EUROPEAN ENDODONTIC JOURNAL

ORIGINAL ARTICLE

Current Trends in the Use of Irrigant Activation Techniques Among Endodontists & Post-Graduate Dental Students in India - A Knowledge, Attitude and Practice Based Survey

Velmurugan NATANASABAPATHY, Archana DURVASULU, Jogikalmat KRITHIKADATTA, Ambalavanan NAMASIVAYAM, Kandaswamy DEIVANAYAGAM, Srinivasan MANALI, Nivedhitha Malli SURESHBABU

ABSTRACT

Objective: The aim of this survey was to examine the practice/use of Irrigant Activation Techniques (IAT) among Endodontists and post-graduate dental students in India.

Methods: An invitation to participate in this survey was sent by electronic mail to 902 members of Indian Endodontic society. A total of 32 questions were finalized for the survey after validation by five endodontic experts. Survey contained 2 demographic questions, 7 knowledge based questions, 11 questions on attitude and 12 questions on practice of IAT. The reliability was checked by randomly asking 10 participants to fill the survey forms again after 15 days. The data was analyzed using chi-square test ($P<0.05$).

Results: The overall response rate for the survey was 30.5%. The content validity ratio for the questionnaire was 0.972 & the reliability calculated using Kappa scores was 0.978. Most of the respondents (87.3%) use IAT, while 4.7% do not use IAT. Most commonly used IAT was Manual dynamic agitation (MDA) used by 28.7%, followed by Ultrasonics in 17.2%. Sonic & negative pressure (EndoVac) was used by less than 10% of respondents. Combination of IAT was used by 39%. In 23 (5 on knowledge, 9 on attitude & 9 on practice) out of the 32 questions in this survey, there was a statistically significant difference ($P<0.05$) in the answers between the groups, with post-graduate dental students opting the correct choices. Sodium hypochlorite (NaOCl) is the preferred choice of irrigant for IAT according to 48.6%, Chlorhexidine (CHX) is used by 4.2% & Ethylene diamine tetra acetic acid (EDTA) by 2.4%. Combination of two irrigants is used by 28.7% and 6% use all the three irrigants.

Conclusion: Vast majority of the Endodontist in India use some form of IAT to improve the efficacy of irrigation. MDA is the most commonly used IAT.

Keywords: Irrigation, irrigant activation, isthmi, KAP survey

Please cite this article as: Natanasabapathy V, Durvasulu A, Krithikadatta J, Namasivayam A, Deivanayagam K, Manali S, Sureshbabu NM. Current Trends in the Use of Irrigant Activation Techniques Among Endodontists & Post-Graduate Dental Students in India - A Knowledge, Attitude and Practice Based Survey. Eur Endod J 2020; 2: 73-80

From the Department of Conservative Dentistry and Endodontics (V.N. ✉ vel9911@yahoo.com, A.D., J.K., A.N.) Faculty of Dentistry, Meenakshi Academy of Higher Education and Research, Meenakshi Ammal Dental College, Chennai, India; Department of Conservative Dentistry and Endodontics (K.D.), Faculty of Dental Sciences, Sri Ramachandra University, Chennai, India; Department of Conservative Dentistry and Endodontics (S.M.), Sri Venkateshwara Dental College and Hospital, Chennai, India; Department of Conservative Dentistry and Endodontics (N.M.S.), Saveetha Dental College, Saveetha University, Chennai, India

Received 07 September 2019, Accepted 09 February 2020

Published online: 22 May 2020
DOI 10.14744/eej.2020.98698

HIGHLIGHTS

- Various irrigant activation Techniques such as Ultrasonics, sonic, apical negative pressure, manual dynamic agitation are used by endodontist to improve the delivery & efficacy of root canal irrigants.
- This survey showed that the vast majority of Endodontists & postgraduate dental students in India use one form or the other of IAT during root canal treatment.
- Manual dynamic activation was the most commonly used technique followed by ultrasonics.

INTRODUCTION

The root canal system is highly complex with extra canals, lateral canals, communications and multiple portal of exit (1). Micro-CT studies showed that more than 35 to 40 % of root canal surface remains untouched by instruments after cleaning and shaping procedures (2, 3). Even newer instruments such as the Self-adjusting files leave 15 to 20% canal surface untouched after instrumentation (4). Root canal irrigation plays a important role in disinfecting these areas of the canal. For irrigation to be effective, it needs to penetrate such portions of the root canal (5). Syringe and needle irrigation (SNI) is the most commonly used method to deliver the irrigants. (6, 7) But SNI fails to deliver the irrigant 1 to 2 mm beyond the needle tip (8), and moreover the presence of a vapor lock limits irrigant diffusion in the critical apical portion of the root canals (9).

