Dental Research Journal

Original Article

Negotiability of mesiobuccal canals in maxillary first molars using different path file systems

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ABSTRACT

Background: In endodontics, glide path creation has been extensively considered a mandatory clinical step to improve the safety and efficiency of rotary nickel–titanium instruments. The high anatomic variations in the mesiobuccal (MB) root of the maxillary molars are observed in the form of canal configuration, number, and position. The aim of this study was to evaluate the negotiability of MB canals in maxillary molars using different pathfiling systems (ProGlider, R-pilot, HyFlex electrical discharge machining [EDM], WaveOne Gold Glider, and C-Pilot).

Materials and Methods: This *in vitro* study included 125 maxillary first molars with closed apex. Before preparation, all teeth were scanned by periapical radiograph for review of the presence of second MB (MB2) canals, without any resorption or calcification, and moderate curve of MB root canal. Subsequently, the access cavity was prepared with a Diamond Fissure Bur. Then, the samples were divided into five groups (ProGlider, R-pilot, HyFlex EDM, WaveOne Gold Glider, and C-Pilot). Certain relevant indices were recorded for analysis, such as the negotiability of the glide path file in the MB canals, file fracture rate, and negotiation speed. The level of significance *P* value was set at 0.05.

Results: In this study, HyFlex EDM was the only path file that could not reach the full working length (WL) in some cases. The highest frequency of file fracture in the MB2 was observed with HyFlex EDM (24%); nevertheless, R-Pilot presented an intermediate fracture rate (16%), and both ProGlider and WaveOne Gold Glider were the safest files (4%) in this regard. However, there were no significant differences between the groups ($P = 0.065$). The lowest and the highest average time of reaching full WL was observed with WaveOne Gold Glider and HyFlex EDM; nonetheless, there was no significant difference between the four rotary groups. The average number of pecks in HyFlex EDM was significantly higher in comparison to those reported for WaveOne Gold Glider and ProGlider.

Conclusion: Path files used for glide path preparation in the MB2 canals of maxillary molars should be flexible with low taper. The use of HyFlex EDM in the MB2 canals is not recommended due to its high taper.

Key Words: Endodontics, molar, root canal

Received: 21-Sep-2021
Revised: 29-Jul-2022
Accepted: 25-Dec-2022
Published: 26-Apr-2023

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INTRODUCTION

Cleaning, disinfecting, and filling the root canal system are regarded as the targets of root canal treatment.[1,2] A smooth radicular tunnel from the orifice to apical constriction, called a glide path, should be created,

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Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480

How to cite this article: Gharechahi M, Khajehpour M, Hamedi A, Peighoun M. Negotiability of mesiobuccal canals in maxillary first molars using different path file systems. Dent Res J 2023;20:54.

especially when using rotary files, to achieve full working length (WL), instrumentation, and canal irrigation.[3] Previous studies have recommended the creation of a glide path as an essential clinical step to enhance the safety and efficiency of rotary nickel–titanium (Ni-Ti) instruments. Such enhancements are achieved by the prevention of the taper lock phenomenon. As a result, with the reduced fracture rates and prevented shaping errors, the lifespan of the instrument increases.[3,4]

Today, different types of single- and multiple-file rotary systems have been proposed for the preparation of glide path procedures. ProGlider is a single-file glide path solution manufactured by machining an M-Wire alloy. ProGlider has a progressive taper (range: 2%–8%). Geometrically, its cross-section has a square shape with four cutting edges, and its tip has a diameter of 0.16 mm. Enlarging the coronal portion of the canal is possible due to the variable taper design of ProGlider. This feature also allows larger files to be utilized in the canal.[5]

HyFlex electrical discharge machining (EDM) is the 5th-generation of Ni-Ti rotary endodontic files and the first file system equipped with controlled memory to benefit from EDM. Previous studies have reported that using EDM will result in a crater-like appearance and enhance cyclic fatigue resistance.[6] There are three different horizontal cross-sections for the HyFlex EDM glide path file. Longitudinally, the HyFlex EDM cross-section is quadratic, trapezoidal, and triangular in the apical third, middle, and coronal, respectively. In addition, the file tip diameter and taper are 0.10 mm and 5%, respectively.[7]

