Original Article

Effect of various volume syringes on solution delivery time using conventional irrigation technique in 0.04 tapered preparations of single straight root canals: An *ex vivo* study

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Abstract

Introduction: The important aspect of endodontic treatment is root canal irrigation. Although agitation systems proved to have enhanced irrigant wall interactions, syringe needle-based delivery systems still play a significant role during the preparatory phases of root canal treatment. The current study aimed to evaluate the time taken for the irrigant delivery during conventional syringe irrigation using different volume syringes in different root canal preparations.

Materials and Methods: Two hundred extracted single-rooted premolars with approximately round canals were randomly instrumented to preferred apical preparation sizes using 0.4 tapered Hyflex-CM rotary Ni-Ti instruments and randomly divided as follows: Group I, instrumentation to size 40, 0.04 taper ($n = 50$); Group II, instrumentation to size 30, 0.04 taper ($n = 50$); Group III, instrumentation to size 25, 0.04 taper ($n = 50$); and Group IV, instrumentation to size 20, 0.04 taper ($n = 50$). Fifty operators were chosen for the experimentation. They were asked to irrigate the prepared specimens using different volume syringes. The entire irrigant delivery time was recorded by a head nurse using a stopwatch, and the values were calibrated and statistically analyzed.

Results: Group I recorded significantly lesser time for irrigant delivery during manual syringe needle irrigation ($P = 0.005$) compared to other groups.

Conclusion: Irrigation delivery time was less in 40/0.04 taper preparations, using 1 ml volume syringes.

Keywords: Endodontics, irrigant, root canal preparation, rotary instrumentation, syringe needle

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INTRODUCTION

Syringe needle irrigation is the most commonly employed technique during root canal irrigation.[1] Syringe needles of various designs have been introduced for irrigant delivery for conventional irrigation.[2] Especially, needles with side-vented channels dispense/irrigant through the most distal end or laterally[3] and tend to improve the hydrodynamic activation of the irrigant and reduce the chances of apical extrusion.[4] Various *in vitro* level-based computational fluid dynamic (CFD) analysis reports employ a flow rate of 0.26 ml/s,[5] for efficient irrigation. Clinically, it might not be possible to deliver 15.6 ml of irrigant consistently in all tapered root canals and by all operators.[6] It leads to the fatigue of the operator, if continuously; such a large volume of irrigant is delivered, within a short time.[7] Clinically, it is impossible to standardize the syringe needle irrigation. The previous report highlighted that the force of delivery of irrigant varies from operator to operator and gender wise and the clinician's experience wise too.[8]

Although the major factor that guards the efficacy of syringe needle irrigation (SNI) is the irrigant penetration and flushing action,[9] various other factors are also involved in improvising the efficacy of SNI. System of delivery,[10] volume of irrigant used[10] and the properties of the fluid used for irrigation,[11] needle choice, needle type,[12] and the insertion depth of the needle placed in root canal[13] have a major role during SNI.

A recent systematic review highlighted that needle placement, taper, and apical preparation sizes are considered the most efficient clinical factors safeguarding the syringe needle irrigation.[12] Literature from *in vitro* level-based studies still emphasizes the ambiguity of various preparation sizes on the irrigant delivery time.[12,14] Literature is scarce on apical preparation size and taper of the root canal relative to simulated irrigant flow time.[15,16] At an *in vitro* level, virtual-based CFD analysis states that increased taper and preparation sizes have a beneficial effect on reducing the simulated irrigation time.[15,16] Although there is no clear-cut evidence on the exact taper and preparation size required to achieve the effective irrigant flow, root canal enlargement to a size larger than 25 appeared to improve the syringe needle irrigation.[16] Hence, the present study tried to assess the solution delivery time in optimally shaped root canals.

The other most important factor that is frequently neglected is the intrabarrel pressure that is developed in due course of root canal irrigation.[7] Especially, when finer needle diameters are considered, the intrabarrel pressure is increased.[8] Considering all these facts, the present study tried to assess the effect of root canal preparation size on the irrigant delivery time using different volume syringes for manual syringe needle irrigation.