Various irrigant activation techniques (IAT) are being used nowadays to improve the delivery and efficiency of root canal irrigants. Manual dynamic activation disrupts the apical vapor lock

by repeatedly moving well-fitted gutta-percha up and down to the working length (10). Endoactivator increases the efficiency of irrigants by creating a hydrodynamic phenomenon using sonic energy (11). It uses a cordless handpiece that oscillates polymer tips at 2-3 kHz to activate the irritants. Passive ultrasonic irrigation (PUI) involves the use of non-cutting file tips that are oscillated at 25-30 kHz (12). Acoustic streaming of irrigants, that occurs during PUI, is known to increase its cleaning efficiency and lateral canal penetration (13). Apical negative pressure technique (ANP) such as Endovac utilizes cannulas connected to the chair side suction that enables the penetration of irrigants to full working length without apical extrusion (14).

In a recent Meta-analysis on the effectiveness of various IAT, Virdee et al concluded that IAT improves canal cleanliness across major portions of the root canal and recommended its use throughout the cleaning and shaping procedure. But they could not establish which among the various IAT was superior as the data collected by them was too heterogenous (15). Two systematic reviews compared PUI with SNI and ANP with SNI did not prove the superiority of these IAT in terms of outcome in Endodontic treatment (16, 17). Recent systematic reviews based on *in vitro* studies reported cleaner canals and isthmi following mechanical activation (18, 19). One of them concluded that mechanical activation can reduce post-operative pain (18). In view of these findings, it will be interesting to know the current practices/trends of IAT amongst Endodontists, noting that survey studies available in the literature investigated the type and concentration of irrigants used by clinicians with no emphasis on the use of IAT (6, 7). Surveys capture the ongoing processes in clinical practice and record the effects that are evident or trends that are developing (20). To the best of knowledge there is no survey done on the use of IAT. Hence, the aim and purpose of this survey was to gather information on Knowledge, Attitude and Practice (KAP) of IAT amongst Endodontists in India.

MATERIALS AND METHODS

An invitation to participate in KAP survey was sent by electronic mail to 902 members of the Indian Endodontic Society after obtaining permission from the Institutional Review board (IRB.NO.MADC/IRB-XVIII/2018/329). Survey questions were based on Knowledge, Attitude and Practice of IAT. The attitude based questions were on a five point Likert scale, the Knowledge based and practice based questions were multiple choices or close ended questions. Initially a set of 30 questions were drafted and sent for content validation to five experts in Endodontic field (3 National and 2 International).The two international experts were from Canada and Malaysia. Five questions (3 in Attitude and 2 in Practice) were modified as suggested by the experts. Two questions were added in Knowledge section based on the suggestion of the International expert in this field. The final questionnaire had 2 demographic questions, 7 knowledge based questions, 11 questions on attitude and 12 questions on practice of IAT (Table 1 and 2). The reliability was checked by randomly asking ten participants to fill the survey forms one more time after 15 days.

Statistical analysis and data handling

The questionnaire was developed using Google forms (Google Inc. Mountain View, CA, USA). The data were stored in excel format in the backend until further analysis. The validity and reliability scores for the survey were calculated using Content validity ratio and kappa test respectively. The data was statistically analyzed using chi square test. Significant differences was set at 0.05 ($P<0.05$). All the analyses were performed using SPSS 16.0 software (IBM Corp., Chicago, IL, USA).

RESULTS

A total of 902 survey invitations were sent to members of Indian Endodontic society, out of which only 695 forms were deliverable. 212 participants completed the survey, with a overall response rate of 30.5%. With regards to the validation of the questionnaire by five Endodontic experts the content validity ratio was 0.972. The reliability among the respondents was calculated using Kappa scores and it was 0.978.

The respondents of the survey, comprised of 41% postgraduates and 59% were qualified Endodontists. Amongst the Endodontists, 24.5% had 0 to 10 years of experience, 21.2% had 11-20 years of experience and 13.2 % had 21-30 years of experience. 36.8% of the respondents were both academicians and in private practice, while 19.3% were full time practitioners and 43.9% were still in training. In 23 (5 on knowledge, 9 on attitude & 9 on practice) out of the 32 questions in this survey, there was a statistically significant difference (Table 3) in the answers between the groups, with post-graduate dental students opting the correct choices (Fig. 1).

