Original Article

Efficacy of two instrument retrieval techniques in removing separated rotary and reciprocating nickel-titanium files in mandibular molars – An *in vitro* study

S. Jitesh, Smita Surendran, Velmurugan Natanasabapathy[1]

Department of Conservative Dentistry and Endodontics, Meenakshi Ammal Dental College, [1]Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India

Abstract

Context: This *in vitro* study aimed to evaluate the efficacy of both the staging platform (SP) and burrow platform (BP) techniques in the retrieval of separated rotary and reciprocating files in mesiobuccal (MB) canals of mandibular molars.

Materials and Methods: Forty extracted human mandibular molars with moderate curvature were used in this study. Anatomically, size-matched samples were equally distributed into two different retrieval techniques: Group SP and Group BP. Each group was further subdivided into two subgroups based on their motion kinematics: rotary and reciprocating subgroups. Four millimeters of ProTaper F1 20/07 (rotary) and WaveOne Gold 20/07 (reciprocating) instruments was separated at the apical third region of the MB canal in mandibular molars. Both techniques' success in retrieving separated files was assessed and the canal volume loss was calculated using cone-beam computed tomography. The total time taken for retrieval was also analyzed.

Results: The overall success rate for retrieval of separated instruments (SIs) was 92.5% (37/40). There was no significant difference in retrieval success rates between SP (95%) and BP technique (90%). BP technique (2.32 mm^3 and 103 min) resulted in significantly lesser canal volume loss and longer time for retrieval when compared to SP technique (3.75 mm^3 and 90 min).

Conclusion: Within the limitations of the current study, in mandibular molars with moderate curvature, the BP technique showed a similar success rate to that of SP technique for retrieval of SI. The BP technique resulted in lesser canal volume loss but took more time for retrieval of SI when compared with SP technique.

Keywords: Burrow platform; reciprocating file; rotary file; separated instrument; staging platform

INTRODUCTION

Separated instruments (SIs) within the root canal pose a significant challenge to clinicians during cleaning and shaping. The presence of an SI can compromise the outcome of root canal treatment.[1] The incidence of nickel–titanium (NiTi) file separation ranges from 0.8% to 21% in various studies.[2-4] Laboratory-based studies have indicated that the incidence of NiTi file separation tends to reduce with reciprocating motion.[5-10] However, it is still unclear if retrieval of separated reciprocating NiTi files is easier than a rotary NiTi file.

Ultrasonics (US) have been proven as an effective method in retrieving SI. US when used in conjunction with a dental operating microscope (DOM) is proven to be highly effective and reliable in retrieving SI from root canals.[9,11]

Address for correspondence:
Dr. Velmurugan Natanasabapathy,
Principal and Head of the Department, Department of Conservative Dentistry and Endodontics, Meenakshi Ammal Dental College, Chennai, Tamil Nadu, India.
E-mail: principal@madch.edu.in

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Studies have shown that the use of dedicated US tips under a DOM enables its accurate and controlled use, thereby minimizing unnecessary dentin removal which improves the instrument retrieval chances by 67%–95%.[10]

The staging platform (SP) technique as suggested by Ruddle[12] is the most commonly employed and effective method for the retrieval of SI. Staging platform (SP) technique involves the use Modified Gates-Glidden (GG) to create a Staging platform around the SI followed by vibration using US to retrieve the SI under DOM. Over the years, several new devices and techniques have been introduced to retrieve SI from root canals. Also more recently, Narasimhan *et al*.[13] suggested a newer technique called the burrow platform (BP) technique which presents as a viable alternative option in retrieval of SI from curved canals and slender roots. The authors suggested conservative removal of root dentin only on the inner aspect of the canal curvature and removing dentin on the outer aspect in the coronal one-third of the root canal. The authors used the BP technique to successfully retrieve SI in two cases. The dentin loss is inevitable after retrieval of SI, and this can be reliably measured using cone-beam computed tomography (CBCT).[14] There are no earlier studies on BP technique, and it is also not clear if reciprocating files are easier to retrieve when compared to rotary NiTi instruments. Hence, this investigation aimed to assess the efficiency of the BP technique in comparison with the SP technique for retrieval of separated rotary and reciprocating NiTi files in mandibular molars. The secondary aim was to assess the canal volume loss and the time taken for retrieval of SI.