MATERIALS AND METHODS

Teeth selection

The present study proposal was approved by the Institutional Review Board and Ethical Committee of Saveetha Dental College and Hospitals, India (SRB: SDC/ENDO-1703/20/455), and ethical consent was obtained from patients before extraction. Two hundred freshly extracted noncarious single-rooted human mandibular premolars undergoing therapeutic orthodontic extraction were collected for the study. Prior pulp sensibility testing was carried out using a cold test (Green-Endo-Ice; Hygienic Corp, Akron, OH, USA) and electric pulp testing (Kerr Analytic Technology Corp, Redmond, WA, USA) before anesthetic administration to confirm the actual status of the pulp. The inclusion criteria for teeth selection were single-rooted intact human mandibular premolars, and teeth with <5° of canal curvature, which was determined using an intraoral periapical radiograph using Schneider's classification,[17] teeth with mature apices were considered. Teeth with calcifications, curvatures >5°, immature apices, and teeth extracted for other reasons were excluded.

Specimen standardization

Immediately after extraction, the soft tissue attached to the tooth surface was curetted and the collected specimens were stored in 5% formalin (Ricca Chemicals, Fisher Scientific, Mumbai, India). After the specimen collection, multiple intraoral periapical radiographs were taken to confirm the single-root morphology.

Specimens were decoronated using a diamond disk mounted on a straight handpiece (Confident Dental Equipments Ltd., India) under adequate water coolant. The specimens were standardized such that the root length was 17 mm totally from a flat reference point to 1 mm short of the major apical foramen terminus. This was confirmed using a working length radiograph. The working length was established before the subjection of the teeth for cone-beam computed tomography (CBCT) imaging to standardize the length of extracted specimens. The patency of the canals was determined using K-files ISO #10 (Dentsply, Maillefer, Ballaigues, Switzerland). Only teeth whose canal width near the terminus was approximately compatible with ISO #15 K-file were included. Once this was confirmed, the teeth were subjected to CBCT imaging to ensure the canal shape.

Imaging

The specimens were imaged using Kodak 9000 CBCT device (Carestream Dental Kodak Systems, Rochester, NY) to identify the single-rooted teeth with a single canal. The resolution of the acquired images was around 0.076 mm, 70 kvp, and 6.3 ma, and field of views was adjusted to 18.4 cm × 20.6 cm with 10.8 s scan time. The scanned specimens were then transferred to DICOM software, where multiple topographic sections were analyzed to make three-dimensional volume reconstructions using GALILEOS Viewer software (version 1.9.5603.25515, Informer Technologies Inc., Los Angeles, USA) at coronal, middle, and apical third to confirm the canal shape from the reference point to the radiographic terminus. Canals confirmed to have an approximately round shape to the entire canal length were included [Figure 1].

Root canal preparation

The specimens were randomly allocated into four groups according to the tapered preparation: Group I, canals were instrumented to size 40, 0.04 taper (n = 50); Group II, to size 30, 0.04 taper (n = 50); Group III, to size 25, 0.4 taper (n = 50); and Group IV, to size 20, 0.4 taper (n = 50)

Instrumentation of the standardized specimens was carried out using a single instrument according to the group allocated. Hyflex CM rotary files (Coltene/Whaledent Inc., USA) were used. The speed and the torque adjustments were as specified by the manufacturer. In due course of instrumentation, irrigation was carried out using 10 ml of 3% sodium hypochlorite (Parcan, Septodont, India) using a 30-gauge side-vented needle (NaviTip, Ultradent Products, South Jordan, UT, USA), placed 1 mm short of the apex. After completing instrumentation, irrigation was carried out using 5 ml of 3% sodium hypochlorite and 3 ml of ethylenediaminetetraacetic acid (MD Cleanser, Meta Biomed, India). The final rinse was carried out using distilled water and canals were dried with paper points. After the procedure was completed, one standardized root specimen from each group was embedded in a wax model containing four root canal-prepared teeth (one from each group). These wax models were assessed for the irrigant delivery time using manual syringe needles with different volume syringes (5 ml, 2.5 ml, and 1 ml).

A total of 50 operators participated in the present study, out of which 30 operators were postgraduates (conservative and endodontics) and 20 of them were experienced clinicians (conservative and endodontics). Each operator was provided with a wax model with one specimen from each group with different tapered preparations (as mentioned previously). The root canal irrigation procedure and the protocol followed were explained to each operator. The specimens were randomly distributed to operators using the opaque-sealed envelope technique. The intraexaminer and interexaminer reliabilities were assessed using Cohen's kappa statistics.