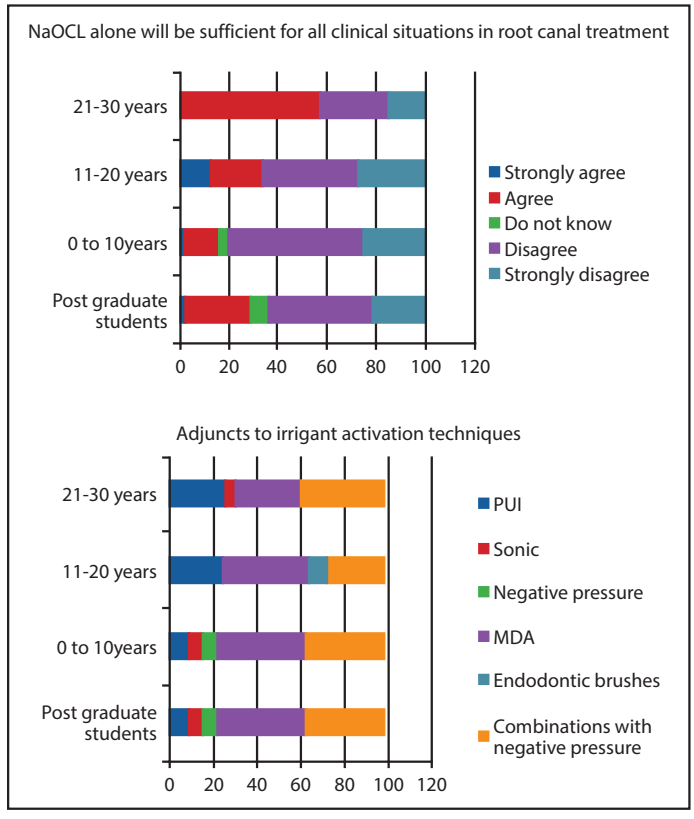

Figure 1. Distribution of irrigant activation practices based on years of experience

TABLE 1. Sample questionnaire

Demographic Questions

1. How many years ago since you completed your postgraduate endodontic training

a) 5-10
b) 11-20
c) 21-30
d) Post graduate student

2. Are you a full-time private practitioner?

a) Yes
b) No (Academician and evening practice)
c) Still in training

Knowledge Based Questions

3. Prevalence of isthmus is high in?

a) Mandibular molars
b) Maxillary molars
c) Maxillary premolars

4. According to you which portion of the root canal is difficult to disinfect?

a) Coronal third of root canal
b) Middle third of the root canal
c) Apical third of the root canal

5. According to you which is the main reason for using irrigant activation techniques?

a) Better antimicrobial capacity
b) Tissue Dissolution
c) Canal Communication
d) Apical third ramifications
e) Smear layer removal
f) Others

6. Position of insert for all the irrigant agitation methods except negative pressure technique?

a) Upto the working length
b) 1 mm short of the working length
c) 2 mm short of the working length

7. Position of insert for negative pressure technique'

a) Upto the working length
b) 1 mm short of the working length
c) 2 mm short of the working length
d)

8. How many cycles of ultrasonic assisted irrigation are required for each canal?

a) One cycle
b) Three cycles
c) Five cycles

9. Duration of micro irrigation(one cycle) for negative pressure technique

a) 30 seconds
b) 45 seconds
c) 1 minute

Attitude Based Questions

10. Sodium hypochlorite irrigant alone will be sufficient for all clinical situations in root canal treatment?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

11. Irrigant penetration into the lateral canal, isthmus and accessory canal is necessary for better treatment outcome

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

12. Do you feel irrigant activation is necessary for root canal disinfection?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

13. Will irrigant activation help in vapor lock disruption?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

14. Manual dynamic activation procedure can disrupt vapor lock

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

15. Do you feel ultrasonic assisted irrigation (PUI) is the most effective method for isthmus disinfection?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

16. Can apical negative pressure technique be used in treating complex root canal morphology?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

TABLE 2. Sample questionnaire continued

17. Do you feel larger apical diameter is necessary for using apical negative pressure technique?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

18. Do you feel complete disinfection of Isthmus is possible with any of these methods?

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

19. Is Apical extrusion common with irrigant agitation methods

a) Strongly agree
b) Agree
c) Do not know
d) Disagree
e) Strongly disagree

20. Reason for not using activation techniques

a) Time consuming
b) Expensive
c) Not having knowledge
d) Others

Practice Based Questions

21. What is your primary irrigant of choice

a) Sodium hypochlorite
b) EDTA
c) Chlorhexidine
d) Saline

22. Do you routinely aim to remove the smear layer?

a) Yes
b) No
c) Not sure

23. Do you differ on choice of irrigant(s) based on the pulpal diagnosis?

a) Yes
b) No
c) Not sure

24. Do you differ on choice of irrigant(s) based on the periapical diagnosis?

a) Yes
b) No
c) Not sure

25. Do you use irrigant activation techniques routinely?

a) Yes
b) No
c) Not sure

26. Choice of irrigants for reversible and irreversible pulpitis

a) Sodium hypochlorite
b) Chlorhexidine
c) EDTA
d) Combination
e) Saline

27. Choice of irrigants for periapical infections

a) Sodium hypochlorite
b) Chlorhexidine
c) EDTA
d) Combination
e) Saline

28. Which of the following irrigants you prefer for activation?

a) Sodium hypochlorite
b) Chlorhexidine
c) EDTA
d) Combination

29. Type of irrigating needle used?

a) Open ended
b) Closed ended
c) Combination

30. Needle gauge?

a) 24 gauge
b) 27 gauge
c) 30 gauge
d) Navitip needles
e) Others

31. Which of the following adjuncts to irrigation do you utilize?

a) Ultrasonic activation
b) Sonic activation (example: EndoActivator)
c) Negative pressure (example: EndoVac)
d) Manual Dynamic agitation with GP
e) Endodontic Brushes
f) Combination

32. Irrigant agitation is performed

a) In-between instruments during instrumentation
b) After instrumentation/enlargement
c) both a & b

Knowledge based questions:

For the question on prevalence of canal isthmus, 49.1% felt it was common in mandibular molars while 37.3% felt it was prevalent in maxillary premolar and 13.7% felt it was maxillary molar. Majority of the respondents, 94.8% felt that apical portion of root canal is the most difficult to disinfect and 5.2% felt middle third portion is difficult to disinfect.

