Apical extrusion of debris in four different endodontic instrumentation systems: A meta-analysis

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Abstract

Background: All endodontic instrumentation systems tested so far, promote apical extrusion of debris, which is one of the main causes of postoperative pain, flare ups, and delayed healing.

Objectives: Of this meta-analysis was to collect and analyze in vitro studies quantifying apically extruded debris while using Hand ProTaper (manual), ProTaper Universal (rotary), Wave One (reciprocating), and self-adjusting file (SAF; vibratory) endodontic instrumentation systems and to determine methods which produced lesser extrusion of debris apically.

Methodology: An extensive electronic database search was done in PubMed, Scopus, Cochrane, LILACS, and Google Scholar from inception until February 2016 using the key terms “Apical Debris Extrusion, extruded material, and manual/rotary/reciprocating/SAF systems.” A systematic search strategy was followed to extract 12 potential articles from a total of 1352 articles. The overall effect size was calculated from the raw mean difference of weight of apically extruded debris.

Results: Statistically significant difference was seen in the following comparisons: SAF < Wave One, SAF < Rotary ProTaper.

Conclusions: Apical extrusion of debris was invariably present in all the instrumentation systems analyzed. SAF system seemed to be periapical tissue friendly as it caused reduced apical extrusion compared to Rotary ProTaper and Wave One.

Keywords: Apical extrusion; debris extruded; endodontic instrumentation; Hand ProTaper; meta-analysis; Rotary ProTaper; self-adjusting file; Wave One

INTRODUCTION

Apical extrusion of debris also referred to as a “worm of necrotic debris,” is a detrimental event that occurs during the instrumentation of the root canal system.[1,2] In asymptomatic chronic periapical lesions, a delicate balance exists between infected canal microbiota and the host defenses. Apical extrusion of bacteria disrupts this balance and causes an acute inflammatory response.[3]

The objectives of this meta-analysis are to systematically analyze all in vitro studies quantifying the apically extruded debris while using Hand ProTaper, Rotary ProTaper, Wave One, and self-adjusting file (SAF) systems, and to determine methods which produce lesser debris extrusion.

METHODOLOGY

Strategy of literature search
Preferred reporting items for systematic reviews and meta-analyses guidelines were followed while conducting this meta-analysis.[4] An extensive electronic database search was done from inception until February 2016 using the key terms “Apical Debris Extrusion, extruded material, and manual/rotary/reciprocating/SAF systems.” The search resulted in 1352 articles in total; 171 articles in PubMed; 1085 articles in Scopus; 10 articles in Cochrane, and 86 in LILACS and Google Scholar. The search was performed by

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two independent reviewers to identify potentially relevant articles, and the reference lists were also hand-searched. After the removal of duplicates and irrelevant articles by initial screening of titles, a total number of ninety articles were selected, and their abstracts were retrieved. In vitro studies that failed to compare at least two of the four interventions (Hand ProTaper, Rotary ProTaper, Wave One, and SAF systems) were all excluded and the process resulted in 25 articles. The full-text of these articles were retrieved and screened based on the following predetermined exclusion criteria.

**Study selection criteria and data extraction**

Exclusion criteria: (1) *in vivo* studies, letters, comments, editorials, case reports, proceedings, personal communications, and any type of literature reviews, (2) other language articles, (3) microbial studies that measured the amount of apically extruded bacteria, (4) studies that measured apical extrusion of debris while performing endodontic retreatment, (5) studies in which nonstandard apical preparations were done, and (6) studies in which the outcome measures that is the mean and standard deviation were not mentioned clearly.

List of studies and their reasons for exclusion as numbered in the study exclusion criteria are given in Table 1. Finally, a total of 12 articles were selected for this meta-analysis, which included 16 direct comparisons in five different combinations: three studies for Hand ProTaper versus Rotary ProTaper, six studies for Rotary ProTaper versus Wave One, three studies for Wave One versus SAF, two studies for Hand ProTaper versus Wave One, and two studies for Rotary ProTaper versus SAF. Out of the possible six combinations of comparisons, one comparison (Hand ProTaper vs. SAF) was not possible because at least two studies are required to conduct a meta-analysis. A flow chart showing the whole process of the study selection is given as Figure 1.

The following information/data were extracted from the studies that met the inclusion criteria: The name of the first author, year of publication, number of samples in each group, intervention used, and the study outcome measured as mean and standard deviation is presented in Figure 2. The four instrumentation systems compared were (Hand ProTaper, Rotary ProTaper, Wave One) (Dentsply-Maillefer, Ballaigues, Switzerland) and SAF systems (ReDent-Nova Raanana, Israel). A standard pair-wise meta-analysis was planned to synthesize the results of different trials evaluating the same interventions (direct comparisons) to obtain an overall estimate of the treatment effect of one intervention relative to the other.