Irrigation protocol

Operators were asked to use a 31-gauge side-vented single-port syringe needle for root canal irrigation. Each operator was provided with 3-volume barrels corresponding to 5 ml, 2.5 ml, and 1 ml, filled with 1 ml of sodium hypochlorite in all the barrels. They were asked to irrigate the root canal-prepared specimens using corresponding barrel syringes continuously without any interference, and the stopwatch was calibrated by a head nurse, once the irrigation was initiated. They were instructed to keep the syringe 1 mm short of the apex and continuously irrigate by moving the needle in short vertical strokes of 2–3 mm amplitude. If any fatigues were elicited by an operator during irrigation, the readings were stopped and the values were not taken into consideration and they were asked to repeat the procedure once again. Each operator was asked to perform the procedure thrice for each tapered preparation and the mean value of all these three readings was taken into consideration. This was done to avoid taking single values, which might not translate into accurate recording. At the end of each reading, operators were provided with a new syringe and barrel to irrigate the prepared canals. The same procedure was continued using

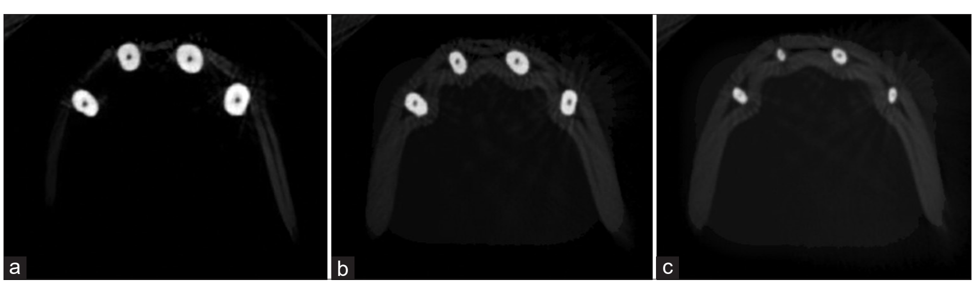

Figure 1: The CBCT sections of (a) coronal, (b) middle, and (c) apical showing approximately round canals, CBCT: Cone-beam computed tomography

three different syringe barrels. First, they were instructed to carry out 5 ml volume irrigation and calibrate three readings and then followed by carrying the protocol using 2.5 and 1 ml syringe barrels, respectively. 10 min of a break was given before performing the procedure for the next reading. This was done to prevent any fatigue-related issues that might vary the results.

Statistical analysis

The collected data were analyzed with IBM SPSS statistics software 23.0 Version (IBM SPSS Predictive Analytics Community, Armonk, New York, USA), Multivariate analysis and two-way ANOVA with Bonferroni's *post hoc* test were used.

RESULTS

The mean, standard deviation, and one-way ANOVA comparison for 5 ml, 2.5 ml, and 1 ml in different groups are presented in Table 1 and Figure 2. Experiences of the operators are presented in Figure 3 and multiple comparison analysis is presented in Table 2. Both one-way ANOVA and Tukey's *post hoc* revealed a statistically significant difference in total irrigation time among the four groups ($P = 0.005$). Among all the groups compared, Group I showed significant results ($P = 0.0005$), as compared to the other three groups. The intraexaminer reliability was found to be between 0.86 and 0.94 and the interexaminer reliability was found to be 0.77.

DISCUSSION

The current study aimed at assessing the solution delivery time in different apical preparation sizes on different syringe barrels. When the preparation size was taken into consideration, 40/0.04 taper preparations required less time ($P = 0.0005$) as compared to the other groups, when 1 ml volume syringes were used for irrigation. The present study results were correlated with previous *in vitro* level-based CFD analysis reports, stating that increased preparation sizes are shown to decrease the simulated irrigation time.[15,16]

In the current study, CBCT imaging was done to confirm the root canal morphology. Our work[18] based on CFD analysis has shown constant increased apical pressures in round root canal morphologies. Hence, we have selected round canals for the present study. Currently, there is an ambiguity in irrigant flow rates in lesser tapered preparations.[12] Therefore, in the current study, we have considered studying clinical solution delivery times in 4% tapered preparations.