The most common reason for using activation methods, is to improve the anti microbial activity of the irrigant according to

TABLE 3. Questions with statistical significance (P<0.05)

S. No	Question	P value
Knowledge Based Questions		
1	Position of insert for all the irrigant agitation methods except negative pressure technique?	0.007
2	Position of insert for negative pressure technique?	0.001
3	How many cycles of ultrasonic assisted irrigation are required for each canal?	<0.001
4	Duration of micro irrigation(one cycle) for negative pressure technique?	0.008
5	According to you which is the main reason for using irrigant activation techniques?	<0.001
Attitude Based Questions		
1	Sodium hypochlorite irrigant alone will be sufficient for all clinical situations in root canal treatment	<0.001
2	Irrigant penetration into the lateral canal, isthmus and accessory canal is necessary for better treatment outcome	0.008
3	Do you feel irrigant activation is necessary for root canal disinfection?	<0.001
4	Will irrigant activation help in vapor lock disruption?	0.003
5	Manual dynamic activation procedure can disrupt vapor lock	0.005
6	Do you feel ultrasonic assisted irrigation (PUI) is the most effective method for isthmus disinfection?	0.007
7	Do you feel larger apical diameter is necessary for using apical negative pressure technique?	0.005
8	Do you feel complete disinfection of Isthmus is possible with any of these methods?	<0.001
9	Is Apical extrusion common with irrigant agitation methods?	0.001
Practice Based Questions		
1	Do you use irrigant activation techniques routinely?	<0.001
2	Which of the following adjuncts to irrigation do you utilize?	<0.001
3	Do you differ on choice of irrigant(s) based on the periapical diagnosis?	<0.001
4	Do you routinely aim to remove the smear layer?	0.005
5	What is your primary irrigant of choice?	<0.001
6	Needle gauge?	0.002
7	Type of irrigating needle used?	<0.001
8	Which of the following irrigants you prefer for activation?	0.009
9	Choice of irrigants for periapical infections?	<0.001

33% of respondents, 7.5% felt it was for better tissue dissolution, 16.5% say it is for disinfection of canal communications, 28.8% felt it was to take care of the apical ramifications and 9.4% felt it is for better smear layer removal.

For the question needle position for IAT except apical negative pressure technique, 51.4% use it 1 mm short of working length, 39.6% use it 2 mm short of working length and 9% use it to full length. With regards to needle position in apical negative pressure technique, 36% use it to full length, 46% use it 1 mm short of working length and 18% use it 2 mm short of working length. For the question on number of cycles used in PUI, 71.8% use three cycles, 19.4% use one cycle and 8.7% use five cycles of activation. With regards to duration of micro irrigation cycle for apical negative pressure, 51.9% use it for 30 seconds, while 27.6% use for it for 45 seconds and 20.5% use it for 1 minute (Fig. 2).

Attitude based questions:

For the question whether Sodium hypochlorite (NaOCl) is sufficient for all clinical situations in root canal treatment, 30.6% strongly agree/agree to it, while 66% feel it alone may not be sufficient in all situations and 3.3% do not know about it.

For the question whether irrigant penetration into lateral canals, isthmus and accessory canals is necessary for better treatment outcome, 89.1% strongly agree/agree to it, while 2.9% disagree/strongly disagree and 8% do not know about it. Entire results of Attitude based questions are given in (Fig. 3).

Practice based questions:

Primary irrigant of choice was NaOCl in 77.8% respondents, while 8.5% people used EDTA, 2.8% used CHX and 10.8% used saline. With regards to smear layer removal, 83% aim to remove it while 7.5% do not remove it, and 9.4% of them are not sure about smear layer removal. Majority of the respondents 60.4% alter their choice of irrigants based on pulpal diagnosis while 34.9% do not alter their choice of irrigants and 4.7% are not sure about it. 23.1% respondents used NaOCl, while 3.3% used CHX, 1.9% used EDTA and 41.5% used combination of irrigants in pulpitis cases. Based on periapical diagnosis 79.7% of them change their irrigants, while 15.6% do not change their

irrigants and 4.7% not sure about it. Choice of irrigants for peri apical infections was as follows, NaOCl in 11.3%, CHX in 20.8%, EDTA in 0.5% whereas 38.7% used combination of irrigants.

Vast majority of the respondents, 87.3% use IAT, while 4.7% do not use IAT and 8.0% not sure about IAT. NaOCl is the preferred choice for use in IAT in 48.6% of respondents, 4.2% use CHX, 2.4% use EDTA. 28.7% use a combination of two irrigants & 6.1% use a combination of all three irrigants (NaOCl+CHX+EDTA).

Open ended needle was used by 45.3%, closed ended needle by 32.1%, while 22.2% used both type of needles. With regards to the needle gauge 45.3% use 27 gauge, 28.3% use 30 gauge, 11.8% use 24 gauge and 9.9% use special Navi tip needles.