The null hypothesis tested was that there is no difference between both the instrument retrieval techniques in terms of success, canal volume loss, and time taken for retrieval.

MATERIALS AND METHODS

Study design, and ethical clearance

In vitro study was conducted after getting ethical committee clearance from the university. The study protocol was submitted to the Institutional Review Board, and the committee reviewed and cleared the study.

Sample size calculation

A pilot study was carried out using 3 samples. Based on these results for a study with 90% power and a significance of 5%, the sample size was determined to be 40 ($n = 10$ per group).

Methods

For this study, a total of forty freshly extracted human mandibular first and second molars were collected and stored in 0.1% thymol solution.

Inclusion criteria

Teeth with intact crowns, mature root apices, an average length between 21 and 23 mm, and a mesiobuccal (MB) root canal with an angle of canal curvature <25° as described by Schneider were selected for this study.

Exclusion criteria

Teeth with dental caries, attrition, crown or root fracture, internal or external resorption, aberrant root canal morphology, curvature more than 25° previously root canal treated, and ones with calcifications were excluded from the study.

Experimental protocol

Under DOM, endo-access bur 2 (Dentsply Maillefer, Ballaigues, Switzerland) was used to gain access and the canals were located using a DG16 explorer (HuFriedy). The canals were negotiated to the apex using a #10 size K-file (MANI, INC). Following this, working length determination was done using a #15 size K-file and the same was established 1 mm short of the apex. Cuspal reduction was done to maintain the length of the tooth at 21 mm.

In the rotary group, root canal instrumentation was done using ProTaper Gold (Dentsply) as per the manufacturer's instructions in the following sequence, Sx, S1, S2, and F1, respectively. Instrumentation with reciprocation files was done using the WaveOne Gold 20/07 (Dentsply) in a pecking motion till the working length was reached. 3.5% NaOCl and 17% ethylenediaminetetraacetic acid (EDTA) were used to copiously irrigate the canals during the shaping phase.

Instrument separation

ProTaper F1 20/07 (rotary) and WaveOne Gold 20/07 (reciprocating) instruments were reduced to ½ its thickness using a diamond disk at a distance of 4 mm from the tip. Using the X-Smart Endomotor (Dentsply), these files were introduced into the MB canal and worked with its respective kinematics until the file separated. A digital radiograph was taken to verify the location of the SI and to confirm its presence at the intersection of the middle and apical third of the canal, if not those samples were excluded from the study.

Samples were then randomly subdivided into the following experimental groups based on the technique used for retrieval of SI and further subdivided based on the type of separated files (rotary/reciprocation).

- Group SP – SP technique group ($n = 20$)
- Group ProTaper gold (PTSP) – Retrieval of rotary file using SP technique

- Group WaveOne Gold (WOSP) – Retrieval of reciprocating file using SP technique
- Group BP – BP technique group ($n = 20$)
- Group Protaper Gold (PTBP) – Retrieval of rotary file (ProTaper gold) using BP technique
- Group WaveOne gold (WOBP) – Retrieval of reciprocating file using BP technique.

Preoperative cone-beam computed tomography analysis

A preoperative CBCT scan was taken in high resolution with a limited field of view (FOV) CBCT image (Planmeca, Finland using Romexis software; voxel size: 75–150 um; small FOV: 4 cm × 5 cm). The first initial CBCT scan was taken after the instrument separation in the respective groups. Every sample was embedded in modeling wax blocks to enable repeated sample placement, which improved the reproducibility of CBCT scans before and after the procedure. Preoperative volumetric analysis [Figure 1e] of the samples was performed using Materialise Mimics software (Materialise NV).

Group staging platform – Staging platform technique [Figure 1a and b]

In this group, under DOM, an SP was prepared as reported by Ruddle.[12] Preparation was done around the SI using a slow-speed contra-angle handpiece with GG drills sizes #1–3. Then, the US tip ET25 (Satelec Corp., France) was used at the lowest power setting to trough around in an anticlockwise direction till the coronal part of the SI was exposed under dry conditions. In between the retrieval, canals were copiously irrigated with 17% EDTA and 3.5% NaOCl followed by which the canals were dried with the help of absorbent points. This procedure was performed until the SI was freed and retrieved by the US tip.

