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The quality of apical preparation in curved root canals using hand and rotary instrumentation techniques

Qualidade do preparo apical em canais radiculares curvos utilizando técnicas de instrumentação manual e rotatória

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Abstract

Objectives: To determine the quality of apical preparation in mesiobuccal root canals of mandibular molars using hand stainless steel K-Flexofile, nickel-titanium rotary ProTaper and ProTaper + ProFile instruments. **Materials and methods**: Thirty freshly extracted mandibular molars were randomly divided into three experimental groups (n = 10). The mesiobuccal root canals were prepared with K-Flexofile and Golden Medium hand files (group 1); with ProTaper (group 2) and with ProTaper + ProFile rotary instruments (group 3). After histological preparation the comparative analysis was performed at 1 mm, 3 mm and 5 mm from the working length. Each sample was evaluated on cleaning and shaping based on established criteria. Data were analyzed statistically by the Kruskal Wallis and Mann-Whitney U tests at a 5% significance of level. **Results**: The hand instrumentation group showed significantly better apical quality preparation than both rotary instrumentation groups ($p < 0.05$). The comparison between the two rotary techniques showed no statistical differences ($p > 0.05$). The buccal and lingual walls of the root canals showed more pulp tissue

remnants than mesial or distal walls. **Conclusions**: None of the three techniques was totally effective in cleaning the apical root canal space of mesiobuccal canals of mandibular molars.

Keywords: Apical preparation. Hand instrumentation. Rotary instrumentation.

Resumo

***Objetivos**: Determinar a qualidade do preparo apical do canal mésio-vestibular de molares inferiores humanos empregando instrumentação manual K-Flexofile, rotatória com instrumentos NiTi ProTaper e ProTaper associado a instrumentos ProFile. **Materiais e métodos**: Foram utilizados 30 dentes molares inferiores humanos, distribuídos aleatoriamente em três grupos (n = 10). O canal mésio-vestibular foi preparado com limas tipo K-Flexofile e Golden medium (grupo 1); com ProTaper (grupo 2) e com ProTaper Perfil + ProFile (grupo 3). Após a preparação histológica, uma análise comparativa foi realizada a 1 mm, 3 mm e 5 mm do comprimento de trabalho. Cada amostra foi avaliada com respeito à limpeza e modelagem com base em critérios preestabelecidos. Os dados foram analisados por meio dos testes de Kruskal Wallis e Mann-Whitney com um nível de significância de 5%. **Resultados**: A instrumentação manual mostrou significativamente uma maior qualidade apical de preparo em ambos os grupos de instrumentação rotatória ($p < 0,05$). A comparação entre as duas técnicas de instrumentação rotatória não mostraram diferenças estatisticamente significativas ($p > 0,05$). As paredes vestibular e lingual dos canais radiculares mostraram mais remanescentes de tecido pulpar que as paredes mesial ou distal. **Conclusões**: Nenhuma das três técnicas foi totalmente eficaz na limpeza do espaço do canal radicular apical de canais mésio-vestibulares de molares inferiores.*

***Palavras-chave**: Preparo apical. Instrumentação manual. Instrumentação rotatória.*

Introduction

The main objectives in root canal preparation are mechanical debridement and disinfection of the root canal system. If the root canal is not adequately enlarged during the shaping procedure, the remaining bacteria can survive and cause periapical changes (1-3).

The success of endodontic treatment varies due to the anatomical complexity of the root canal system, particularly in the apical region (3-6). There is evidence that the apical diameter of the instrument determines its effectiveness in removing intracanal microbiota (7). For example, an instrument with a smaller diameter leaves more of the root canal surface untouched, which may affect disinfection of the root canal. Conversely, errors in preparation are more likely to occur if oversized hand files are used to prepare the apical third region, particularly in curved canals (7). Usually, a #25 or #30 master apical file is recommended for routine use in hand instrumentation techniques for narrow root canals, such as the mesial canals of permanent molars (8).