**Outcome measures and statistical analysis**

The study outcome measure was the mean and standard deviation of apical extrusion of debris measured in milligrams. The overall effect size was calculated from the raw or unstandardized mean difference. The analyses were carried out using fixed and random effect models. The $r^2$, Chi-square, and $F$ statistics were used to measure
heterogeneity among the studies. The quality of reporting in the included in vitro studies was assessed using modified Consolidated Standards of Reporting Trials guidelines, by taking into consideration, a prespecified question – was the item correctly reported?: Yes (reported) or no (not reported) and is presented in Table 2. The mean, standard deviation, and sample size for each group in each study are extracted, and the computation of the effect size and its variance is carried out. All statistical analyses were performed using the statistical software RevMan 5.3 provided by The Cochrane Collaboration (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark, 2014). The value is set as 0.01 with 99% confidence interval.

RESULTS

Raw mean difference values, forest plots, heterogeneity measures, the overall effect size estimates and P values for all the five comparisons are also given in Figure 2.

Hand ProTaper versus Rotary ProTaper

There was substantial heterogeneity (I² = 68%) when data from three studies were pooled; therefore, a random effects model of analysis was used. This meta-analysis revealed that there was greater apical extrusion of debris in the Hand ProTaper group compared to Rotary ProTaper group; however, the difference was not statistically significant (P = 0.9), that is P > 0.01.
Rotary ProTaper versus Wave One

There was considerable heterogeneity ($I^2 = 93\%$) when data from six studies$^{[20,22-26]}$ were pooled; therefore, a random effects model of analysis was used. This meta-analysis revealed greater apical extrusion of debris in the Rotary ProTaper group compared to Wave One group; however, the difference was not statistically significant ($P = 0.24$) that is $P > 0.01$.

Wave One versus self-adjusting file

There was considerable heterogeneity ($I^2 = 98\%$) when data from three studies$^{[24,27,28]}$ were pooled; therefore, a random effects model of analysis was used. This meta-analysis revealed that Wave One group showed significantly greater apical extrusion of debris compared to SAF group ($P < 0.0001$) that is $P < 0.01$.

Hand ProTaper versus Wave One

Only two studies$^{[20,29]}$ included in this meta-analysis compared Hand ProTaper and Wave one groups. There was substantial heterogeneity ($I^2 = 62\%$) when data from the two studies were pooled; therefore, a random effects model of analysis was used. This meta-analysis revealed greater apical extrusion of debris in Wave One group compared to Hand ProTaper group; however, the difference was not statistically significant ($P = 0.03$), that is $P > 0.01$.

Rotary ProTaper versus self-adjusting file

Only two studies$^{[24,30]}$ included in the meta-analysis compared Rotary ProTaper versus SAF groups. There was no notable heterogeneity ($I^2 = 3\%$) when data from the studies were pooled; therefore, a fixed-effects model of analysis was used. This meta-analysis revealed that Rotary ProTaper group showed significantly greater apical extrusion of debris when compared to SAF group ($P = 0.0001$), that is $P < 0.01$.

**DISCUSSION**

All endodontic instrumentation systems tested so far cause apical extrusion of debris to some extent, with some systems extruding less and the others more.$^{[2]}$ Such differences in the amount of extruded debris may be crucial for the development of postoperative pain as systems that extrude more debris increase the risk of flare-ups.$^{[31]}$ Several in vitro studies have been conducted so far to quantify the apical extrusion of debris while using different endodontic instrumentation systems.

A systematic review and meta-analysis conducted by Caviedes-Bucheli$^{[8]}$ concluded that inflammatory reaction due to apical extrusion of debris is not influenced by the number of files but the type of movement and the instrument design. Therefore, this meta-analysis aims at comparing four different endodontic instrumentation systems showing varied type of movements (manual, rotary, reciprocation, and transline in-and-out vibratory motion).

The objectives of this meta-analysis are to identify, assess, and analyze all in vitro studies quantifying the amount of apically extruded debris while using Hand ProTaper (manual), ProTaper Universal (rotary), Wave One (reciprocating), and SAF (vibratory) endodontic instrumentation systems; to determine methods which produce lesser extrusion of debris; and to identify gaps in available knowledge where new trials are required.