Group burrow platform – Burrow platform technique [Figure 1c and d]

In this group, a BP[13] was performed by starting with coronal access preparation using a high-speed fine needle diamond bur or fissure carbide bur with a safety tip to establish straight-line access to all canal orifices. Radicular access was created with the help of a thin, tapered, and diamond-coated US tip using ET20D and ET40D. A partial platform was created about 180° around the SI which was oriented toward the inner wall of the canal curvature. Smooth, tapered US tips were used to trough along the partial platform in a counterclockwise motion to expose the coronal part of SI. Finally, US tips were placed in between the SI and the inner wall of the partial platform and activated, enabling the instrument to disengage from the canal walls.

Retrieval was attempted by using both techniques for a maximum of 2 h, after which it was considered unsuccessful.

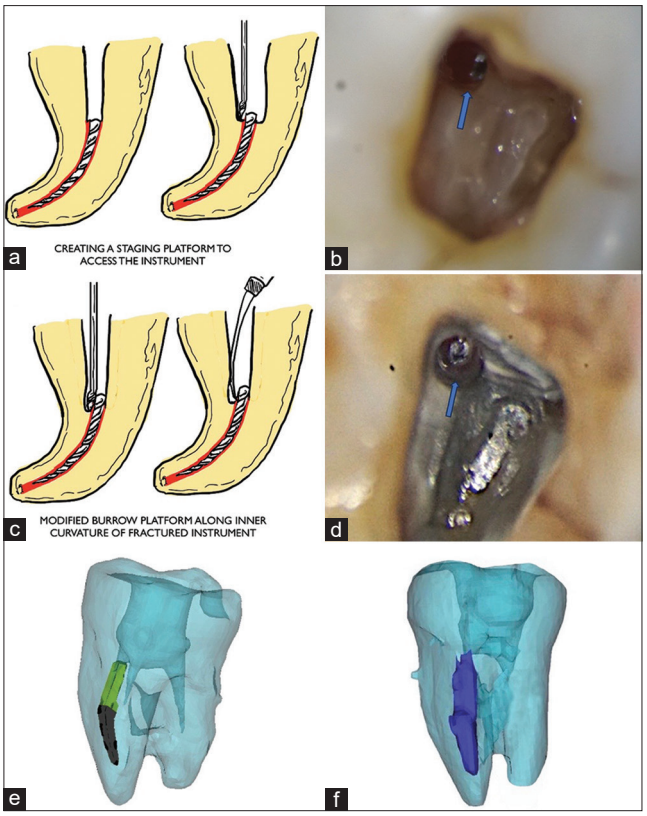

Figure 1: (a) Creating a staging platform to access the separated instrument, (b) staging platform was created to expose the coronal part of the separated instrument (blue arrow), (c) creating a burrow or modified burrow platform to access the separated instrument, (d) Burrow platform was created to expose the coronal part of the separated instrument (blue arrow), (e) three-dimensional volume analysis-after instrument separation before retrieval, (f) volume analysis - after retrieval

Postoperative cone-beam computed tomography analysis

The samples were rescanned with CBCT postoperatively [Figure 1f] to evaluate the total volume of dentin removed for each MB canal by subtracting the recorded postoperative root canal volume measurement from preoperative root canal volume using Materialise 3D imaging software – Leuven, Belgium. All the individual slices of the CBCT were selected and the area of interest was summated and volume was calculated.

Evaluation of time taken

Time taken was recorded in minutes from the beginning of the instrument retrieval procedure until the SI was retrieved. This was noted for all the groups and subgroups using a digital stopwatch.

Statistical analysis

The data were analyzed using SPSS (IBM SPSS Statistics for Windows, Version 26.0, Armonk, NY, USA: IBM Corp.

Released 2019). The Normality test (Kolmogorov-Smirnov and Shapiro-Wilks tests) results revealed that all the variables follow normal distribution. Therefore, Fisher's exact test was applied to compare the success rate between groups. Independent samples *t*-test was applied to compare mean values between retrieval groups, and paired *t*-test was applied to compare mean values between before and after retrieval. The significance level is fixed as 5% (α =0.05).