Nickel-titanium (NiTi) instruments represent a new approach to root canal preparation because of their standardized tapers (9). Studies have shown that Ni-Ti instruments can effectively produce a well-tapered root canal with minimal risk of transporting the original root canal. However, different Ni-Ti instruments show variable effectiveness in debris removal, especially in flattened root canals (10-11).

Different outcomes in root canal preparation have been demonstrated using the ProTaper and ProFile rotary systems (12-15). A recent study found no statistically significant differences in debris removal in root canals instrumented with either hand ProTaper, hand ProFile or hand Hero Shaper systems (16). As such, more studies are needed to provide information on which techniques or combinations of techniques yield better cleaning, especially in the apical third of curved root canals. Consequently, the aim of this study was to determine the quality of apical preparation in the mesiobuccal root canals of mandibular molars using hand stainless steel K-Flexofile and nickel-titanium rotary ProTaper and ProTaper + ProFile techniques.

Materials and methods

In this study, 30 non-restored human mandibular molars freshly extracted were used. Only teeth displaying vitality and completely formed apices were used. This research project, including the collection of dental specimens, was conducted in accordance with the institutional ethics committee.

After endodontic access, the working length was determined by subtracting 1 mm from the length at which a #10 K-file (Dentsply/Maillefer, Ballaigues, Switzerland) tip extruded apically. The root canal curvature, determined using the method described by Schneider, ranged between 25° and 40°. The mesiobuccal root canals were randomly divided into three groups (n = 10) with equal distribution of types of curvature. The adjacent uninstrumented mesiolingual root canals were used as positive controls.

The root canals were flushed with 1 mL of 1% NaOCl solution (Aspheric Chemical Industry Ltd., São Caetano do Sul, SP, Brazil) between files using a plastic syringe (Ultradent Products, South Jordan, Utah, USA) with a needle NaviTip n. 2 (Ultradent Products, South Jordan, Utah, USA) inserted as deep as possible into the root canal without binding. After instrumentation, root canals were flushed with 1 mL of 17% EDTA solution (Aspheric Chemical Industry Ltd., São Caetano do Sul, SP, Brazil).

The teeth were immobilized by means of a lathe table (Tramontina, Canoas, Rio Grande do Sul, Brazil) and the root apices were sealed with wax (Aspheric Chemical Industry Ltd., São Caetano do Sul, Brazil) in order to retain the irrigant solution inside the root canal during instrumentation. The rotary systems were attached to the electric motor Pro-Driller (Endo Pro, VK Driller, Jaguaré, São Paulo, Brazil) with a hand piece (Dabi Atlante, Ribeirão Preto, São Paulo, Brazil) and set to a constant speed and torque control in accordance with the manufacturer's instructions.

Group 1 - Crown-down hand technique

The root canals were prepared by the crown-down technique. The preparation of the coronal and middle thirds was performed with Gates Glidden burs #2 and #3 (Dentsply/Maillefer, Ballaigues, Switzerland). The apical file size was determined using the Grossman criterion of three sizes larger than the first file that bound at working length. The apical third were instrumented at working length up to a K-Flexofile #35 or #40 (Dentsply/Maillefer, Ballaigues, Switzerland) and Golden Medium files #12 - #37 (Dentsply/Maillefer, Ballaigues, Switzerland) were used to facilitate the subsequent use of the standardized instruments.

Group 2 - ProTaper instrumentation technique

The root canals were prepared with a crown-down technique using the ProTaper Universal system (Dentsply/Maillefer, Ballaigues, Switzerland). Hand exploration of the root canal was performed with #10 and #15 K-Flexofile (Dentsply/Maillefer, Ballaigues, Switzerland). The instrument sequence SX was used to prepare the coronal third, S1 and S2 were used by brushing movements to prepare middle thirds and the sequence F1, F2 and F3 was used to instrument the apical thirds with no-brushing movements. The files were first introduced manually to eliminate tension points and then introduced by activation with passive pressure movement.

Group 3 - ProTaper + ProFile instrumentation technique

The root canals were explored with #10 and #15 K-Flexofile (Dentsply/Maillefer, Ballaigues, Switzerland) and instrumented according to the crown-down technique using the SX to prepare the coronal third, S1 and S2 ProTaper files to enlarge the middle thirds. The apical third was instrumented with #20, #25, #30 and #35 ProFile .02 rotary instruments used at working length.

