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Original Research

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Effect of Passive Ultrasonic Irrigation on the Cleanliness of Dentinal Tubules in Non-surgical Endodontic Retreatment with and without Solvent: A Scanning Electron Microscope Study

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***Abstract*:**
Background: To evaluate the effectiveness of passive ultrasonic irrigation on the cleanliness of dentinal tubules in curved root canals during endodontic retreatment with and without solvents using scanning electron microscope (SEM).
Materials and Methods: A total of 36 extracted maxillary molars were obturated with gutta-percha and AH Plus sealer. Retreatment was done with or without using solvent. Time was also recorded. Passive ultrasonic irrigation was done in one group. The roots were split longitudinally and observed under an SEM at ×2000. All the specimens were evaluated for a total number of dentinal tubules and the number of those either completely or partially filled. The data were analyzed by one-way ANOVA followed by Tukey's *post-hoc* was used for intergroup comparison.
Results: It was observed that more open tubules were present in Group IV followed by Group III, Group II, and Group I, respectively, and this difference was statistically significant ($P < 0.05$) hence, endodontic retreatment without using any solvent showed more cleanliness of dentinal tubules when compared with the groups using Endosolv-R solvent. However, cleanliness was better in the group where ultrasonic irrigation was done.
Conclusion: The use of solvent in this study did not hasten the removal of gutta-percha and AH Plus sealer. Use of passive ultrasonic irrigation after gutta-percha and sealer removal in non-surgical endodontic retreatment enhances the cleanliness of dentinal tubules.

***Key Words*:** Open dentinal tubules, passive ultrasonic irrigation, Protaper retreatment files, resin solvent, retreatment

Introduction

The thorough removal of gutta-percha and sealer from the root canal is of utmost importance in retreatment for the removal of leftover necrotic tissues or bacteria that are responsible for treatment failure. It also enables the clinician to perform thorough chemo-mechanical disinfection of the root canal systems.[1-5] Furthermore, root filling material remnants might reduce adaptation and adhesion of sealers and cement used for posts.[2,6-8]

Gutta-percha removal can be affected by endodontic hand files, heat carrying instruments, ultrasonic devices, or rotary nickel-titanium retreatment instruments such as Protaper, M2, and R-Endo files with and without the aid of solvents.[5,8-12] Nickel-titanium rotary instruments have been proved to be more efficient and safer than traditional hand files.[1] Recently introduced Protaper universal retreatment files (Dentsply, Tulsa), a NiTi rotary system includes D1, D2, and D3 as retreatment files. The three files are designed to facilitate the removal of filling material. Each file of this system has different lengths, tapers, and apical tip diameters.[13] Till date, there have been very few studies investigating the behavior of Protaper universal retreatment files in non-surgical endodontic retreatment.

Solvents such as chloroform and xylene are used to expedite the removal of gutta-percha from the canal during retreatment.[12-14] Endosolv-R (Septodont product, France) (66.5% formamide and 33.5% phenylethelic acid) as a solvent was introduced for removing resin based sealers. This solvent has shown to penetrate deep into the dentinal tubules and remove the unfilled resin sealer. The removal of resin sealer cement from the canal walls and anatomical ramifications is mandatory for effective disinfection and resealing of the root canal. The use of passive ultrasonic irrigation has been found to eliminate bacteria from the canal more efficiently than hand instrumentation due to its ability to penetrate and distribute the irrigating solution to apical third of canal and in uninstrumented areas.[14] Till date, there is no literature regarding the use of passive ultrasonic irrigation for evaluating the cleanliness of dentinal tubules in retreatment cases.

The aim of this *in-vitro* study was to evaluate the effectiveness of passive ultrasonic irrigation on the cleanliness of dentinal tubules in curved root canals during endodontic retreatment with and without solvents using scanning electron microscope (SEM).

