Comparative evaluation of apical debris extrusion associated with using reciprocating and rotary systems with variable tapers

including single- and multiple-file sequences, and the influence of the glide path

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Introduction

The attainment of successful root canal cleaning and shaping is dependent on the glide path and specific biological and mechanical objectives, which were beautifully described by Herbert Schilder in 1974.[1] To reduce the risk of instrument fracture, root canal aberrations and transportation, it is recommended to create a glide path, a smooth, possibly narrow passage from the coronal orifice to the radiographic or electronically determined terminus that allows instrumentation without resistance for 3D cleaning and shaping without altering the canal morphology.[2,3]

Nowadays, most nickel–titanium (NiTi) instruments work on torque control modes and employ different file designs and instrumentation techniques. Advancements in designs include modifications to the tip, alterations of the cutting edge, variations of the taper, changes in pitch length, and heat and surface treatments, which enhance efficacy and safety.[4] These advancements allow better control of root canal shaping, facilitating better irrigation and obturation.

New-generation files also offer single-file or multiple-file sequences, have offset or centred mass of rotation and employ principles of rotary or reciprocating motion, the clockwise and anticlockwise angles of which may be equal or unequal. Offset-designed files produce a mechanical wave of motion along the active length to remove debris as well as offer flexibility.[5]

Instruments using reciprocating motion are beneficial in narrow and more curved canals because of reduced binding to the dentinal walls, reducing torsional stress.[5] An example of such a system is WaveOne Gold (Dentsply Sirona), which is a combination of second- and third-generation file systems and is made of M-Wire, a special heat-treated NiTi alloy with gold technology to increase flexibility and cyclic fatigue resistance.[6] This is a variable taper system.

File systems with continuous motion require less inward pressure and fewer cycles and offer improved quality of augering debris out of a canal. Such a file system with a variable taper is One Shape (MicroMega), which has a triangular cutting edge, asymmetrical cross sections over the entire blade and a long pitch design that changes progressively from three to two cutting edges between the apical and coronal parts for cutting action. Additional cutting edges are present in the apical and coronal parts. One Shape is a single-file system. Also designed to continuously rotate clockwise, the Mtwo instrument (VDW) has an S-shaped cross section with two active cutting surfaces and a constant taper. Another rotary system, the HyFlex EDM file (COLTENE) has controlled memory and is manufactured using electrical discharge machining. This file has a quadratic cross section apically, trapezoidal cross section in the middle and triangular cross section coronally.[7,8]

In this study, the influence of a glide path on apical debris extrusion was investigated with reference to single- and multiple-file sequences employing rotary HyFlex EDM a single file system, One Shape, Neoendo [Orikam Healthcare], Mtwo) and reciprocating systems (WaveOne Gold) with different tapers. Quantification of apical debris was done to deduce the effect of the instrumentation kinematics and techniques. No previous single study has evaluated the effect of glide path creation taking into consideration file

Table 1: Descriptive statistics of extruded debris for each group.

Group no.	n	Mean	SD	SE	95% confidence interval of the mean		Minimum	Maximum
					Lower bound	Upper bound		
IA	20	0.0248	0.02373	0.00531	0.0137	0.0359	0.00	0.10
IB	20	0.0372	0.03618	0.00809	0.0203	0.0541	0.01	0.13
IIAa	20	0.0162	0.02364	0.00529	0.0051	0.0272	0.00	0.11
IIAb	20	0.0008	0.00096	0.00022	0.0004	0.0013	0.00	0.00
IIAc	20	0.0293	0.01381	0.00309	0.0228	0.0357	0.01	0.06
IIAd	20	0.0035	0.00244	0.00055	0.0024	0.0047	0.00	0.01
IIBa	20	0.0214	0.04764	0.01065	−0.0009	0.0437	0.00	0.18
IIBb	20	0.0019	0.00103	0.00023	0.0014	0.0024	0.00	0.00
IIBc	20	0.0532	0.05456	0.01220	0.0277	0.0787	0.00	0.20
IIBd	20	0.0229	0.03160	0.00707	0.0081	0.0377	0.00	0.11
Total	200	0.0211	0.03313	0.00234	0.0165	0.0257	0.00	0.20

design and taper and the number of files used regarding apical debris extrusion.

Materials and methods

Two hundred and twenty freshly extracted, single-rooted human mandibular premolars with canals with mature apices (25–30° curvature, according to Schneider) were selected and cleaned with an ultrasonic device. The radii of curvature were 4–9 mm, and the apical diameters corresponded to a #15 K-file, as observed under a dental operating microscope at 25× magnification (Sanma Medineers Vision). Carious, fractured or previously restored teeth or teeth with calcified canals were excluded. The crown of each tooth was flattened with a high-speed bur to obtain standardised tooth lengths of 19 mm. Disinfection was done by immersing the teeth in 0.1% thymol for 24 hours, and then the teeth were stored in normal saline at room temperature until required.