Most commonly used IAT was Manual Dynamic agitation (MDA) used by 28.7%, followed by Ultrasonics in 17.2%, Sonic 7.2%, Negative pressure (Endovac) by 7%. More than one form of IAT was used by 39% of respondents (Fig. 4). IAT is used after instrumentation by 35.8% respondents, 8% use it between instruments and 56.1% use it both during and after instrumentation.

DISCUSSION

Recent studies reported that root canal system is highly complex than what has been established earlier (21, 22). The use of IAT allows for substantial cleaning across portions of the root canal (15).

To the best of knowledge there is no earlier cross-sectional survey done on IAT among Endodontists. There is only one earlier survey done among Academic Endodontists and postgraduate students in India by Gopi Krishna et al. (6) in 2012, however that survey focused on irrigation protocols followed in various dental colleges. The primary objective of this present survey was to investigate the prevalent practices of IAT among Endodontists in India. The response rate achieved in our study was 30.5%, which is similar to the response rates of earlier survey studies conducted among Endodontists in India and United states (6, 7).

Majority of the respondents (77.8%) use sodium hypochlorite as the primary irrigant, whereas in an earlier survey by Gopi krishna et al. amongst Endodontists in India 92.8% used NaOCl (6). This difference in result could be attributed to the selection of survey participants, which comprised of only academicians in the later study while it was both academicians and Endodontic practitioners in our study. Most of the respondents in our survey routinely aim to remove the smear layer (83%), but it was only 68% in earlier Indian survey and 77% in an earlier American survey (6, 7). 66% felt that NaOCl alone will not be enough for the different clinical situations that can arise during Endodontic treatment.

87.3% of the respondents used IAT, which is much higher than what was reported in an American study (7), where only 50% of them IAT. This difference in result could be due to increased awareness of the fact that the root canal system is more complex than what was earlier imagined and hence, the subsequent use irrigant adjuncts disinfect these portions is needed. Most commonly used individual IAT, was MDA by

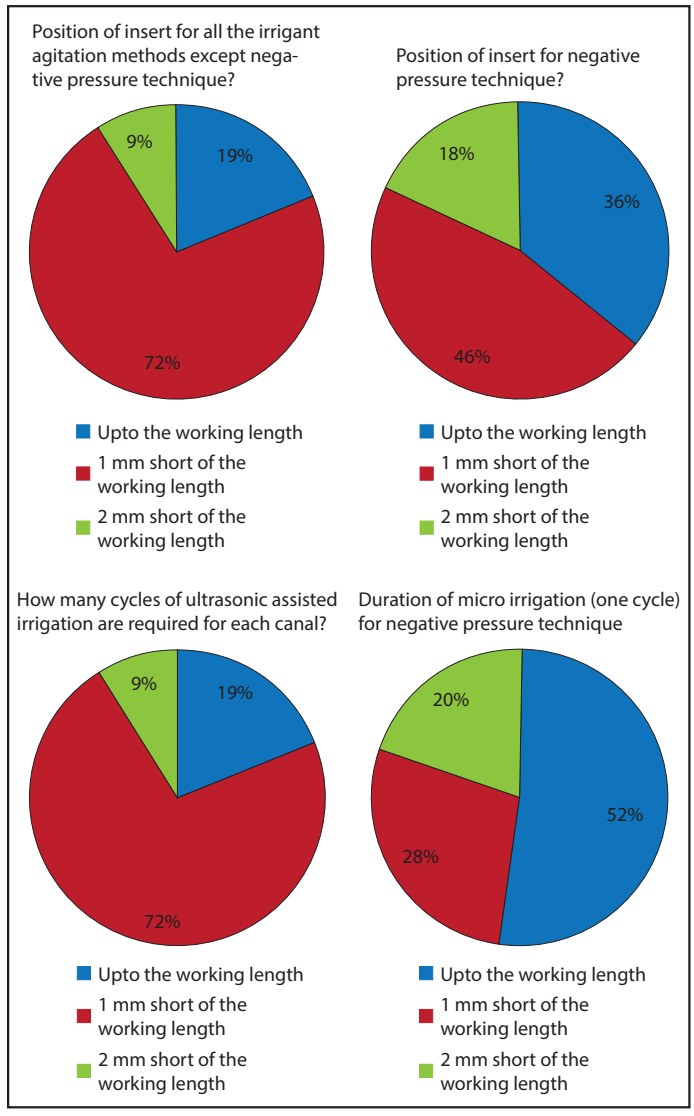

Figure 2. Current knowledge on Irrigant activation methods amongst Endodontists in India