Materials and Methods

A total of 60 freshly extracted human maxillary molar teeth (both 1st and 2nd molars) were selected and cleaned ultrasonically for removing calculus and debris. Mesiobuccal and distobuccal roots were separated following decoronation. 36 roots, either mesiobuccal or distobuccal measuring 16 mm with the curvature of 15-30°, with no calcification, no internal resorption, no previous root canal filling and fully formed apices were selected. The scan was taken to confirm the presence of single canal in the mesial and distal roots. Size 10 No. K-file was inserted into all the canals until it could be seen at the apical foramen. The working length was established 1 mm short of the apical foramen. The canals were instrumented with up to size 20 K-file followed by Protaper rotary instrument up to size F1 in a crown-down technique under copious irrigation using 3% NaOCl (2 ml) and Glyde (Dentsply). Saline solution (1 ml) was used as a final rinse to terminate the action of irrigants. The roots were dried with paper points and obturated with gutta-percha (2% cones/Dentsply) and AH Plus sealer (Dentsply) by lateral compaction method. The extent of the root filling was limited to 14 mm from the apex for standardization. Excess gutta-percha was removed, and the roots were radiographed to confirm the adequacy of root filling. The access cavity was restored with Type II glass ionomer cement (GC). All the specimens were stored at 37°C in 100% humidity till the retreatment program.

Endodontic retreatment protocol

The 36 root samples were randomly divided into four groups of nine samples each. The sample size determination was done using data from a previous study[2] with an alpha error at 5% and 80% power of the study. Group I samples were treated with Endosolv-R solvent (0.5 ml) before using Protaper retreatment files D1, D2, and D3 with crown down technique (500-700 RPM) to remove gutta-percha until the working length. In Group II, the samples were instrumented with Protaper universal retreatment files without using any solvent. In Group III, the samples were instrumented with Protaper universal retreatment files with Endosolv-R solvent followed by further irrigation with passive ultrasonic irrigation (Satelec Ultrasonic Unit) using 3% NaOCl. In Group IV, the samples were instrumented with Protaper universal retreatment files without using any solvent followed by passive ultrasonic irrigation. After gutta-percha removal, the canals were irrigated with saline solution (1 ml). Further instrumentation was done with Protaper rotary file size F2 up to the working length in all the four groups, and the canals were dried with paper points. In all the groups, the time was recorded from the beginning of instrument use till the use of paper points to dry the canal.

Passive ultrasonic irrigation protocol

Passive ultrasonic irrigation with the intermittent flow was used in this study. A total volume of 4 ml of 3% NaOCl was used. The canals were initially irrigated ultrasonically using 1 ml of 3% NaOCl with K 15 size files, which was placed 2 mm above the apical end for 1 min. Then, canals were irrigated with 1 ml of 3% NaOCl using disposable syringe and needle. Passive ultrasonic irrigation with 1 ml of 3 % NaOCl for 1 min was repeated and final irrigation with 1 ml of 3% NaOCl using syringe and needle. The canals were then flushed with saline solution to remove all traces of the irrigating solution, and canals were dried with paper points.

SEM evaluation

The roots of nine samples from each group were split longitudinally into two halves and subjected to SEM evaluation. The root halves were washed with 0.5 ml of saline solution to remove any cutting debris during splitting.

One-half of the split root of all the specimens were dehydrated at 37°C for 7 days, and sputter coated with gold (SCD 050 Sputter Coater) and the coronal middle and apical thirds of root halves were examined using SEM (Hitachi, S-3400) and at a standard magnification of ×2000. The coronal, middle, and apical third in all the specimens were evaluated for the total number of dentinal tubules and the number of those either completely or partially filled with material.

Statistical analysis

For statistical analysis, the ratio of a total number of dentinal tubules and the number of dentinal tubules either completely or partially filled with materials were recorded for all four groups. The mean time of gutta-percha removal was also evaluated. The normality of the data was checked using the Kolmogorov–Smirnov normality test, and it was found to be normal. Hence, the data were analyzed by one-way ANOVA followed by Tukey's *post-hoc* was used for intergroup comparison. All calculations were completed using Proc mixed with the repeated statement from the statistical software SAS 9.1.2 (USA). The statistical significance was considered at $P < 0.05$.

