ± 1.06
Manuel	3.37 ± 1.09	4.00 ± 0.78	4.13 ± 0.77	3.96 ± 0.84
Mean	3.27 ± 1.09	3.91 ± 0.83	4.07 ± 0.72	

Discussion

In this study, debris and smear layer remained after endodontic preparation of oval root canals with Quantec LX or HERO 642 rotary systems, or manual instrumentation were evaluated using SEM. Since the effectiveness of the systems and techniques were being examined, irrigation was performed only with NaOCl and no chelating

agent was used. In addition, the teeth had been stored in 0.1% thymol solution, not in formaldehyde solution, because formaldehyde solutions may change dissolution and ultrastructural properties of dentin by cross-linking with collagen.[19] Such an alteration may also affect debris and smear layer formation and does not reflect the clinical condition of the substrate.

In the present study, completely cleaned root canals were not found in any group. Even though it was not found statistically significant, coronal thirds received the best scores for both debris and smear layer formation followed by middle, then apical thirds being irrespective of the system or instruments. This was a consistent finding with other researchers stating that there was less debris or smear layer in coronal thirds than middle and apical thirds.[9,10] In rotary NiTi groups, instruments with greater taper (0.12 for Quantec LX and 0.06 for Hero 642) provided more lateral cutting in dentine walls resulting decreased debris and smear layer scores especially in the coronal third. Similarly, in manual technique, the use of Gates Glidden burs created the same results.

Taha et al.[10] compared the filing effects of hand, rotary and Anatomic Endodontic Technology (AET: a root canal shaping system which was designed to prepare oval canals in a reciprocating slow-speed handpiece) using histologic cross-sections. With regard to the residual debris, rotary instruments were reported to perform better than AET and hand filing in the apical third. AET and hand instrumentation were successful in the middle area leaving untouched surfaces in coronal and apical region.

Grande et al.[2] in a similar study, evaluating AET and rotary systems, concluded that AET was more successful in the coronal and middle area preparation in terms of removing more tooth structure at these levels.

Also in a recent study by ElAyouti et al.[9] the middle thirds of oval root canals were evaluated in terms of preparation quality enlarged using two rotary (MTwo and Protaper) and NiTi hand files. Rotary files were reported to be better than hand files. When considering the performance of each rotary file system, ElAyouti et al.[9] made a comparison with a previous study reported by Weiger et al.[13] using Hedström files and HERO 642 in which HERO 642 system was not successful regarding its smaller taper and lower cutting efficiency. Rotary files *once again* were unable to completely prepare oval root canals.

When using rotary instruments in oval root canals, tapers larger than 0.04 was shown to be more efficient than hand files[9] but still leaving uninstrumented areas (Fig.1&2). Besides, it should be kept in mind that overinstrumentation of the dentin coronally may jeopardize the root structure therefore care should be taken especially near the danger zones with minimum dentin thickness to prevent perforations.[20] In a recent study by Paque´ et al.,[15] oval-shaped root canals were prepared by Protaper Universal instruments up to the finishing file F4 (size 40 , 0.06 taper) with different manipulation protocols. In one experimental group, distal canal of the mandibular molar teeth were prepared as two individual canals with a circumferential filing motion. Preparations were reported to leave a variable portion of surface area untouched regardless of the different manipulation protocols however, considering oval canals as two separate entities during preparation was suggested to increase overall prepared surface.

A particular difference in the present study was related to the smear layer results. Total percentage of scores 3, 4 and 5 (Fig.4B) was higher than scores 1 and 2 (Fig.4A) for all groups, indicating that there was a dominant presence of homogenous to heavy smear layer within the study. In contrast with our results, Bertrand et al.[21] reported that only a thin or no smear layer was observed in most areas of their specimens instrumented with Quantec Series. Similarly, Hülsmann et al.[7] noted scores 1 and 2 on smear layer with 53.3 % for HERO 642 and 41.4 % for Quantec SC. However, a chelating agent had been used in their study. Root canals

instrumented by rotary systems in the present study had unprepared surfaces similar to those observed by other researchers.[7,22,23] In some specimens, these unprepared surfaces were extending from coronal to apical third in buccal or lingual extensions. It is inevitable for NiTi rotary instruments *not to touch* some root canal walls particularly in oval canals since they are super elastic and can not be pressed against the dentinal walls in extensions. Rather, rotary NiTi files act in a self-centering mode along the root canal wall creating a circular bulge in the center of the canal but leaving the extensions unprepared.[8] In such cases, circumferential usage of hand files having a certain degree of rigidity may be recommended to prepare recesses in oval canals following the completion of rotary instrumentation.[10] In the present study, root canals walls in buccal or lingual extensions had been successively prepared with H-files using step-back technique even though they had slightly higher smear layer scores.

Present study reports that significantly less debris (particularly in the apical third) was remained and slightly less smear layer was formed after preparation with Quantec LX instruments. According to Medioni et al.,[24] the superiority of the Quantec system demands on the asymmetric design of the file, continuously graduating tapers and the cutting blades which have positive cutting edges. A main difference between Hero and Quantec instruments may be the symmetrical design of Hero files having three equally-spaced cutting edges.without radial lands. A radial land is a flat area located behind the cutting edge which facilitates the movement of debris in the coronal direction leaving less smear layer.[25] In the present study, low smear layer scores of Quantec LX may be directly correlated with the large radial lands of the system. Also, slightly positive cutting angle may have provided additional cutting efficiency as likely as the active cutting blades which have been reported to increase root canal cleanliness by removing smear layer.[25]

Conclusions

Although Quantec LX instruments demonstrated better cleaning than did HERO 642 and manual instrumentation, these techniques were not very effective in cleaning oval root canals of mandibular incisors in respect to debris and smear layer formation. In addition, uninstrumented areas were observed in all root canals prepared by rotary systems. Therefore, some modifications should be done in the working action of rotary systems in order to have optimal canal preparations in teeth having oval canal forms. Hybrid techniques combining hand and rotary instrumentation may be an alternative to overcome this problem. This study reinforces the concept that no technique or instrument design is so far totally effective in cleaning all regions of oval-shaped root canals.

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