RESULTS

The overall success rate for retrieval of SI was found to be 92.5% (37/40). The success rate of 95% was reported with SP technique and 90% with BP technique, respectively, with no statistical significance. In three samples, the SI was not retrieved (2 in reciprocating and 1 in rotary subgroups).

With respect to the retrieval of files based on kinematics, overall retrieval of rotary files had a success rate of 95% (19/20) and reciprocating files had a success rate of 90% (18/20), with no statistical significance. Within the groups, retrieval of rotary files using SP technique was 100%, while for BP technique, it was 90%. For the retrieval of reciprocating files, both the techniques (SP and BP) had an equal success rate of 90% [Supplementary Table 1].

With respect to mean canal volume loss (mm^3), the group BP technique resulted in lesser canal volume loss when compared with group SP which was highly significant [Supplementary Table 2].

Mean canal volume loss (mm^3) showed a high statistically significant difference in the SP group between the rotary and reciprocating files ($P < 0.05$) [Table 1 and Figure 2a].

The mean canal volume loss showed high statistically Significant difference between Group SP (42.67%) and Group BP (23.58) in rotary subgroup ($P < 0.001$) [Supplementary Table 3].

With regard to time taken for retrieval, Group BP (103 min) took significantly more time for the procedure than Group SP (90 min) ($P < 0.001$) [Supplementary Table 4]. In Group BP, there was a significant difference in the subgroups with reciprocating subgroup (97 min) needing lesser time for removal than the rotary subgroups (108 min) ($P < 0.001$) [Supplementary Table 5 and Figure 2b].

In the rotary subgroups, the time taken was significantly more for the BP technique (108 min) than the SP technique (90 min). For the reciprocating files, the time taken was 97 min in BP, while it was only 91 min in the SP technique [Table 2 and Figure 2b].

DISCUSSION

The incidence of rotary NiTi instrument fracture is around 1.0%, and it ranges from 0.4% to 3.7%.[15,16] Canal curvature plays an important role in instrument retrieval.[17-19] MB root canals of human mandibular molars with <25° curvature (moderate) were selected for this study to standardize the samples.

Table 1: Independent samples *t*-test to compare mean canal volume loss between two groups

Group	Variable	File type	*n*	Mean±SD	*P*
Group SP	Canal volume loss (mm^3)	Rotary	10	4.40±1.64	0.032*
		Reciprocating	9	3.03±0.64	
Group BP	Canal volume loss (mm^3)	Rotary	9	2.60±0.64	0.067 NS
		Reciprocating	9	2.04±0.55	

*$P<0.05$ is considered to be statistically significant. NS: Statistically nonsignificant, SP: Staging platform, BP: Burrow platform, SD: Standard deviation

Table 2: Independent samples *t*-test to compare mean time taken between two subgroups

File type	Variable	Group	*n*	Mean±SD	*P*
Rotary	Time taken (min)	Group SP	10	90±3.82	<0.001**
		Group BP	9	108±7.87	
Reciprocating	Time taken (min)	Group SP	9	91±3.20	0.035*
		Group BP	9	97±7.45	

*$P<0.05$ is considered to be statistically significant, **$P<0.001$ is considered to be highly statistically significant. SP: Staging platform, BP: Burrow platform, SD: Standard deviation

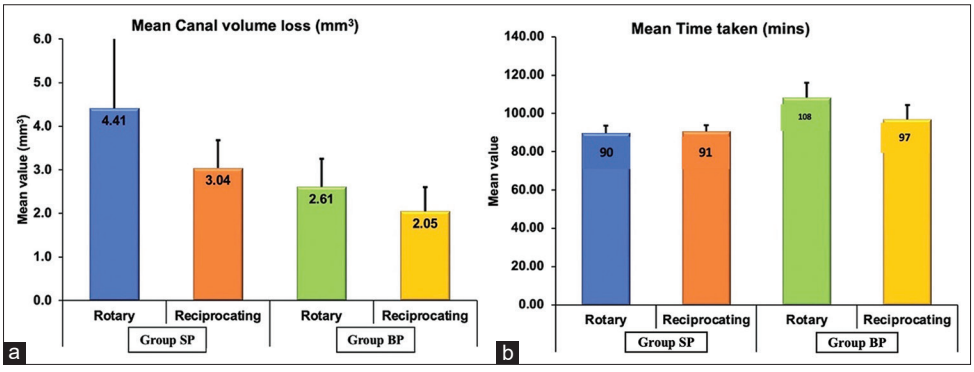

Figure 2: (a) Mean canal volume loss (mm^3) between subgroups, (b) time taken (min) between subgroups