The main findings from the results of this meta-analysis are (1) none of the endodontic instrumentation systems, be it manual or rotary or reciprocating or vibratory systems, can limit the apical extrusion of debris completely. (2) SAF system shows significantly lesser apical extrusion of debris compared to Rotary ProTaper and Wave One. (3) Results derived from other combinations are all not statistically significant.
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In the present study, the overall effect size is calculated from raw or unstandardized mean difference, because the outcome is measured in a meaningful scale (weight in milligrams) and all the studies included in the analysis use the same scale. Greater weights are given to the results from the studies that provide more information and are more precise (narrower confidence interval) because they are likely to be closer to the “true effect.” The interpretation of I² values, which is calculated to measure heterogeneity, is based on a rough guide: 0%–40% - might not be important, 30%–60% - may represent moderate heterogeneity, 50%–90% - may represent substantial heterogeneity, 75%–100% - considerable heterogeneity. If I² statistics indicated heterogeneity; then, a random effects model of analysis is used (DerSimonian–Laird method); if not, a fixed-effects model (Mantel–Haenszel method) is used.

**Hand ProTaper versus Rotary ProTaper (manual vs. rotary)**

This meta-analysis revealed that there was a greater but statistically nonsignificant increase in apical extrusion of debris in the Hand ProTaper group compared to Rotary ProTaper group, which is consistent with the previous studies. The reason for this may be attributed to the fact that Hand ProTaper prepares the apical area for an extended period, and the rotational movement of the file is an operator controlled variable factor; whereas, Rotary ProTaper contacts the apical area for a limited period and also the rotational speed and torque are fixed. Another study revealed results contrary to this meta-analysis; the reason speculated was that the use of Hand ProTaper in a modified balanced force technique, permitted a controlled pressure of the instrument inside the root canal, allowed better removal of adhering debris, thus reducing the apical extrusion of debris.

**Rotary ProTaper versus Wave One**

This meta-analysis revealed that there was a greater but statistically nonsignificant increase in apical extrusion of debris in the Rotary ProTaper group compared to Wave One group, which is consistent with the previous studies. The reason for this may be attributed to the fact that, in a Wave One instrument, reciprocation tries to mimic the balanced force technique kinematics, which is well known as being a pressure less movement pushing less material periapically. The interplay among several factors such as instrument design, improved alloy, fewer instruments, high cutting ability, and reciprocation kinematics of Wave One system can be used to support their improved control of apically extruded debris found in the present study. Three other studies included in this meta-analysis showed results contrary to this meta-analysis. The reason speculated was that continuous rotation of a Rotary ProTaper instrument may improve coronal transportation of debris by acting such as a screw conveyor. Moreover, the reciprocation movement in Wave One system is formed by a wider cutting angle and smaller release angle. While rotating in the releasing angle, the flutes tend to push the debris apically.

**Wave One versus self-adjusting file**

This meta-analysis revealed that Wave One group showed significantly greater apical extrusion of debris compared to SAF group, which is consistent with the previous studies. The reason for this may be attributed to the closer adaptation of the metal mesh in the SAF system to the canal walls, back-and-forth grinding motion providing scrubbing action on the canal walls, continuous irrigation and additional activation of the irrigant through vibratory motion, continuous replenishment of fresh irrigant from the rotating hub and lack of positive pressure because the solution easily escapes through openings in the file lattice.

**Hand ProTaper versus Wave One**

This meta-analysis revealed that there was a greater but statistically nonsignificant increase in apical extrusion of debris in the Wave One group compared to Hand ProTaper group, which is consistent with the studies. The reason for this may be attributed to the difference in design of the instruments; the presence of radial lands in a Wave One instrument, which reduces the coronal debris removal capacity enhancing apical extrusion of debris whereas a ProTaper instrument lacks radial lands causing decreased apical extrusion of debris.

**Rotary ProTaper versus self-adjusting file**

This meta-analysis revealed that Rotary ProTaper group showed significantly greater apical extrusion of debris when compared to SAF group, which is consistent with the studies. The present results may be explained by differences in the instrument design and movement kinematics of SAF and is explained in the comparison of Wave One versus SAF.

**Limitations**

Limitations of this meta-analysis are: (1) This meta-analysis is conducted by pooling the findings from several in vitro studies; making it less reliable compared to in vivo studies. (2) All the studies included in this meta-analysis use Myers and Montgomery method to quantify apical extrusion of debris, the reliability of which is questioned, due to the absence of barrier mimicking the periapical tissues present in the actual clinical situation. (3) Funnel plots for assessing publication bias could not be made for this meta-analysis as it requires a minimum of ten studies to make a meaningful funnel plot. (4) The summary of results when both significant and nonsignificant data are included is Hand ProTaper ≥ Rotary ProTaper ≥ Wave One > SAF.
However, a statistically nonsignificant finding from the third combination of comparison is that Hand ProTaper ≤ Wave One, which is contradictory to the summary stated above. The reason for these self-contradictory results may be attributed to heterogeneity of studies clubbed in this meta-analysis.