The present study results proved that there was no significant difference in the mean irrigant delivery time

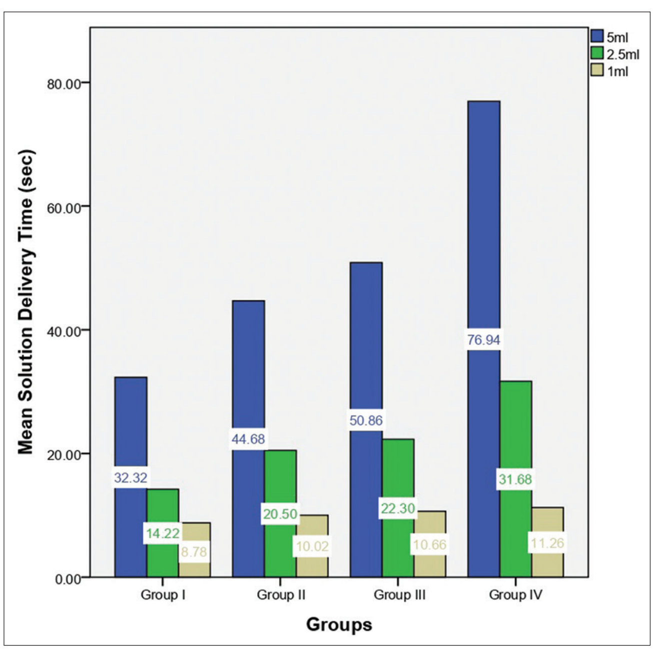

Figure 2: The mean solution delivery time between various groups and syringe

Table 1: Two-way ANOVA comparing the mean solution delivery time on using 5 ml, 2.5 ml, and 1 ml syringe in different groups assessed

Experimental groups	Number of samples	Mean±SD	*F*	*P*
5 ml volume syringe				
Group I	50	32.32±10.15	117.596	0.0005
Group II	50	44.68±11.34		
Group III	50	50.86±9.70		
Group IV	50	76.94±16.62		
2.5 ml volume syringe				
Group I	50	14.22±3.86	8.729	0.0005
Group II	50	20.50±15.22		
Group III	50	22.30±17.41		
Group IV	50	31.68±25.40		
1 ml volume syringe				
Group I	50	8.78±1.06	36.061	0.0005
Group II	50	10.02±1.24		
Group III	50	10.66±1.47		
Group IV	50	11.26±1.21		

SD: Standard deviation

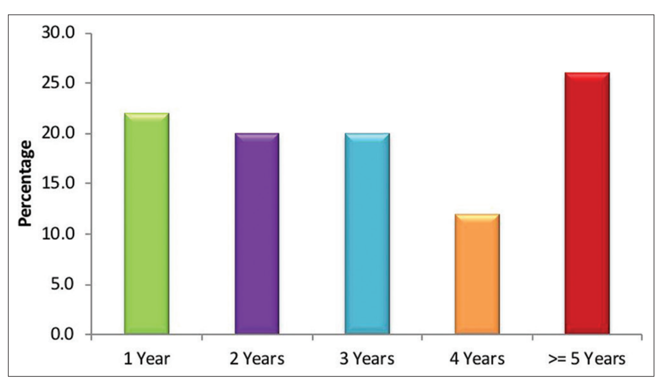

Figure 3: The experience of the operators selected

Table 2: Multiple comparison analysis on solution delivery time on using 5 ml, 2.5 ml, and 1 ml syringes in different groups assessed

Experimental groups	Mean difference	SE	*P*	95% CI	
				Lower bound	Upper bound
5 ml volume syringe					
Group I					
Group II	−12.360	2.453	0.0005	−18.72	−6.00
Group III	−18.540	2.453	0.0005	−24.90	−12.18
Group IV	−44.620	2.453	0.0005	−50.98	−38.26
Group II					
Group III	−6.180	2.453	0.060	−12.54	0.18
Group IV	−32.260	2.453	0.0005	−38.62	−25.90
Group III					
Group IV	−26.080	2.453	0.0005	−32.44	−19.72
2.5 ml volume syringe					
Group I					
Group II	−6.280	3.457	0.269	−15.24	2.68
Group III	−8.080	3.457	0.093	−17.04	0.88
Group IV	−17.460	3.457	0.0005	−26.42	−8.50
Group II					
Group III	−1.800	3.457	0.954	−10.76	7.16
Group IV	−11.180	3.457	0.008	−20.14	−2.22
Group III					
Group IV	−9.380	3.457	0.036	−18.34	−0.42
1 ml volume syringe					
Group I					
Group II	−1.240	0.250	0.0005	−1.89	−0.59
Group III	−1.880	0.250	0.0005	−2.53	−1.23
Group IV	−2.480	0.250	0.0005	−3.13	−1.83
Group II					
Group III	−0.640	0.250	0.54	−1.29	0.01
Group IV	−1.240	0.250	0.0005	−1.89	−0.59
Group III					
Group IV	−600	0.250	0.0005	−1.25	0.05