When the length of the fragment is >3.1 mm, it resulted in a prolonged retrieval time.[20] The average length of the SI in previous studies was 3–4 mm and hence it was decided to have a length of 4 mm of separated fragment in the current study.

For the mechanical removal of SI, various techniques and devices were used earlier, namely the Stieglitz forceps,[21] wire and loop,[22] M-K extractors,[23] and Canal finder system (CF-S) and US methods. Majority of the studies have suggested the use of US instruments for successful retrieval of SI.[11] SI (94%) <4.6 mm can be retrieved only with the help of US.[17]

Small-diameter US tips combined with a DOM enable minimally invasive root canal preparations and minimal damage to the dentin and make it easier to retrieve SI safely.[20,24-26] The most widely used technique for successful retrieval[27-29] of SI is "SP" suggested by Ruddle.[12]

Recently, a new technique has been suggested by Narasimhan *et al*.,[13] known as "BP technique (Modified Partial Platform Technique)." This is a microscope-aided approach using US tips to gain access to the SI in the middle and apical thirds of the root canal. It preserves root dentin by limiting the removal of root dentin only on the inner aspect of the canal curvature. According to the authors, in addition to potentially preserving radicular dentin and reducing retrieval-related complications, this approach improves operator control as well.

Both SP (95%) and BP (90%) techniques were found to be effective for the retrieval of rotary and reciprocating NiTi files. Similar retrieval success rates were observed in earlier studies by Pruthi *et al*.[27] and Garg and Grewal.[28] ProUltra tips and the TFRK were used to retrieve SI, with a success rate of 90% and 95% in the study conducted by Pruthi *et al*.[27] Garg and Grewal[28] used Ultrasonic EMS Tips (US-EMS) and ProUltra tips for instrument retrieval and reported a success rate of 87.5%. Abdeen *et al*.[29] did a study on the success rate of instrument retrieval using SP technique and Terauchi file retrieval technique. The retrieval rates were 70% and 80%, respectively, which is in contrast to the results of the present study. Shen *et al*.[19] reported a success rate of 83% for instrument retrieval in canals with moderate curvature. This success rate in the later two studies is comparatively lower than the present study, and this might be attributed to the difference in techniques and armamentarium used for retrieval.

While cyclic fatigue, torsional overload[30,31] or a combination of both have been suggested as the main reasons for the separation of rotary NiTi files and the reasons for the separation of reciprocating files are still not clear.[2,5,7] Future studies should establish the fatigue features responsible for reciprocating file separation.

The mean canal volume loss (mm^3) in the present study was significantly higher for the SP (3.75) than BP (2.32) group. The significant difference in the canal volume in SP and BP might be attributed to the preparation of the canal being restricted only to 180° around the SI in the BP group. An earlier study conducted by Abdeen *et al*.,[29] compared Teruchi File retrieval kit (TF-K) group with Ruddle's technique in the retrieval of SI. TF-K group (1.28 ± 0.78 mm^3) showed an overall mean root canal volume less volume loss less than Ruddle's technique (2.33 ± 1.03 mm^3). The mean canal volume loss (%) was significantly higher in SP and BP groups in rotary subgroups, which were 42.67% and 23.58%, respectively. Contrasting results were obtained in another study, where the volume loss was higher with EMS US tips than for ProTaper US tips.[28] This difference in canal volume loss (%) can be attributed to the employment of varied treatment protocols used for retrieval in the current study.