The Ni-Ti glide path file used in reciprocating motion and manufactured with M-Wire alloy is R-Pilot with geometric properties, including an S-shaped cross-section, tip diameter of 0.125 mm, and 4% fixed taper.[8] WaveOne Gold Glider is a single-file system and equipped with Gold Wire Technology. WaveOne Gold Glider works through a reciprocating motion with high flexibility and cyclic fatigue resistance. The geometric properties of WaveOne Gold Glider include a tip diameter of 0.15 mm, progressive taper (range: 1.5%–6%), and length of 16 mm.[9]

The high anatomic variations in the mesiobuccal (MB) root of the maxillary molars are observed in the form of canal configuration, number, and position. Scouting and negotiating the second MB (MB2) canal, a narrow, curved, and intricate root canal, is challenging once it is located. According to the literature, about 96% of the maxillary molars have MB2 canals; however, the standard techniques using a small hand file, even if using an operating microscope, can successfully negotiate <80% of them.[10] The classic techniques cannot clinically scout, negotiate, and treat a large amount of the MB2 canals appropriately.[11,12] With this background in mind, the current study evaluated the frequency, in which the four previously glide path instruments could scout the MB2 and first MB (MB1) canals of maxillary molars and reach full WL.

MATERIALS AND METHODS

The protocol of this *in vitro* study was approved by the Ethics Committee of Mashhad University of Medical Sciences, Mashhad, Iran (IR.MUMS.DENTISTRY.REC.1398.053). In the first step, to determine if the teeth met the inclusion criteria, preoperative radiographs (Eastman Kodak, Anaheim, CA, USA) were taken. A total of 125 first maxillary molars that met the criteria were used in this study. The inclusion criterion used in this study was that the Schniederhs technique[13] was first utilized to select the first maxillary molars with a curvature of 20°–40°. These teeth had an MB root length of 19 mm–22 mm, with two separate canals. Furthermore, these root canals had no internal resorption or calcification.

To disinfect the teeth, they were stored in 0.5% sodium hypochlorite for 48 h.[14] In the next step, the cone-beam computed tomography device (voxel size = 160 µ6, FOV = 8 cm × 8 cm, KVP = 70, MA = 8) was used to scan the selected teeth to confirm the presence of separated MB canals and recheck the curvature of the canals in both coronal and sagittal slices. The high-speed handpiece and fissure burs were employed to prepare the access cavity. The MB2 and MB1 canals were explored with a precurved #6 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and a #10 K-file, respectively. With the passive penetration of the file into the root canal until the file tip was visible at the apical foramen, every root canal WL was determined. The orange dental 2.7 × High-Resolution Binocular Loupes (Orange Dental, Germany) were also used. The value measured was subtracted by 0.5 mm for the determination of the WL.

The MB2 canals with the possibility to be negotiated without any resistance up to the apex with #8 K-file (or larger) and MB1 with #15 K-file (or larger)

were not considered in the present study; therefore, no bias was caused by the initial canal width. The five experimental groups containing 25 canals, each for glide path enlargement, were randomly assigned by the molars. During the instrumentation, 5% NaOCl (Niclor 5, OGNA, Muggio, Italy) was used to fill the pulp chamber. In addition, GlydeTM (Dentsply Maillefer, Ballaigues, Switzerland) was employed for lubrication. In the next step, according to the manufacturer instructions, ProGlider (Dentsply Sirona, Ballaigues, Switzerland), R-Pilot (VDW, Munich, Germany), HyFlex EDM (Coltene/Whaledent, Switzerland), and WaveOne Gold Glider (Dentsply Maillefer, Switzerland) were utilized for the preparation of the glide path in each group. Furthermore, a single group was taken into account as a hand C-file control group. The stainless steel C-file (Dentsply Maillefer, Ballaigues, Switzerland) of sizes 6–15 with a watch-winding motion was employed to prepare the manual glide path in the selected control group. Then, as the stainless steel was engaged, it was coronally moved as long as it reached the full WL.

A contra-angle handpiece (Sirona, Bensheim, Germany) supplied by an electric motor (VDW Silver, VDW, Munich, Germany) was used to drive the mechanical instrument. After each three pecking motions, the instruments were cleaned. Subsequently, the irrigation of the root canal was carried out using 5.25% sodium hypochlorite between each preparation step. Reaching full WL (RFWL) was attempted in all the groups until resistance was encountered and the autoreverse mode of the motor was automatically triggered, preventing the instrument from being introduced to any further fracture.[14] In case the instrument cannot reach the full WL, this would be labeled as not RFWL (NRFWL).