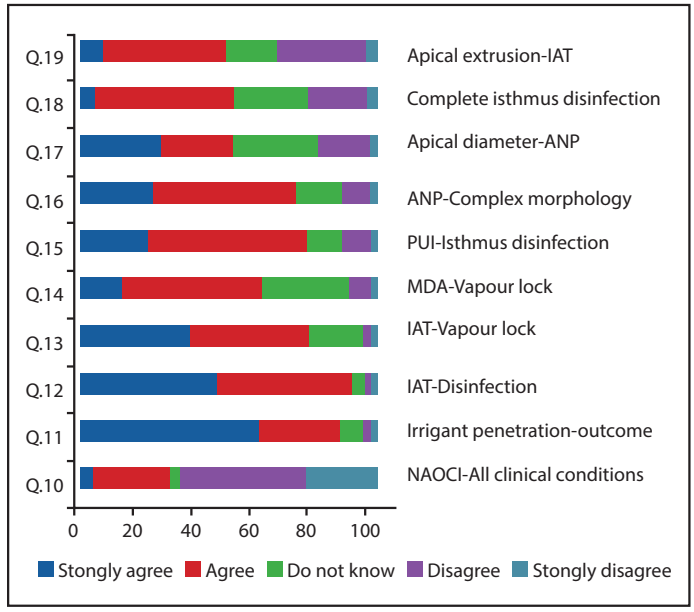

Figure 3. Attitude of survey participants on Irrigant activation methods

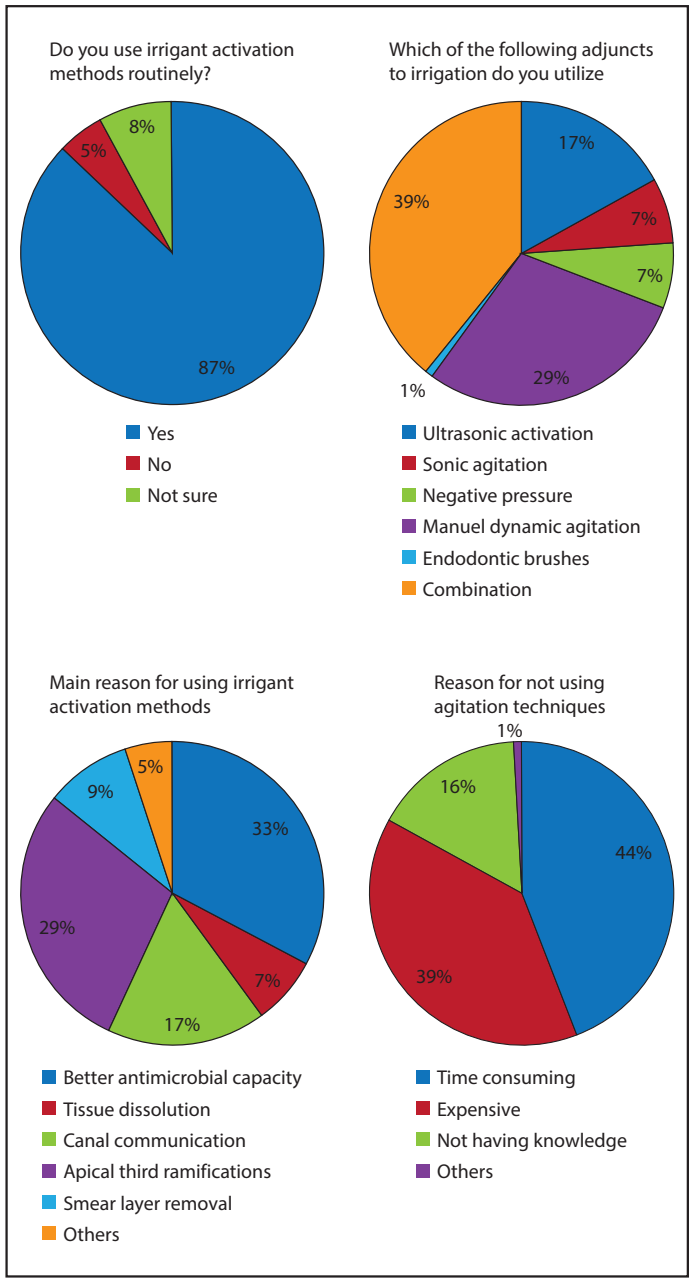

Figure 4. Distribution of irrigant activation practices among Endodontists in India

28.7%, followed by Ultrasonic in 17.2%. Sonic and ANP was used by only very few people. But interestingly, 38.8% use combinations of IAT. In a recent study done by Spoorthy et al., it was proved that a combination of IAT (PUI+ANP) allows for better three dimensional penetration of irrigant to both full working length and also into lateral canals (23). Another study reported better debris clearance from canal isthmus by simultaneous use of ANP and SNI in adjacent canals (Modified Endovac Technique) (24).

With regards to MDA, our results are in contrast to earlier study by Gopi Krishna et al., where only 17% used activation techniques such as MDA and K-file activation. The main reasons for not using IAT was, time and cost according to 38.7% and 34.4% respondents respectively. Cost is a major concern as most of the dental treatments in India are not covered by insurance. This could be the reason for MDA being the more popular IAT technique, as it does not require any extra equipment and is also simple and easy to perform. However, a previous clinical trial comparing the incidence of post operative pain following the use of different IAT, showed increased pain with MDA group especially at the end of 24 hours (25). But there was no difference in pain between the techniques at other time intervals.