CONCLUSIONS

Although the articles included in this meta-analysis showed high heterogeneity and high risk of bias, the in vitro literature seems to suggest that: (1) Apical extrusion of debris was invariably present in all the instrumentation systems analyzed. (2) SAF system seemed to be periapical tissue friendly, as it caused reduced apical extrusion of debris compared to Rotary ProTaper and Wave One.

Implications for future research: (1) Need for in vivo randomized controlled trials evaluating postoperative pain or incidence of flare-ups while using different instrumentation systems. (2) Need for a reliable method to test apical extrusion of debris in the laboratory with a suitable method mimicking the positive pressure to apical extrusion provided by the periapical tissues. (3) Need for more in vitro randomized controlled trials comparing Hand ProTaper versus SAF systems, facilitating direct comparisons in future meta-analytic research.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Seltzer S, Naidorf IJ. Flare-ups in endodontics: I. Etiological factors. J Endod 1985;11:472-8.
2. McKendry DJ. Comparison of balanced forces, endosonic, and step-back filing instrumentation techniques: Quantification of extruded apical debris. J Endod 1990;16:24-7.
3. Siqueira JF Jr. Microbial causes of endodontic flare-ups. J Endod 2003;36:453-63.
4. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. Open Med 2009;3:e123-30.
5. Törk CR, Testarelli L, De Luca M, Milana V, Plotino G, Grande NM, et al. The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4:152-5.
6. Gambarini G, Testarelli L, De Luca M, Milana V, Plotino G, Grande NM, et al. The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4:152-5.
7. Garlapati R, Venigalla BS, Patil JD, Raju R, Rammohan C. Quantitative evaluation of apical extrusion of intracanal bacteria using K3, Mtwo, RaCe and protaper rotary systems: An evaluation of apically extruded debris using different root canal instrumentation systems. Mustansirya Dent J 2014;11:1-10.
8. Logani A, Shah N. Apically extruded debris with three contemporary Ni-Ti instrumentation systems: An ex vivo comparative study. Indian J Dent Res 2008;19:182-5.
9. Burklin S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012;38:850-2.
10. Lu Y, Chen M, Giao F, Wu L. Comparison of apical and coronal extrusions using reciprocating and rotary instrumentation systems. BMC Oral Health 2015;15:92.
11. Oztu D, Karatas E, Arslan H, Topcu MC. Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems. Eur J Dent 2014;8:504-8.
12. Surakanti JR, Venkata RC, Vernisetty HK, Dandolu RK, Jaya NK, Thota S. Comparative evaluation of apically extruded debris during root canal preparation using ProTaper™, Hyflex™ and WaveOne™ rotary systems. J Conserv Dent 2014;17:129-32.
13. Lizun I, Glüer B, Ózyürek T, Tunc T. Apical extrusion of debris using reciprocating files and rotary instrumentation systems. Niger J Clin Pract 2016;19:71-5.
14. Farmakis ET, Sotopoulos GG, Ábravízov I, Solomonov M. Apical debris extrusion associated with oval shaped canals: A comparative study of WaveOne vs Self-Adjusting File. Clin Oral Investig [Internet]. 2016. p. 1-8. Available from: http://link.springer.com/article/10.1007%2Fs00784-016-1709-3. [Last cited on 2015 Sep 9].
15. Bürklein S, Glüer B, Özyürek T, Tunc T. Apical extrusion of debris using different root canal instrumentation systems. Mustansirya Dent J 2011;41:237-41.
16. Kirchhoff AL, Fariñiu LF, Melo I. Apical extrusion of debris in flat-oval root canals after using different instrumentation systems. J Endod 2015;41:237-41.
17. Faggion CM Jr. Guideline for reporting pre-clinical in vitro studies on dental materials. J Evid Based Dent Pract 2012;12:182-9.
18. Ferrarini LF, Carapin MF, Lopes RM, Belladonna FG, Senna PM, Souza EM, et al. Comparison of apically extruded debris after large apical preparations by full-sequence rotary and single-file reciprocating systems. Int Endod J 2016;49:700-5.
19. De-Deus GA, Nogueira LealSilva EJ, Moreira EJ, de Almeida Neves A, Belladonna FG, Tameirão M. Assessment of apically extruded debris produced by the self-adjusting file system. J Endod 2014;40:526-9.
20. Gambarini G, Testarelli L, De Luca M, Milana V, Plotino G, Grande NM, et al. Apically extruded dentin debris by reciprocating single-file and full-sequence rotary file systems. Clin Oral Investig 2015;19:367-61.
21. Kim MK, Min JB, Hwang HK. The effect of early coronal flaring about symptomatic apical periodontitis. A systematic review and meta-analysis. Open Med 2009;3:e123-30.
22. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012;38:850-2.
23. Siqueira JF Jr. Microbial causes of endodontic flare-ups. J Endod 2003;36:453-63.
24. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. Open Med 2009;3:e123-30.
25. Törk CR, Testarelli L, De Luca M, Milana V, Plotino G, Grande NM, et al. The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4:152-5.
26. Garlapati R, Venigalla BS, Patil JD, Raju R, Rammohan C. Quantitative evaluation of apical extrusion of intracanal bacteria using K3, Mtwo, RaCe and protaper rotary systems: An in vitro study. J Conserv Dent 2011;14:187-90.
27. Farmakis ET, Sotopoulos GG, Ábravízov I, Solomonov M. Apical debris extrusion associated with oval shaped canals: A comparative study of WaveOne vs Self-Adjusting File. Clin Oral Investig [Internet]. 2016. p. 1-8. Available from: http://link.springer.com/article/10.1007%2Fs00784-016-1709-3. [Last cited on 2015 Sep 9].
28. Payaw AM, Pewar MG, Metzger Z, Kokate SR. The self-adjusting file instrumentation results in less debris extrusion apically when compared to WaveOne and ProTaper Next. Clin Oral Investig [Internet]. 2015;19:89-93.
29. Singh A, Arunagiri D, Pushpa S, Sawhny A, Misra A, Khetan K. Apical extrusion of debris and irrigants using ProTaper hand, M-two rotary and WaveOne single file reciprocating system: An ex vivo study. J Conserv Dent 2015;18:405-8.
30. Szabó S, Koczak MM, Saglam BC, Türker SA, Sagsen B, Er Ö. Apical extrusion of debris using self-adjusting file, reciprocating single-file, and 2 rotary instrumentation systems. J Endod 2013;39:1278-80.
31. Siqueira JF, Barnett F. Interapicinal pain: Mechanisms, diagnosis, and treatment. Endod Topics 2004;7:93-109.
32. Borenstein M, Hedges LV, Higgins JP, Rothstein HR. Effect sizes based on means. Introduction to Meta-Analysis. Chichester, UK: John Wiley and Sons, Ltd.; 2009. p. 21.
33. Garg AK, Hackam D, Tonelli M. Systematic review and meta-analysis: When one study is just not enough. Clin J Am Soc Nephrol 2008;3:253-60.