Results

All the groups in all the sections showed partially or completely blocked dentinal tubules with debris. Table 1 demonstrates the comparison of the mean of the ratios evaluated in SEM (number of open tubules/total number of tubules in mm^2) between the study groups using one-way ANOVA. It was observed that more open tubules were present in Group IV followed by Group III, Group II, and Group I, respectively, and this difference was statistically significant ($P < 0.05$). Tables 2 and 3 show the comparison of the mean of the ratios evaluated in SEM (number of open tubules/total number of tubules in mm^2) within the study groups using one-way ANOVA followed by Tukey's *post-hoc*. The middle third has a number of open tubules as compared to the coronal and

Table 1: Comparison of mean of the ratios evaluated in SEM (number of open tubules/total number of tubules in mm²) between groups using one-way ANOVA.

Groups	Mean±SD				*F* value	*P* value
	Group I	Group II	Group III	Group IV		
Coronal	0.2600±0.01897	0.3683±0.02317	0.4150±0.00548	0.4867±0.01506	282.140	0.000*
Middle	0.3183±0.01835	0.4617±0.02317	0.5450±0.00548	0.6250±0.02739	373.731	0.000*
Apical	0.1533±0.02582	0.2150±0.01378	0.2900±0.01549	0.3667±0.01751	219.273	0.000*
Total	0.2439±0.07309	0.3483±0.010629	0.4167±0.10754	0.4928±0.011034	23.463	0.000*

*The mean difference is significant at the 0.05 level. SD: Standard deviation, SEM: Scanning electron microscope

the apical third, and this difference is statistically significant across all four groups ($P < 0.05$). More open tubules were present in middle third followed by the coronal and apical third, respectively, which indicates that cleanliness of dentinal tubules is more in the middle third. Table 4 shows the mean time (in minutes) required to remove the gutta-percha and AH Plus sealer, with and without Endosolv-R solvent. The retreatment time has been shown less for the samples where Endosolv-R is not used, and the difference is statistically significant ($P < 0.05$). Graph 1 illustrates the mean of the ratios evaluated in SEM (number of open tubules/total number of tubules in mm²) between groups. Graph 2 shows the mean time required for removing gutta-percha and AH Plus sealer in minutes. Figures 1 and 2 show the representative SEM images of all the four groups in this study.

Table 2: Comparison of mean of the ratios evaluated in SEM (number of open tubules/total number of tubules in mm²) within the study groups using one-way ANOVA.

Groups	Mean±SD			
	Group I	Group II	Group III	Group IV
Coronal	0.2600±0.01897	0.3683±0.02317	0.4150±0.00548	0.4867±0.01506
Middle	0.3183±0.01835	0.4617±0.02317	0.5450±0.00548	0.6250±0.02739
Apical	0.1533±0.02582	0.2150±0.01378	0.2900±0.01549	0.3667±0.01751
F value	138.668	331.504	1463.246	351.434
P value	0.000*	0.000*	0.000*	0.000*

*The mean difference is significant at the 0.05 level. SD: Standard deviation, SEM: Scanning electron microscope

Table 3: Estimated ratios of mean difference evaluated in SEM (number of open tubules/total number of tubules in mm²) between coronal, middle, and apical third of each group using Tukey's *post-hoc*.

Groups	Subgroup (I)	Subgroups (J)	Mean difference (I-J)	*P* value
Group I	Coronal	Middle	−0.05833*	0.000
		Apical	0.10667*	0.000
	Middle	Apical	0.16500*	0.000
Group II	Coronal	Middle	−0.09333*	0.000
		Apical	0.15333*	0.000
	Middle	Apical	0.24667*	0.000
Group III	Coronal	Middle	−0.13000*	0.000
		Apical	0.12500*	0.000
	Middle	Apical	0.25500*	0.000
Group IV	Coronal	Middle	−0.13833*	0.000
		Apical	0.12000*	0.000
	Middle	Apical	0.25833*	0.000

*The mean difference is significant at the 0.05 level. SEM: Scanning electron microscope

Table 4: Mean time required for removing gutta-percha and AH Plus sealer in minutes.