In the section on Knowledge based questions, 49.1% felt canal isthmus was prevalent in Mandibular molars, 37.3% felt it was common in Maxillary premolar and 13.7% felt it is common in Maxillary molars. This is contrary to existing literature, which indicates canal isthmus to be more prevalent in maxillary molars when compared to maxillary premolars (26). For the question on portion of root canal most difficult to disinfect, 94.8% felt it is the apical third and 5.2% felt that it is the middle third. This is in line with earlier studies that have indicated the problems in disinfecting apical portion of root canal (27, 28). Most of the Endodontists (93.4%) in our survey felt the need to use IAT to disinfect the root canal.

Majority of respondents (77.3%) felt that PUI is the most effective IAT for disinfection of the canal isthmus. 73.6% of the respondents strongly agree/agree that apical negative pressure can be used to treat complex root canal morphology. A systematic review comparing the apical negative pressure and syringe irrigation by Kostantinidi et al. (16) concluded that there is insufficient evidence to claim superiority of ANP against SNI for treatment outcome. One randomised clinical trial found that ultrasonic activation in straight canals with periapical lesions did not result in a superior clinical outcome when compared with needle irrigation (29). But a recent *in vitro* study showed a compelling evidence of the increased efficacy of PUI in root canals with minimal preparation (30). Other *in vitro* studies comparing an individual IAT with syringe irrigation proved superiority, (13, 14, 24). A recent meta analysis comparing various IAT and SNI proved otherwise. The authors concluded that the data is heterogeneous and hence, the superiority of individual techniques over one another cannot be determined (15).

More than one irrigant was used during IAT by 27.8% of the respondents and 6.1% used all three irrigants, NaOCl, EDTA and CHX. However clinicians should exert caution as using combinations of irrigants can lead to the formation of precipitate that can be toxic and also difficult to remove (31).

The difference in results between the groups for knowledge based questions on IAT could be due to the reason that, IAT such as EndoVac, Endoactivator have been introduced recently. Hence the respondents who have been qualified more than 10 years ago may not have answered some of these questions correctly. There is a need for periodic updates in the form of Continued Dental Education programmes emphasizing on these new techniques to improve the knowledge on IAT. The decision to involve postgraduate students in this survey had worked in favor of identifying the target population for continued updation in IAT. General practitioners were not included in this survey which can be considered

as a limitation. As a continuation of this study we are planning to conduct this survey across other countries. The result of such a survey will enable us to understand the different practices of IAT across the world and also will be help us in for formulating hypothesis for future clinical trials on IAT. It is also necessary for leading Endodontic associations to come out with practice guidelines on IAT.

CONCLUSION

Within the limitations of this study, it can be concluded that vast majority (87.3%) of the Endodontist in India use IAT. Manual dynamic agitation is the most commonly used IAT. Knowledge and Attitude on IAT is largely positive among Endodontist in India.

Disclosures

Conflict of interest: No conflict of interest.

Ethics Committee Approval: IRB.NO.MADC/IRB-XVIII/2018/329

Peer-review: Externally peer-reviewed.

Financial Disclosure: No funding was received for this study.

Authorship contributions: Concept – V.N., D.A., J.K.; Design – V.N., D.A., J.K.; Supervision – A.N., S.M., K.D.; Funding - V.N.; Materials - None; Data collection &/or processing – V.N., D.A., J.K., N.M.S.; Analysis and/or interpretation – V.N., D.A., J.K., N.M.S.; Literature search – V.N., A.N., S.M., K.D.; Writing – V.N.; Critical Review – V.N., A.N., S.M., K.D., N.M.S.