Sample preparation

In order to facilitate subsequent procedures, the mesial roots were sectioned from the crown at the cemento-enamel junction and each sample was decalcified in Morse solution (Sodium citrate at 20% and Formic acid at 50%) for a period of two to three weeks. Following decalcification, the specimens were rinsed in water for 24 hours, dehydrated and embedded in paraffin blocks (Isofar Produtos Químicos, Rio de Janeiro, Brazil) so that the apex was oriented perpendicularly to the base of the paraffin block.

The blocks were oriented to ensure that sections were cut perpendicular to the root canal. Successive sections were cut at 5 µm thickness starting from the apex, continuing until the working length was reached. Three cross-sections were taken at 1, 3 and 5 mm from the working length. These sections were mounted on glass slides and stained with hematoxylin and eosin (H&E).

Evaluation

The sections were evaluated under an optical microscope (Olympus CX21) at 40x to assess their cleanliness. The images obtained with the microscope were recorded using a digital camera attached to the microscope and stored as .jpg files (Figure 1). The root canal was divided into four segments corresponding to the buccal (B), lingual (L), mesial (M) and distal (D) walls. The examination of each quadrant was performed by a single examiner (endodontist) trained and calibrated for the study according to the following scoring system (8): score 0, root canal wall that was planed, without remnants of pulp tissue; score 1, root canal wall that was planed with remnants of pulp tissue and score 2, root canal wall unplaned with remnants of pulp tissue.

Due to non-parametric data, the Kruskal-Wallis test was used to evaluate the scores of cleaning in experimental groups (at 1, 3 and 5 mm). When *F* was significant, the Mann-Whitney U test was used for paired comparisons at a 5% level of significance.

Results

The results of the evaluation of cleaning scores of root canals are shown in Table 1. Significant differences were found between the different techniques. The hand instrumentation group showed significantly better apical quality preparation than both rotary instrumentation groups ($p < 0.05$).

The comparison between the two rotary instrumentation groups showed no statistical differences. There were statistically differences in dentin cleanliness scores for the mesial, lingual, buccal and distal walls ($p < 0.05$). Hand instrumentation group showed differences between mesial ($p = 0.001$) and distal ($p = 0.004$) walls to compare with lingual walls. Similarly the ProTaper group showed differences between mesial ($p = 0.001$) and distal ($p = 0.007$) walls to compare with lingual walls. In the ProTaper/ ProFile group, there were differences between mesial with lingual ($p = 0.000$) and buccal ($p = 0.002$) walls and in distal walls with lingual ($p = 0.000$) and buccal ($p = 0.006$) walls.

Discussion

The complex anatomy of the root canal system decisively influences the quality of endodontic treatment (3-6). Various studies have illustrated the difficulty of preparing oval or flattened canals with stainless steel hand files and rotary NiTi instruments (2, 8, 17, 18).

The results of the present investigation, in agreement with previous studies, showed that no instrumentation technique was able to completely clean

Table 1 - Results of canal cleanliness scores at root canal sections [n (%)]

	1 mm		
Score	**Hand**	**ProTaper**	**ProTaper Profile**
0	21 (52.5%)^{a,1}	13 (32.5%)^{b,1}	9 (22.5%)^{a,1}
1	9 (22.5%)^{a,1}	11 (27.5%)^{b,1}	8 (20.0%)^{a,1}
2	10 (25.0%)^{a,1}	16 (40.0%)^{b,1}	23 (57.5%)^{a,1}
	3 mm		
0	22 (55.0%)^{a,b,2}	12 (30.0%)^{a,2}	4 (10.0%)^{b,2}
1	11 (27.5%)^{a,b,2}	15 (37.5%)^{a,2}	18 (45.0%)^{b,2}
2	7 (27.5%)^{a,b,2}	13 (32.5%)^{a,2}	18 (45.0%)^{b,2}
	5 mm		
0	24 (60.0%)^{a,b,3}	14 (35.0%)^{a,3}	8 (20.0%)^{b,3}
1	6 (15.0%)^{a,b,3}	12 (30.0%)^{a,3}	15 (37.5%)^{b,3}
2	10 (25.0%)^{a,b,3}	14 (35.0%)^{a,3}	17 (42.5%)^{b,3}