9. Dincer O, Cakici BC. Evaluation of apically extruded debris during root canal retreatment with several NiTi systems. Int Endod J 2015;48:1194-8.
10. Silva EJ, Sá L, Belladonna FG, Neves AA, Accorsi-Mendoça T, Vieira VT, et al. Reciprocating versus rotary systems for root filling removal: Assessment of the apically extruded material. J Endod 2014;40:2077-80.
11. Kim MK, Min JB, Hwang HK. The effect of early coronal flaring about apical extrusion of debris. Restor Dent Endod 2004;29:147-52.
12. Mittal R, Singla MG, Garg A, Dhawan A. A comparison of apical bacterial extrusion in manual, ProTaper rotary, and One Shape rotary instrumentation techniques. J Endod 2015;41:2040-4.
13. Silva EJ, Carapii MF, Lopes RM, Belladonna FG, Senna PM, Souza EM, et al. Comparison of apically extruded debris after large apical preparations by full-sequence rotary and single-file reciprocating systems. Int Endod J 2016;49:700-5.
34. Higgins JP, Green S. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0. The Cochrane Collaboration; 2011. Available from: http://www.cochrane-handbook.org. [Last updated on 2011 Mar 20].
35. Lin JC, Lu JX, Zeng Q, Zhao W, Li WQ, Ling JQ. Comparison of mineral trioxide aggregate and calcium hydroxide for apexification of immature permanent teeth: A systematic review and meta-analysis. J Formos Med Assoc 2016;115:523-30.
36. Nevares G, Xavier F, Gominho L, Cavalcanti F, Cassimiro M, Romeiro K, et al. Apical extrusion of debris produced during continuous rotating and reciprocating motion. ScientificWorldJournal 2015;2015:267264.
37. Myers GL, Montgomery S. A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. J Endod 1991;17:275-9.