The number of pecking motions and required time for the glide path were recorded. The stopwatch started and stopped at the entry point of the canal and instrument retrieval point. The time taken to perform the functions, including changing files, cleaning debris from instrument flutes, irrigating, recapitulating, and re-irrigating the canal, was not recorded.[15] The new instruments were utilized for each canal. An endodontist, with 14 years of clinical experience, conducted the procedures of glide path preparation for all the groups.

Statistical analysis

For each group, both mean and standard deviation were calculated. Then, three tests, including the Chi-square, analysis of variance, and Kruskal–Wallis test, were used to statistically compare the data.

RESULTS

The results are provided in three parts, including the examination of the variables related to the MB2 canal listed in Table 1, the investigation of the variables related to the MB1 canal listed in Table 2, and the comparison of the variables of the MB1 and MB2 canals.

Examination of variables related to the second mesiobuccal canal

Reaching full working length in the second mesiobuccal canal

Out of 125 samples, NRFWL occurred in four samples (3.2%). All of these four samples were related to the HyFlex EDM file. The file RFWL rate had a significant difference in the MB2 canal among the groups.

File fracture rate in the second mesiobuccal canal

Out of 125 samples, the fracture occurred in 13 samples (10.4%). The frequency of maximum

Table 1: Frequency of reaching full working length, number of file fracture, average time, and average number of pecks in mesiobuccal 2 channel by groups as number (percentage)

	RFWL (mm), *n* (%)	Fracture, *n* (%)	Average time (*s*), *n* (%)	Number of pecks
HyFlex EDM	21 (84.0)	6 (24.0)	20.96	20.12
R-Pilot	25 (100.0)	4 (16.0)	19.85	15.12
ProGlider	25 (100.0)	1 (4.0)	16.12	11.00
WaveOne Gold Glider	25 (100.0)	1 (4.0)	13.65	10.80
C-Pilot	25 (100.0)	1 (4.0)	173.54	-
P	<0.05	0.065	<0.05	<0.05

REWL: Reaching full working length, EDM: Electrical discharge machining

Table 2: Frequency of reaching full working length, number of file fracture, average time, and average number of pecks in mesiobuccal 1 channel by groups as number (percentage)

	RFWL, *n* (%)	Fracture, *n* (%)	Average time (*s*)	Number of pecks
HyFlex EDM	25 (100.0)	1 (4.0)	8.68	9.08
R-Pilot	25 (100.0)	1 (4.0)	5.67	4.52
ProGlider	25 (100.0)	1 (4.0)	4.16	3.28
WaveOne Gold Glider	25 (100.0)	0	4.00	3.12
P		1.00	0.050	<0.05

RFWL: Reaching full working length, EDM: Electrical discharge machining

fracture was related to HyFlex EDM (n = 6), followed by R-Pilot (n = 4). All of the remaining files had a single-file fracture.

Reaching full working length speed in the second mesiobuccal canal

The maximum and minimum of the recorded mean time were related to the C-Pilot and WaveOne Gold Glider groups, respectively. There was a significant difference between the groups in terms of mean time. A pairwise comparison of the groups revealed that the average time in the C-Pilot group was significantly higher than that reported for other groups; however, no significant difference was observed among the other groups. The maximum and minimum numbers of mean recorded pecks were related to the HyFlex EDM and WaveOne Gold Glider, respectively. The average number of pecks in the HyFlex EDM group was significantly higher than that reported for the WaveOne Gold Glider and ProGlider groups. Nevertheless, there was no significant difference among the other groups.

Comparison of variables related to the first mesiobuccal canal among the groups

The file RFWL rate, file fracture frequency, and average time and number of pecks in the MB1 canals are listed in Table 2. The maximum and minimum numbers of recorded pecks were related to the HyFlex EDM and WaveOne Gold Glider groups, respectively. There was a significant difference between the groups in terms of the number of pecks.