Group	*N*	Mean±SD	*T* value	*P* value
Protaper+Solvent	18	5.3361±0.31561	7.3913	0.000
Protaper+without solvent	18	4.3304±0.48336		

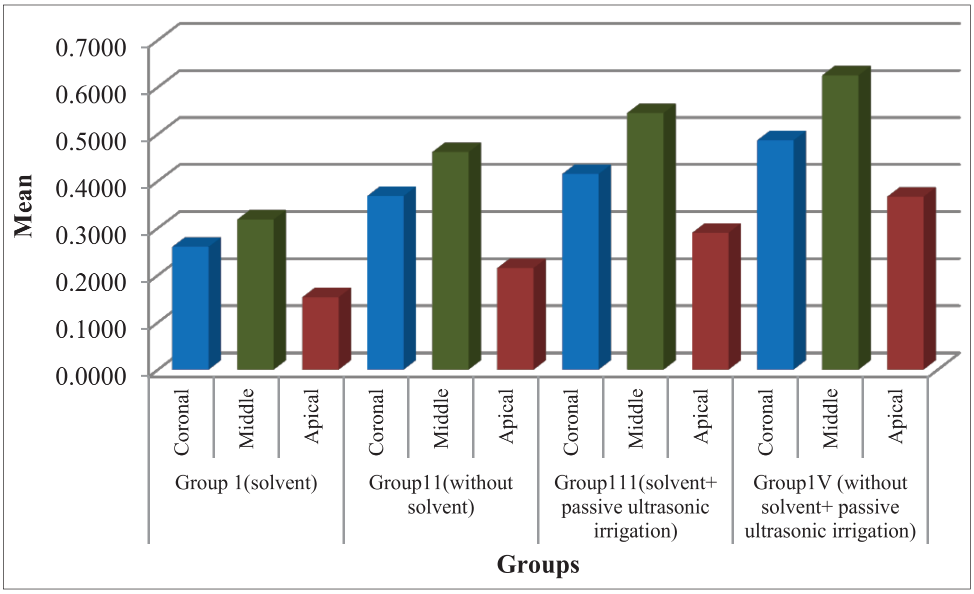
SD: Standard deviation

Discussion

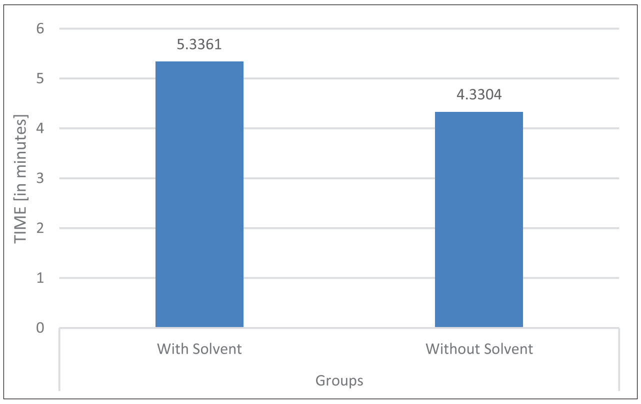
When non-surgical retreatment is indicated, efficient removal of the filled material from the root canal system is essential to ensure a favorable outcome.[15] In curved root canals, the removal of filling materials and further cleaning and shaping are more difficult when compared with straight canals. Furthermore, it may cause instrument distortion or instrument separation.[16] In roots obturated with resin sealer, the better adhesion to dentinal walls makes its removal from canal wall difficult.[17] The root fillings can be removed from the root canals by endodontic hand files, heat carrying instruments, ultrasonic devices, rotary instruments with or without the aid of solvents, or by combining any above instruments.[9,18] Irrigation allows for canal debridement beyond that can be achieved by root canal instrumentation alone and is, therefore, essential in both endodontic treatment and non-surgical retreatment cases.[14]