REFERENCES

1. Paqué F, Balmer M, Attin T, Peters OA. Preparation of oval-shaped root canals in mandibular molars using nickel-titanium rotary instruments: a micro-computed tomography study. J Endod 2010; 36(4):703–7.
2. Peters OA, Schönenberger K, Laib A. Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro computed tomography. Int Endod J 2001; 34(3):221–30.
3. Coelho BS, Amaral RO, Leonardi DP, Marques-da-Silva B, Silva-Sousa YT, Carvalho FM, et al. Performance of Three Single Instrument Systems in the Preparation of Long Oval Canals. Braz Dent J 2016; 27(2):217–22.
4. Paqué F, Peters OA. Micro-computed tomography evaluation of the preparation of long oval root canals in mandibular molars with the self-adjusting file. J Endod 2011; 37(4):517–21.
5. Siqueira JF Jr, Rôças IN. Optimising single-visit disinfection with supplementary approaches: a quest for predictability. Aust Endod J 2011; 37(3):92–8.
6. Gopikrishna V, Pare S, Pradeep Kumar A, Lakshmi Narayanan L. Irrigation protocol among endodontic faculty and post-graduate students in dental colleges of India: A survey. J Conserv Dent 2013; 16(5):394–8.
7. Dutner J, Mines P, Anderson A. Irrigation trends among American Association of Endodontists members: a web-based survey. J Endod 2012; 38(1):37–40.
8. Munoz HR, Camacho-Cuadra K. In vivo efficacy of three different endodontic irrigation systems for irrigant delivery to working length of mesial canals of mandibular molars. J Endod 2012;38 (4):445–8.
9. Tay FR, Gu LS, Schoeffel GJ, Wimmer C, Susin L, Zhang K, et al. Effect of vapor lock on root canal debridement by using a side-vented needle for positive-pressure irrigant delivery. J Endod 2010; 36(4):745–50.
10. McGill S, Gulabivala K, Mordan N, Ng YL. The efficacy of dynamic irrigation using a commercially available system (RinsEndo) determined by removal of a collagen 'bio-molecular film' from an ex vivo model. Int Endod J 2008; 41(7):602–8.
11. Gu LS, Kim JR, Ling J, Choi KK, Pashley DH, Tay FR. Review of contemporary irrigant agitation techniques and devices. J Endod 2009; 35(6):791–804.
12. van der Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J 2007; 40(6):415–426.
13. de Gregorio C, Estevez R, Cisneros R, Heilborn C, Cohenca N. Effect of EDTA, sonic, and ultrasonic activation on the penetration of sodium hypochlorite into simulated lateral canals: an in vitro study. J Endod 2009; 35(6):891–5.
14. Nielsen BA, Craig Baumgartner J. Comparison of the EndoVac system to needle irrigation of root canals. J Endod 2007; 33(5):611–5.
15. Virdee SS, Seymour DW, Farnell D, Bhamra G, Bhakta S. Efficacy of irrigant activation techniques in removing intracanal smear layer and debris from mature permanent teeth: a systematic review and meta-analysis. Int Endod J 2018; 51(6):605–21.
16. Konstantinidi E, Psimma Z, Chávez de Paz LE, Boutsioukis C. Apical negative pressure irrigation versus syringe irrigation: a systematic review of cleaning and disinfection of the root canal system. Int Endod J 2017; 50(11):1034–54.
17. Căpută PE, Retsas A, Kuijk L, Chávez de Paz LE, Boutsioukis C. Ultrasonic Irrigant Activation during Root Canal Treatment: A Systematic Review. J Endod 2019; 45(1):31–44.e13.
18. Susila A, Minu J. Activated Irrigation vs. Conventional non-activated Irrigation in Endodontics - A Systematic Review. Eur Endod J 2019; 4(3):96–110.
19. Nagendrababu V, Jayaraman J, Suresh A, Kalyanasundaram S, Neelakantan P. Effectiveness of ultrasonically activated irrigation on root canal disinfection: a systematic review of in vitro studies. Clin Oral Investig 2018; 22(2):655–70.
20. Kothari CR. Research Methodology: Methods and Techniques. Chapter 6. 4th ed. New Delhi: New Age International Publishers; 2019.
21. Somma F, Leoni D, Plotino G, Grande NM, Plasschaert A. Root canal morphology of the mesiobuccal root of maxillary first molars: a micro-computed tomographic analysis [published correction appears in Int Endod J. 2009 Oct;42(10):954]. Int Endod J 2009; 42(2):165–74.
22. Verma P, Love RM. A Micro CT study of the mesiobuccal root canal morphology of the maxillary first molar tooth. Int Endod J 2011; 44(3):210–7.
23. Spoorthy E, Velmurugan N, Ballal S, Nandini S. Comparison of irrigant penetration up to working length and into simulated lateral canals using various irrigating techniques. Int Endod J 2013; 46(9):815–22.
24. Thomas AR, Velmurugan N, Smita S, Jothilatha S. Comparative evaluation of canal isthmus debridement efficacy of modified EndoVac technique with different irrigation systems. J Endod 2014; 40(10):1676–80.
25. Topçuoğlu HS, Topçuoğlu G, Arslan H. The Effect of Different Irrigation Agitation Techniques on Postoperative Pain in Mandibular Molar Teeth with Symptomatic Irreversible Pulpitis: A Randomized Clinical Trial. J Endod 2018; 44(10):1451–6.
26. Estrela C, Rabelo LE, de Souza JB, Alencar AH, Estrela CR, Sousa Neto MD, et al. Frequency of Root Canal Isthmi in Human Permanent Teeth Determined by Cone-beam Computed Tomography. J Endod 2015; 41(9):1535–9.
27. Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: a scanning electron microscopic study. J Endod 2011; 37(6):871–4.
28. Plotino G, Özyürek T, Grande NM, Gündoğar M. Influence of size and taper of basic root canal preparation on root canal cleanliness: a scanning electron microscopy study. Int Endod J 2019; 52(3):343–51.
29. Liang YH, Jiang LM, Jiang L, Chen XB, Liu YY, Tian FC, et al. Radiographic healing after a root canal treatment performed in single-rooted teeth with and without ultrasonic activation of the irrigant: a randomized controlled trial. J Endod 2013; 39(10):1218–25.
30. Lee OYS, Khan K, Li KY, Shetty H, Abiad RS, Cheung GSP, et al. Influence of apical preparation size and irrigation technique on root canal debridement: a histological analysis of round and oval root canals. Int Endod J 2019; 52(9):1366–76.
31. Basrani BR, Manek S, Sodhi RN, Fillery E, Manzur A. Interaction between sodium hypochlorite and chlorhexidine gluconate. J Endod 2007; 33(8):966–9.