CI: Confidence interval, SE: Standard error

among the experienced clinicians versus postgraduates. Although experienced clinicians felt delivered the irrigating solution with ease, there were statistically significant differences that were observed. Both females and males were selected equally in the present study, as previous literature states that the irrigant delivery time using a manual syringe needle also varies according to the force used during irrigation, which might be gender related too.[8] When considered, the other factor that plays an essential role in using side-vented needles for irrigation is the experience with usage of the needles for root canal irrigation. In considering this factor, operators were chosen in such a way that they had varying levels of skill. Postgraduates from 1st, 2nd, and 3rd years were selected, out of which 1st-year graduate students did not have any previous experience using the specific syringe and needle for root canal irrigation. Hence, maybe, the present study would be appropriate in including all groups of operators to avoid operator-related bias.

The results of the present study showed a positive correlation with the aim of the experiment. The current study focused on assessing the irrigant delivery time on using different volume syringes in different prepared root canal specimens, the study results proved lesser delivery times at greater preparation sizes on using lesser volume syringes, when used for root canal irrigation. Although in a true clinical scenario, it is not always possible to refill 1 ml syringes for root canal irrigation, 2.5 ml volume syringes tend to serve the purpose. However, when thin tapered canals are taken into account, to prevent operator fatigue and to maintain the optimal flow rates, 1 ml volume syringes serve the purpose.

When comparison of the present study results has to be considered, none of the previous study reports can be compared, as the protocol for the assessment of the present study is different from the previous CFD analysis-based reports.[6,15,19-21] Specifically when previous *in vitro* study results on solution delivery time are considered, irrigant delivery time increases on using thinner gauge needles on using higher volume syringes.[6,8,21] Our results agreed with the previous study reports, which assessed different variables with a similar study concept. A recent simulation-based study assessed irrigant delivery time using CFD analysis, whose results could not be clinically comparable as it was a simulation-based study.[14] The current study mainly focused not only on the delivery time but also on the operator variations clinically on using different volume syringes. The topic is clinically more relevant as compared to the previous publication. As Sujith *et al*.[14] highlighted the increased pressures in smaller tapers and sizes, we have decided to conduct this study on multiple operators. The study protocol and outcomes are different from the previous simulation-based studies, published to date.[12]

An *in vivo* study done by Gopikrishna *et al*.[22] evaluated the irrigant flow rates in prepared mesial canals (instrumented to size 30, taper 0.6) of mandibular molars using different gauge open or side-vented needles and concluded that needle gauges have a significant influence on endodontic irrigation outcomes. However, to increase the effectiveness of irrigating agents, especially at the apical third, it is not advisable to prepare larger shapes and tapered preparations.[22] In a clinical scenario, where we tend to encounter thin and narrow shaped canals with varied canal curvatures, such larger preparations tend to cause deviations in original canal shapes. Hence, assuming the concept of shaping optimal to achieve maximal efficiency of the irrigating agent delivered,[23,24] the present study laid a unique way of assessment of different volume syringes on the irrigant delivery time in prepared canals.

However, the present study also has various limitations, which might not translate into a true clinical scenario. Although the current study was standardized, it included multiple operators, with different experience levels, genders, and age groups, which could have given some varied results. The other limitation was considering straight and single-rooted canals with minimal or no curvatures. Hence, future investigations are advised to be carried on using the same protocol, especially for the assessment of prepared curved canals, which would be much more appropriate. Future studies can also better concentrate on the irrigant delivery and replacements using activation devices.

CONCLUSION

Within the limitations of the present study, it can be concluded that 40.04 taper preparations recorded the least irrigant delivery time when 1 ml syringes were used for irrigation.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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