In the present study, endodontic retreatment without using any solvent (Group II) showed more cleanliness of dentinal tubules when compared with the groups using Endosolv-R solvent (Group I). This is because usage of solvents will dissolve gutta-percha and sealer and a fine layer of softened gutta-percha and sealer is formed. This will adhere to the root canal wall and is difficult to remove completely from the canal walls.[9,15] Wilcox and Juhlin have reported that the use of solvents causes the deposition of a thin layer of filling material on the root canal walls which proves to be difficult to remove. This layer attenuates the action of intra-canal antibacterial medicaments and might impair the adaptation of the subsequent filling material to the root canal walls.[15]

When considering the cleaning of dentinal tubules in coronal, middle, and apical third after retreatment with or without solvent, the middle and the coronal third showed more open tubules than the apical third. This is due to the differences between the taper and diameter of the D1, D2, and D3 files and apical diameter of the D3 files (size 20) is designed to reach the working length, and it does not permit



Graph 1: Mean of the ratios evaluated in scanning electron microscope (number of open tubules/total number of tubules in mm^2) between groups.



Graph 2: Mean time required for removing gutta-percha and AH Plus sealer in minutes.

a complete cleaning action. This result is similar to the study by Gu *et al*., where Protaper retreatment files showed more debris in the apical portion than in middle and coronal third of the canal.[13]

This present study demonstrated that the greater filling material remained in apical area than in the middle and coronal third. The existence of curvature in many planes of deep grooves and depressions on dentine walls in the apical third, well explain the presence of these less instrumented areas making it impossible to direct Protaper files against entire root canal walls.[6] Moreover, files placed in curved canals will be deflected from their long axis with resultant inequality of cutting and cleaning effectiveness, depending on the pressure with which the cutting instrument contacts different walls of the root canal. This instrument deflection produces greater cutting and cleaning efficiency in the direction opposite to the curvature of the instrument.[6] Schirrmeister *et al*. on their study on retreatment using Protaper system demonstrated that more debris found in the apical region due to the smaller size of the Protaper files, which reduce the efficacy in the apical region.[11]

In the present study, endodontic retreatment with Protaper retreatment files alone (Group II) showed less retreatment time than the groups used Endosolv-R solvent (Group I). This is because Protaper retreatment files remove a significant amount of gutta-percha in spirals around the instrument than in small encircles which do not adhere to the instruments.[13] When solvents are used for removing gutta-percha and sealer, more time is needed for the solvent to soften the gutta-percha, and moreover, the fine layer of softened gutta-percha that forms and it adheres to the root canal wall which is difficult to remove completely from the canal walls.[9,15] The result of our study is consistent with the previous study by Gu *et al*. and Pirani *et al*. where NiTi rotary instruments without using any solvent proved to be faster.[1,15]

In the present study, passive ultrasonic irrigation used following the gutta-percha and sealer removal (Group III and IV) showed a better result when compared to groups where ultrasonic irrigation is not used. During passive ultrasonic irrigation, the energy is transmitted from an oscillating file or a smooth wire to the irrigant in the root canal using ultrasonic waves. The latter induces acoustic streaming and cavitation of the irrigant.[14] Acoustic streaming creates a higher volume and higher velocity of the irrigant at flow in the canal. Passive ultrasonic irrigation enhances the tissue dissolving capacity of NaOCl. The smear layer and debris are wetted completely by the solution during ultrasonic irrigation and facilitate removal of the ultrasonic