In the present study, between the reciprocating and rotary subgroups, the mean values of canal volume before and after retrieval were significantly lower in the reciprocating subgroup. This might be attributed to the motion kinematics of the file, file design of the reciprocating file, and increased debris creation and screwing in of the rotary file into canal walls which might have led to increased canal preparation in the retrieval phase.[32]

Time taken in BP (103 min) was significantly more than SP (90 min). The mean time taken for the SP was significantly lower than BP, irrespective of the motion kinematics (rotary/reciprocation). In contrast to the present study, a previous study reported that the average time required for the ProUltra-system to retrieve SI was 63.89 min, whereas for the EMS system, it was 50.22 min.[28] In a study conducted by Kumar *et al*.,[33] the mean time taken to remove the SI varied between 11 and 42 min. Terauchi *et al*.[34] stated that TF-K required significantly lesser time than Ruddle's technique in anterior teeth. The difference in retrieval time in the present study might be attributed to difference in technique and operator experience.

The major strength of the present study is the first study to check for the retrievability of separated rotary and reciprocating files using SP and BP. Furthermore, in this investigation tooth type, canal anatomy, curvature, and size of the SI were standardized. The use of mandibular teeth with moderate curvature and the study being *in vitro* in nature can be considered as limitations of this study. Future clinical studies and laboratory studies on teeth with severe curvature are necessary.

CONCLUSION

Within the limitations of the current study, in mandibular molars with moderate curvature, BP technique

showed a similar success rate to that of SP technique for retrieval of SI.

Borrow platform technique resulted in lesser canal volume loss but took more time for retrieval of SI when compared with SP technique.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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Supplementary Table 1: Success rates between retrieval groups

File type	Success	Group			*P*
		Group SP, *n* (%)	Group BP, *n* (%)	Total, *n* (%)	
Total	Yes	19 (95.0)	18 (90.0)	37 (92.5)	0.995*
	No	1 (5.0)	2 (10.0)	3 (7.5)	NS
	Total	20 (100.0)	20 (100.0)	40 (100.0)	
Rotary	Yes	10 (100.0)	9 (90.0)	19 (95.0)	0.999*
	No	0	1 (10.0)	1 (5.0)	NS
	Total	10 (100.0)	10 (100.0)	20 (100.0)	
Reciprocating	Yes	9 (90.0)	9 (90.0)	18 (90.0)	0.999*
	No	1 (10.0)	1 (10.0)	2 (10.0)	NS
	Total	10 (100.0)	10 (100.0)	20 (100.0)	

*Fisher's exact *P*-value. NS: Statistically nonsignificant, SP: Staging platform, BP: Burrow platform

Supplementary Table 2: Independent samples *t*-test to compare mean canal volume loss between two groups

Variable	Group	*n*	Mean±SD	*P*
Canal volume loss (mm^3)	Group SP	19	3.75±1.42	0.001**
	Group BP	18	2.32±0.64	

**$P<0.001$ is considered to be highly statistically significant. SP: Staging platform, BP: Burrow platform, SD: Standard deviation

Supplementary Table 3: Independent samples *t*-test to compare mean canal volume loss between two groups

File type	Variable	Group	*n*	Mean±SD	*P*
Rotary	Canal volume loss (%)	Group SP	10	42.67±11.57	0.001*
		Group BP	9	23.58±9.17	
Reciprocating	Canal volume loss (%)	Group SP	9	27.85±8.59	0.131 NS
		Group BP	9	22.59±4.57	

*$P<0.05$ is considered to be statistically significant. NS: Statistically nonsignificant, SP: Staging platform, BP: Burrow platform, SD: Standard deviation

Supplementary Table 4: Independent samples *t*-test to compare mean time taken between two groups

Variable	Group	*n*	Mean±SD	*P*
Time taken (min)	Group SP	19	90±3.47	<0.001**
	Group BP	18	103±9.45	

**$P<0.001$ is considered to be highly statistically significant. SP: Staging platform, BP: Burrow platform, SD: Standard deviation

Supplementary Table 5: Independent samples *t*-test to compare mean time taken between two groups

Group	Variable (min)	File type	*n*	Mean±SD	*P*
Group SP	Time taken	Rotary	10	90±3.82	0.602 NS
		Reciprocating	9	91±3.20	
Group BP	Time taken	Rotary	9	108±7.87	0.006*
		Reciprocating	9	97±7.45	

*$P<0.05$ is considered to be statistically significant. NS: Statistically nonsignificant, SP: Staging platform, BP: Burrow platform, SD: Standard deviation