Note: 0 = Canal wall that was planed, without remnants of pulp tissue; 1 = Canal wall that was planed with remnants of pulp tissue; 2 = Canal wall unplaned with remnants of pulp tissue; the same superscript letters in columns indicate no significant differences among instrumentation techniques in the same section; the same superscript letters in rows indicate significant differences among instrumentation techniques in the same section; the same superscript numbers in rows indicate significant differences among sections in the same instrumentation technique.

Source: Research data.

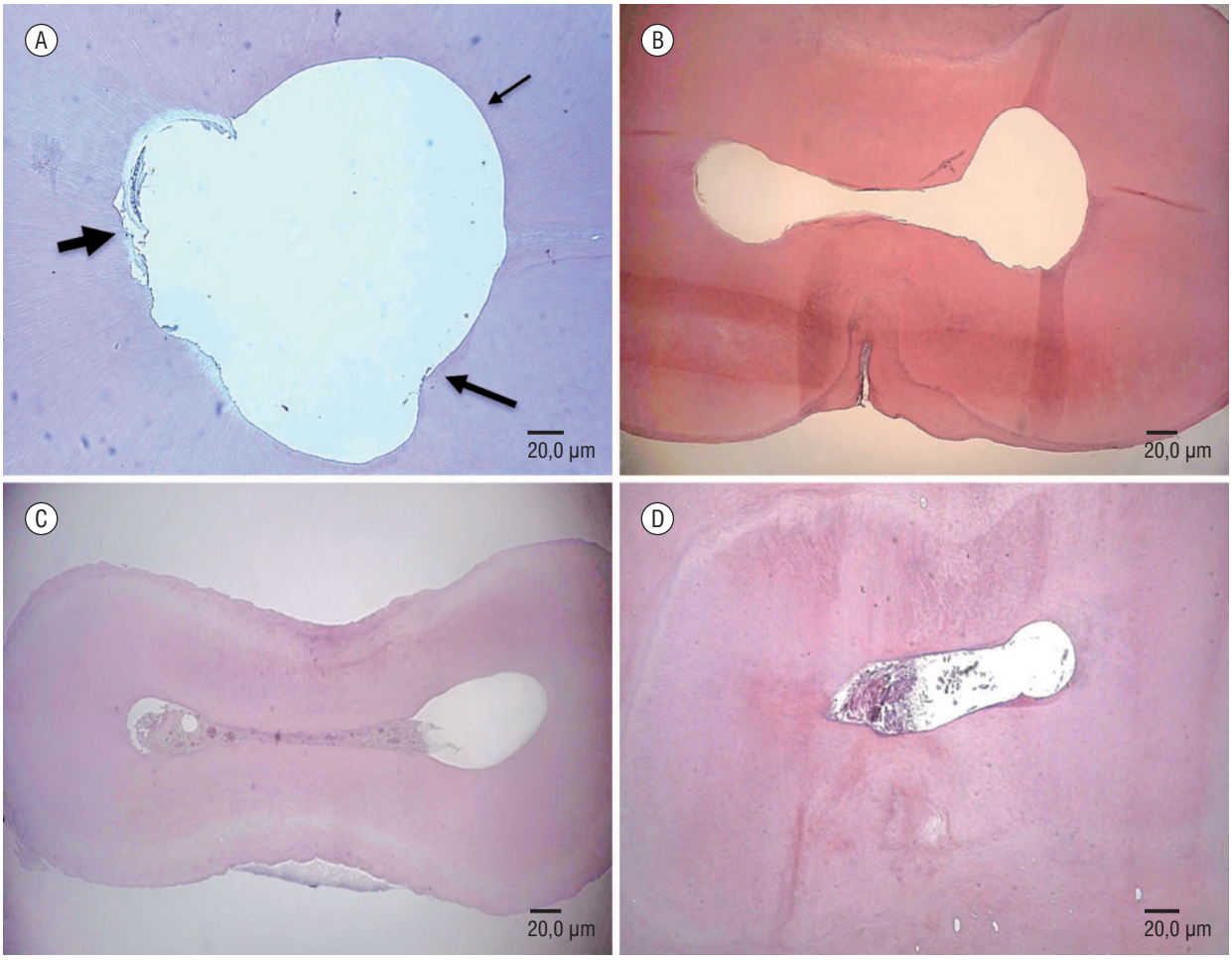

Figure 1 - (A) Cross-section of an instrumented canal showing canal wall planed (score 0, *small arrow*), part of original canal wall that was planed but with remnants of pulp tissue or dentin debris attached (score 1, *medium arrow*), and the original canal wall that was unplaned with pulp tissue remaining attached to the canal wall (score 2, *large arrow*). (B) Cross-section of a manual instrumentation at 5 mm. (C) Cross-section of ProTaper instrumentation at 3 mm. (D) Cross-section of ProTaper/ProFile instrumentation at 1 mm

the root canals (2, 3, 8). In this study the hand preparation technique has shown to be more effective than rotary instrumentation techniques in cleaning curved root canals. In this sense, the preflaring in the cervical and middle thirds and/or greater apical enlargement was beneficial in attempting to further debride the apical third region in mesiobuccal root canal of mandibular molars. It seems that the preflaring preparation and crown-down technique decreases the interferences along the root canal and allows more effective removal of debris due to the possibility of deeper penetration of irrigants (19). In addition, the larger volume of 1% NaOCl irrigating solution (15 mL) used during hand preparation technique respect to the ProTaper (8 mL) or ProTaper/ProFile (9 mL) rotary techniques would have contributed decisively to obtain the best results.

The rotary instruments tend to stay centered in the apical region of the root canal due to flexibility of the NiTi alloy (2, 20). When apical transportation is considered, the use of size #30, #35 nickel-titanium rotary instruments is an effective method for apical preparation of the root canals (21). In our study, the apical preparation with ProTaper was performed up to F3 (#30) instrument for its proven cleaning ability of the apical third of flattened root canals (10) and capacity to reduce the amount of bacteria in the mechanical disinfection of the root canal system (22). In the ProTaper/ProFile group, the use of ProFile .02 instruments was chosen because it has