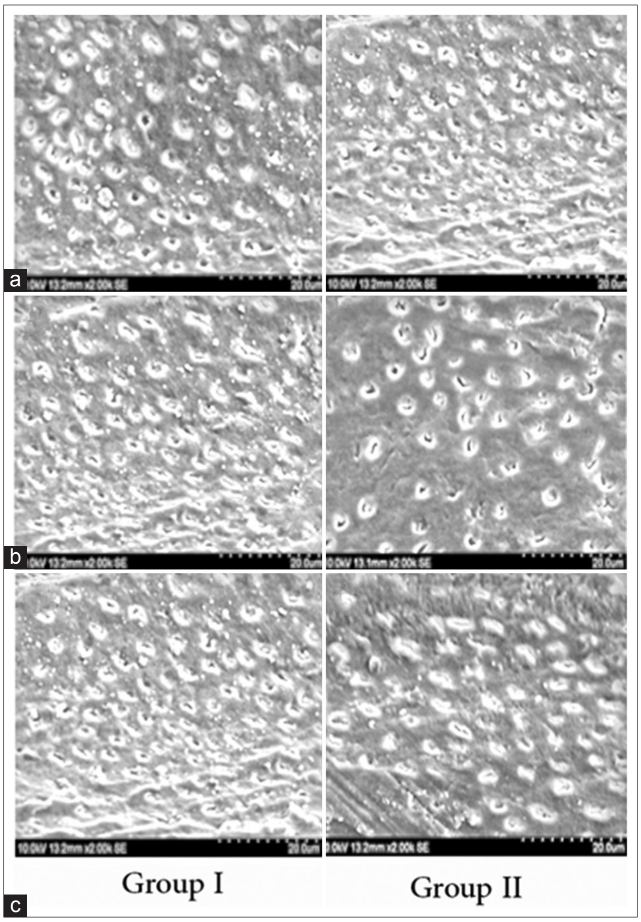


Figure 1: Scanning electron microscope images of Group I and Group II at (a) Coronal, (b) middle, and (c) apical third.

energy imparted from the energized instrument producing acoustic streaming.[16]

The better effect of passive ultrasonic irrigation can also be attributed to the fact that the ultrasonic vibration generates a continuous movement of the irrigant which leads to the efficient cleaning of the root canal. Furthermore, the agitation leads to a rise in the temperature of irrigant which enhances NaOCl chemical reactivity and hence disinfecting potential.[19]

In this study, even though passive ultrasonic irrigation reduces the debris from the canal walls better, it could not completely remove the filling material from the canal walls. This study showed more debris was found in the apical third than in the middle and coronal third. The reason is that this study is done in curved molar roots where root diameter influences the efficacy of ultrasonic irrigation. A straight instrument placed in a curved canal will have at least three contact points with root canal walls.[20] Narrow and curved canals compromise the effectiveness of ultrasonic irrigation and when file rotates in canals the file binds thus restricting their vibratory motion and cleaning efficiency. For the irrigant to be effective, they have to be in direct contact with the surface. In small diameter roots, the irrigating solution has difficulty in reaching the apex and this also influences the efficiency of the passive ultrasonic irrigation.[16] Hence, in this study, further preparation of the canal with the F2 file was recommended to facilitate better contact of the irrigating solution to reach the apex of the root canal and also to allow free oscillation of ultrasonic files to impart more ultrasonic effects in the irrigating solution.