Comparison of variables between first mesiobuccal and second mesiobuccal canals

The average time and number of pecks in the MB2 canal were significantly higher than those of the MB1 canal. In the HyFlex EDM group, the number of file fractures was significantly higher than that reported for the MB1 canal. In addition, the number of fractures in the MB2 canal was generally higher than that reported for the MB1 canal despite the group type.

DISCUSSION

In this study, the NRFWL was observed in four cases (3.2%), out of 125 cases, in the HyFlex EDM and MB2 canals; however, in the MB1 canal, the NRFWL was not observed in the groups. The reason for this may be attributed to the specific design of HyFlex EDM, including high and constant taper (5%), compared to those of other systems. In the narrow canals, such as the MB2 canals of the maxillary molars, this can increase contact surface with canal walls and resistance against the RFWL.[16]

In most cases, unlike the distobuccal and palatal root, the MB root of maxillary first molars indicates more variations in the number, position, and shape of the canal. The possibility of the presence of MB2 is high (96%).[11,17] Furthermore, it should be noted that negotiating such a narrow, curved, and complicated canal in the clinic is a challenging effort. As a result, this canal has been selected as the primary purpose of the present study. For this goal, the ability of four different types of path files in terms of RFWL, negotiation speed, and file fracture rate in the MB1 and MB2 canals in maxillary first molar teeth was determined. The WaveOne Gold Glider, R-Pilot, HyFlex EDM, and ProGlider files were investigated in the present study. These files are different in terms of motion types, alloy, and tapers. In addition, C-Pilot was considered the control group to manually create the glide path.

De-Deus[4] investigated the ability to reach WL of different path files in the molar teeth. The results of the aforementioned study showed that ProGlider could reach the full WL in only 51.6% of the cases, which is contrary to the findings of the present study. The reason for this difference may be due to the methodological difference of the two studies. In a study performed by De-Deus,[4] contrary to the manufacturer recommendations for the files, no K-file has been manually used before the rotary file is applied. This can highlight the need for using fine manual files before the application of the rotary files. In another study, NazariMoghadam[18] reported that the RFWL of ProGlider, in the MB2 canals, is 87% that is closer to that of the present study.

The results obtained for the fracture rate in the MB2 canals revealed that the maximum fracture frequency of the files occurred in the HyFlex EDM file (24%), followed by R-Pilot (16%). On the other hand, WaveOne Gold Glider and ProGlider were safer (in terms of fracture frequency) and each one had a failure rate of 4%. According to the Fisher exact test, there was no significant difference between the obtained results; however, it was close to the significance level (P = 0.065), which can be clinically important.

The lower fracture rates of the WaveOne Gold Glider and ProGlider files may be due to their progressive

and varying tapers. Moreover, the lower constant taper (4%) of R-Pilot, in addition to its smaller tip size (0.1 mm), compared to that of HyFlex EDM (with a constant taper of 5% and tip size of 0.125 mm), can also provide a description for the lower fracture rate of R-Pilot than that of HyFlex EDM in the MB2 canal. When the file reaches the WL, it undergoes stress with two main factors, including taper lock and cyclic fatigue.[17] Because path files are generally flexible, cyclic fatigue is less important than taper lock in relation to their fracture in the canal. The fracture rate of files in narrow canals increases as the taper of the instrument, thereby increasing the occurrence of the taper lock phenomenon.

On the other hand, file fracture occurred in only 2.4% of the MB1 canals (a single case for each of the HyFlex EDM, R-Pilot, and ProGlider files), which was significantly less than that reported in the MB2 canals. Moreover, in the HyFlex EDM group, the fractures in the MB2 canal were significantly higher than those of the MB1 canal. Therefore, it can be deduced that utilizing the HyFlex EDM file in the MB1 canal, unlike MB2, can be safe.

In terms of speed for RFWL of files in the MB2 canal, the minimum and maximum of the mean recorded time were related to WaveOne Gold Glider and HyFlex EDM, respectively. This difference can be attributed to the high constant taper (5%) of HyFlex EDM. There was no significant difference between HyFlex EDM and R-Pilot (with a constant taper of 4%); however, the number of pecks increased in comparison to those reported for the other two files (with a varying taper). In the MB1 canal, the maximum and minimum of mean recorded time and number of pecks were related to the HyFlex EDM and WaveOne Gold Glider groups, respectively. The average number of pecks in the HyFlex EDM group was significantly higher than those of the WaveOne Gold Glider and ProGlider groups. Again, this finding can reveal that the files with varying tapers were more appropriate than the files with constant and high tapers in terms of negotiating fine canals.