been suggested that ProTaper instrumentation may be implemented with other systems with less taper (23) and more centering ability to prepare this apical region in mesiobuccal curved canals (12).

In this study, according to different studies (1, 16, 24), the rotary systems, ProFile and ProTaper, showed no better behaved than hand preparation technique. Ahlquist et al. (25) found significantly less debris in the apical region with a manual technique than the ProFile rotary technique, and Barbizam et al. (26) observed that the manual crown-down technique was more effective in cleaning mesiodistal flattened root canals than the rotary ProFile 0.4 technique. Also, the debridement quality of the ProTaper system has shown suboptimal in oval canals to respect round canals (27) and in smear layer removal of maxillary and mandibular molars root canals (14).

The preparation of oval-shaped root canals in mandibular molars left a high percentage of canal surfaces unprepared, regardless of the instrumentation technique used (28). By the criteria established in this study, the unplaned wall that we found exemplifies the impossibility of perfect circumferential preparation in cases of oval or flattened root canals. The use of hand and rotary instruments results in irregular enlargement with marked wear on the mesial and distal walls, where they made contact (29). El Ayouti et al. (2), comparing manual and rotary systems, found that none of the techniques were able to satisfactorily prepare the root canals circumferentially, even when using instruments with greater taper.

These findings suggest that the irrigants we used assisted in cleaning the root canal, supporting the effectiveness of the instrument's mechanical action associated with irrigation. In accordance with De Deus et al. (20), we observed that when a larger taper is used, the quality of the preparation depends more on the irrigation protocol than on the rotary system.

Conclusion

None of the three techniques was entirely effective in cleaning the apical root canal region of the mandibular molar mesiobuccal canal. For manual preparation, the highest-quality results were obtained when an increased volume of irrigation solution was used.

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