The apparatus used in Myers and Montgomery was modified for debris and irrigant collection.[9] Eppendorf tubes and vials were pre-weighed with 10–5 g precision on an electronic microbalance (SI-234, Denver Instrument). The mean of three consecutive readings was taken.

Access cavity preparation was done with a high-speed round carbide bur (DIATECH, COLTENE) in all teeth. A barbed broach (VDW) was used to remove the remnants of pulp. The working length (WL) was 0.5 mm short of the standardised tooth length. The crown-down technique was used for biomechanical preparation.

The samples (N = 200) were divided into groups according to instrumentation as follows:

- Group A (n = 100) for instrumentation with a glide path:
  - Subgroup IA (n = 20): WaveOne Gold; and
  - Subgroup IIA (n = 20 in each group): (a) Sub-subgroup IIAa: HyFlex EDM; (b) Sub-subgroup IIAb: One Shape; (c) Sub-subgroup IIAc: Mtwo; and (d) Sub-subgroup IIAd: Neoendo.
- Group B (n = 100) for instrumentation without a glide path:
  - Subgroup IB (n = 20): WaveOne Gold; and
  - Subgroup IIB (n = 20 in each group): (a) Sub-subgroup IIBa: HyFlex EDM; (b) Sub-subgroup IIBb: One Shape; (c) Sub-subgroup IIBc: Mtwo; and (d) Sub-subgroup IIBd: Neoendo.

For Group A, the 19/.02 Neoendo glide path file was used to create a glide path, using a brushing motion. For Groups A and B, the canals were prepared in the same manner.

Table 2: ANOVA test values.

	Total sum of the square	df	Mean square	*F*	Significance
Between groups	0.050	9	0.006	6.230	0.000
Within groups	0.169	190	0.001		
Total	0.218	199			

The 25/0.06 WaveOne Gold file were used with a slow in and out pecking motion, the 25/.12 and variable taper 25/~ HyFlex EDM files were used, the 25/.06 One Shape file were used without pressure and with an in and out motion, the Mtwo files were used in the sequence of 10/.04, 15/.05, 20/.06 and 25/.06, and the variable taper Neoendo files were used in the sequence of 15/.02, 20/.04, 25/.04 and 25/.06 according to the manufacturers' instructions. During instrumentation, each file was removed after three pecking motions and cleaned with gauze. Distilled water was used to irrigate the canals using a 29-gauge side-vented irrigation needle. The procedure was repeated until the file reached the WL: as verified with an apex locator (Endo-Eze FIND Apex Locator, Ultradent). A single operator performed all the procedures to avoid any inter-operator variability.

The roots were rinsed with 1 ml distilled water to remove debris adherent to the external surface of the roots and collected in the Eppendorf tubes. The tubes were incubated at 70 °C for five days to evaporate the irrigant. The dry debris was weighed, and the mean of three consecutive readings was recorded. The amount of debris was calculated by subtracting the weight of the pre-weighed empty Eppendorf tubes from the tubes with debris after instrumentation.

Statistical analysis and results

Statistical analysis was performed utilising SPSS software (Version 16, IBM). A one-way analysis of variance (ANOVA) and Tukey's post hoc test were used to analyse the data for multiple comparisons. The level of significance was taken as $P < 0.05$.

The results showed that the instruments tested caused a measurable amount of debris extrusion apically. The highest amount of debris extrusion was seen in Sub-subgroup IIBc, and Sub-subgroup IIAb showed the least amount of debris extrusion apically (Tables 1 & 2).

Discussion

This study highlights the role of root canal preparation techniques, kinematics, the number of files used, file cross section, design, taper and motion, and glide path on apical debris extrusion. During root canal preparation, even if the WL is controlled, the risk of extrusion of fragments of pulpal tissue, dentine chips, necrotic debris, microorganisms and intracanal irrigants beyond the apical foramen is present. This can trigger an inflammatory reaction and thus result in postoperative complications. However, apical debris extrusion may differ according to the instrumentation technique and the file design.[10, 11]

Factors that could affect the extrusion of debris are (a) natural physical factors, such as the anatomy of the apical constriction, hardness of root dentine, quantity, pressure and flow of the irrigation, and position of the tooth; (b) mechanical factors, such as the final instrument, apical size, instrumentation technique, pitch design, degree of rotation of the file (full rotation versus reciprocation), speed, number of files used and operator's skill.[12–14]