Similar results were obtained in a study carried out by Vorster *et al*.[19] The results of the aforementioned study showed that the preparation time of the glide path in the canals of the mandibular molar teeth by WaveOne Gold Glider was less than that of PathFile and K-files. In another study conducted by Han *et al*.,[20] ProGlider, HyFlex EDM, PathFile, and K-file were compared in the simulated canals. The results indicated that the ProGlider had a lower glide path preparing time than HyFlex EDM. In the present study, the average preparing time in the MB2 canal by ProGlider (16.12 s) was lower than that reported for HyFlex EDM (20.96 s). Finally, the average time and peck number in the MB2 canal were significantly higher than those of the MB1 canal, which may be due to the narrower and more curvature path.

In the present study, all the file fractures in the MB1 canal were located in the apical one-third region. In the MB2 canal, fractures mostly belonged to the apical one-third region. In studies carried out by Kırıcı and Kuştarcı[7] and Al-Sudani *et al*.[21] that have investigated the rate of file fracture in S-shaped canals, the maximum failure rate firstly occurred in the apical and then in the coronal region.

In 2008, Yared[16] indicated that the path files with reciprocal motion have higher cyclic fatigue resistance than the path files with rotary motion. Keskin *et al*.[22] reported that WaveOne Gold Glider and R-Pilot with reciprocal motion had higher fracture resistance than ProGlider with fully rotary motion. In a study carried out by Coelho *et al*.,[23] it was reported that the prevalence of fracture of fully rotary path files is within the range of 0%–23%; however, this prevalence for reciprocal path files falls within the range of 0%–1.71%. Kırıcı and Kuştarcı.[7] showed that the fatigue resistance of WaveOne Gold Glider was higher than that reported for ProGlider. In the present study, all the cases of NRFWL occurred in HyFlex EDM, a rotary file, and the MB2 canal. The total number of fractures in the MB2 canal was in the rotary group (14%) and the number was lower in the reciprocal group (10%). However, the results were not statistically significant.

Moreover, an evaluation of the three R-Pilot, HyFlex EDM, and PathFile files in the simulated canals was carried out by Uslu *et al*.[8] Their results demonstrated that the R-Pilot file with reciprocal motion had a higher fracture resistance, which was also shown in the present study. In addition, the rate of file fracture in the MB2 for the R-Pilot group was lower than that reported for the HyFlex EDM group. In general, in both canals, the fracture rates of the rotary and reciprocal groups were 9% and 6%, respectively. In terms of speed, reciprocal files in both canals were slightly faster than rotary files; however, the difference was not statistically significant.

CONCLUSION

According to the results of the present study, the files used for providing a glide path in the MB2 canals should be flexible and have no high taper. Gold Wire Technology in WaveOne Gold Glider and M-Wire alloy in ProGlider lead to higher flexibility and higher cyclic fatigue resistance. Furthermore, the progressive varying taper design indicates a lower possibility for the occurrence of a taper lock. As a result, these files are more appropriate for narrow canals, such as MB2. The fracture rate of HyFlex EDM in the MB2 canals was significantly higher than that reported for the MB1 canals. Therefore, to create a glide path in the MB2 canals, it is recommended not to utilize HyFlex EDM (due to high taper). The speed for providing the glide path in the MB1 canals was higher than that of the MB2 canals. It seems that the motion nature (i.e., reciprocal and rotary) has a negligible effect on the MB canals. It could be concluded that the anatomical condition of the canal (in terms of calcification, curvature, and narrowness) is an essential factor for file selection. In addition, it can even have a more critical effect than the file type (regarding alloy type, file motion, and design) on the examined parameters.

Acknowledgments

This study was supported by a grant from the Vice Chancellor of the Research Council of Mashhad University of Medical Sciences, Iran. The results presented in this study have been taken from a student thesis (No. 3210) in Mashhad University of Medical Sciences. The authors deny any conflicts of interest related to this study.

Financial support and sponsorship

This study was supported by a grant from the Vice Chancellor of the Research Council of Mashhad University of Medical Sciences, Iran.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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