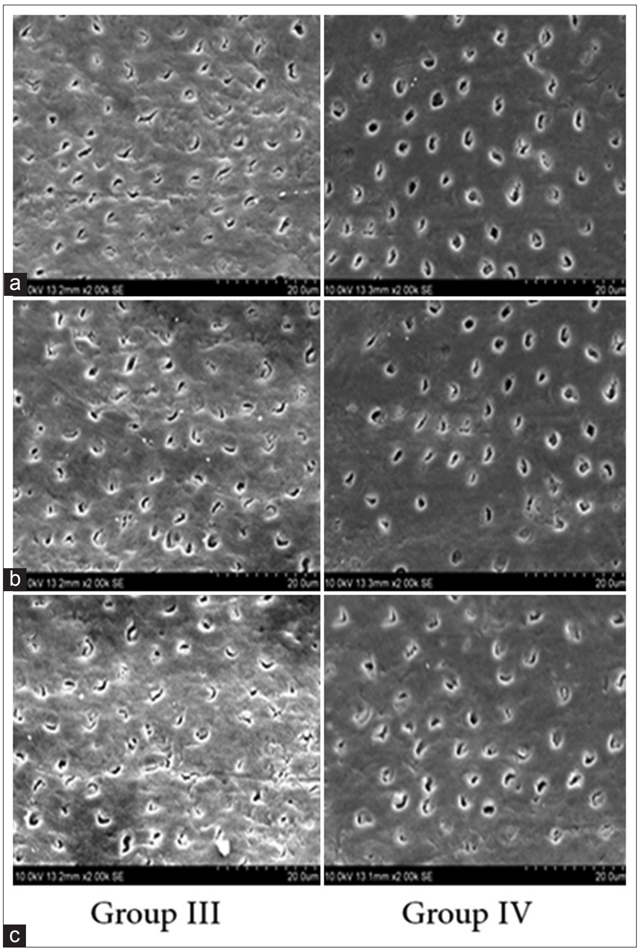


Figure 2: Scanning electron microscope images of Group III and Group IV at (a) Coronal, (b) middle, and (c) apical third.

Moreover, when evaluating irrigation of the apical third, the phenomenon of vapor lock should be considered. The root canal system behaves such as a close-ended channel, which results in gas entrapment at the apical third. Vapor lock is created by the organic decomposition of NaOCl into a bubble of carbon dioxide and ammonium. This prevents the flow of irrigant into the apical region and adequate debridement of the canal system. A study by Gu *et al.* shown that when ultrasonically activated tips leave the irrigant and enters the apical vapor lock, acoustic streaming, and cavitation becomes physically impossible.[14]

The result is in accordance with the study by Al-Jadaa *et al.* where they found in more curved canals the greater force by which a tip contacts the canal walls might reduce the ultrasonic efficiency.[20]

The results of this study showed that more open tubules were found in the middle third of the canals after passive ultrasonic irrigation. The reason may be due to the placement of ultrasonic files 2 mm away from the apical foramen for the free oscillation of the file. The file in an ultrasonic device vibrates in a sinus wave like fashion. A standing wave has areas with maximum displacement (antinodes) and regions with no displacement (nodes). The tip of the instrument exhibits an antinode. Furthermore, acoustic streaming creates small intense, circular fluid movements (eddy flow) around the instrument. The eddying occurs closer to the tip than the coronal end of the file (Cohen). So, since the file is placed 2 mm away from the apical area and more action of the files remain on file tips than the coronal end of the files. Moreover, when ultrasonic files activate in the canal, the flushing action of the file moves the irrigant toward the apex during initial oscillation of files and the irrigant flushes out with the removed debris away from the file tip. During this process, there are chances for the debris to accumulate in the coronal third. Thus, the null hypothesis was rejected.

Conclusion

The present study concludes that Protaper universal retreatment files without using any solvent are more efficient in removing the gutta-percha and AH Plus sealer in non-surgical endodontic retreatment. The use of Endosolv-R led to more gutta-percha and sealer on root canal walls and inside dentinal tubules. The use of a solvent in this study even proved to be a time-consuming factor in removing gutta-percha and AH Plus sealer. Therefore, use of solvents should not be recommended during endodontic non-surgical retreatment procedure. An additional step of using passive ultrasonic irrigation after gutta-percha and sealer removal in non-surgical endodontic retreatment will enhance the cleanliness of dentinal tubules further. However, further investigation should be done to evaluate the effect of other irrigation techniques such as Endovac, Navitip, and Max I Probe on the cleanliness of dentinal tubules during non-surgical endodontic retreatment.

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