Crown-down preparations with a file with a short pitch design is advised, which results in less debris extrusion.[15] Caviedes-Bucheli et al. suggest that instrument design is the most influential factor rather than the number of files used and type of file motion.[16] Side-vented needles were used to reduce periapical extrusion of debris and irrigant compared with open-ended needles. The One Shape file system has a modified triangular design with three sharp cutting edges in the apical and middle parts as well as an S-shaped design with the two cutting edges near the shaft, explaining the reduced debris extrusion. However, the value for Sub-subgroup IIAa was not significant compared with the values for Sub-subgroups IIAb and IIBb. This may be because of HyFlex EDM being a single-file system with controlled memory and a variable cross-section design.[17–19]

In this study, the rotary file systems showed the least debris extrusion, and efficiency was increased by using glide path files. Improved coronal transportation of dentine chips and debris was seen with continuous movement, whereas reciprocating motion enhanced debris transportation towards the apex.[20] Bergmans et al. advocate the use of hand instruments before the use of rotary instruments, which also implies glide path preparation.[21] Berutti et al. determined the role of a glide path for safely shaping the canal before any instrumentation using reciprocating motion.[22]

Subgroup IA extruded less debris than did Subgroup IB and Sub-subgroups IIAc and IIBc. To cut the dentine forwards, WaveOne Gold uses anticlockwise rotation and progressively shorter clockwise rotation to prevent flexural fatigue of the file and to prevent locking into the canal walls, reducing cyclic fatigue. The file's reverse cutting helix, distinct cross sections (parallelogram with two cutting edges and one point contact) along the length of the active portions, and tip diameters provide greater flexibility of the file. The reduced debris extrusion in Subgroup IA in comparison with Sub-subgroups IIAc and IIBc may be because of WaveOne Gold having a fixed taper at D1–D3 but a progressively decreasing taper at D4–D16. The cross sections with changing pitch and helical angle along the active portions serves to preserve dentine. Fewer pecking motions were needed to reach full WL with WaveOne Gold when a glide path was created as was found in the study reported in this article and supported by other studies.[23,24]

With regard to kinematics, reciprocal motion appears to increase the transportation of debris towards the apex, whereas continuous rotation provides the coronal transportation of dentine. Topçuoğlu et al. report that no significant difference was seen regarding the type of motion if a glide path was created beforehand.[25] In this study too, no significant difference was seen between Subgroup IA and Subgroup IB. The same was found by Gunes and Yesildal Yeter.[26] Less debris extrusion was seen with the reciprocating file system compared with full-sequence rotary instrumentation, which is also supported by this study.

Debris extrusion was less for file systems with variable tapers. A variable taper ensures a deep shape and predictable apical resistance. Whereas, file systems utilizing a constant taper tend to force more debris out apically.

Sub-subgroup IIAd had significantly less debris extrusion than did Subgroups IA and IB, and Sub-subgroups, IIBc and IIAc, but this difference was not significant for Sub-subgroups IIBb, IIAb, IIAa and IIBa. Neoendo files undergo a proprietary heat treatment method which does not cause the flutes to open as a result of stress. Surface treatments of files result in superior cutting efficiency of the files. Moreover, heat-treated file systems have improved flexibility and greater cyclic fatigue resistance.

It should be considered that there are no guidelines for calculating the optimal final canal size preparation clinically. The Scandinavian approach encourages larger apical preparations, whereas the Peters approach advocates more conservative apical enlargement. An increase in apical diameter promotes debris extrusion.[28]

Limitations

The extruded debris was collected by a modified Myers and Montgomery method to make it simple, practical and affordable. An extremely low amount of debris was collected, requiring care to be taken by the operator, avoiding contact with moist or greasy fingertips. Simulation of periapical tissue was not done. Thus, different results may be seen clinically. A difference in microhardness values of dentine may also have affected the study results. The lack of vital pulp tissue or necrotic tissue that may be present within lateral canals and apical ramifications could be another limitation.

Conclusion

Root canal instrumentation requires thorough biological knowledge. In the present study, single-file systems with variable tapers caused less extrusion of debris than did multiple-file system with variable tapers. The reciprocating file systems with a variable taper caused more debris extrusion than did rotary file systems with variable tapers but less debris compared with the rotary file system with a constant taper. The creation of a glide path led to a decrease in debris extrusion with both reciprocating and rotary file systems. It is hoped that these study results will help clinicians to take advantage of each particular system to reach the goal of endodontics without compromising the structural integrity of the tooth.

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