Original Article

Comparative evaluation of increase in temperature on the external root surface of teeth during retrieval of broken NiTi instrument using two ultrasonic tips and two power settings: An *in vitro* study

Ashish K. Jain, Rishabhkumar Jain, Rahul Rao, Prajakta Rao[1], Pooja Yadav, Vinayak Thorat[1]

Departments of Conservative Dentistry and Endodontics and [1]Periodontology, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, Maharashtra, India

Abstract

Context: An unfavorable event that can hinder endodontic treatment and affect the outcome of root canal treatment is the separation of endodontic instruments. Endodontic instrument separation can occur due to clinical or metallurgical factors. Friction between the ultrasonic tip and the remaining dentin generates heat, which is subsequently transferred to the external root surface. Elevated temperatures exceeding 10°C above body temperature for more than a minute may result in injury to periodontal or bone tissue.

Aim: The aim of this study was to evaluate and compare temperature rise on the external root surface of teeth during retrieval of broken NiTi instrument using two different ultrasonic tips and two power settings.

Materials and Methods: In each group, a sample size of 8 was sufficient to attain a statistical power exceeding 90%, enabling the detection of a minimum mean difference of 0.9204 (delta) through a one-way ANOVA test at a 95% confidence level (alpha 0.05). After access opening and working length determination, samples were randomly distributed into two groups - Group 1 (A and B) - ProUltra tip at high and low power settings and Group 2 (A and B) - Cric Dental IR3 at high and low power settings. The temperature rise was measured using K-type thermocouple thermometer. The comparisons were analyzed using the Kruskal–Wallis test with pairwise comparisons using the Dunn's test.

Results: Group 1A and Group 1B resulted in lower heat generation compared to Group 2A and 2B and its difference was statistically significant ($P < 0.05$). Minimum temperature rise is seen in the ProUltra group at lower power settings (Group 1A) at the apical level and maximum temperature rise is seen in the Cric Dental IR3 group at higher power settings (Group 2B) at the middle third level.

Conclusion: It was found that there is a significant temperature rise seen when ultrasonic tips are used for the retrieval of separated files, especially at higher power settings. The ProUltra tip demonstrated the lowest temperature rise at lower power settings, particularly at the apical level, whereas the IR3 Cric Dental tip exhibited the highest temperature rise, notably at higher power settings and the middle third level.

Keywords: Instrument separation; NiTi; retrieval; ultrasonic

Address for correspondence:
Dr. Pooja Yadav,
Bharati Vidyapeeth Dental College and Hospital, Sector 7 CBD Belapur, Navi Mumbai - 400 614, Maharashtra, India.
E-mail: dr.poojayadav806@gmail.com

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INTRODUCTION

An undesirable occurrence that could impede endodontic treatment and have an impact on the outcome of

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root canal treatment is the separation of endodontic instruments.[1] This issue can nevertheless arise even in skilled hands, frustrating both practitioners and patients.[2] Incidence of stainless steel file separation is around 0.25%–6% whereas for NiTi rotary instruments, incidence is reported to be ranged between 1.3% and 10%.[3-5] The reason for the separation of endodontic instruments can be because of the presence of any coronal interference or torsional and cyclic fatigue.[2]

Management of the fractured instruments is either by removing the instrument, bypassing the instrument, or obturating the remaining root canal.[6] Removal of separated fragments would be considered one of the best options as it would aid in performing complete chemomechanical preparation of the root canal and get rid of all microorganisms.[7] Various methods are available for the conservative removal of fractured fragments, one of them being the use of ultrasonics. The success rates for fragment removal using ultrasonics in clinical trials have varied, with Nagai *et al*. reporting 67%, while Cujé *et al*. and Fu *et al*. reported success rates of 88% and 95%, respectively, in their recent studies.[8-10]

Due to friction between the ultrasonic tip and the remaining dentin, heat is generated which is then transferred to the external root surface. Injury to periodontal tissue or bone tissue may occur with a temperature rise of 10°C over body temperature that lasts for more than a minute.[11] When the temperature rises above 45°C, cementum resorption and bone ankylosis or necrosis of soft tissue and bone. Thus, care must be taken while using ultrasonic tips to ensure that there is minimal heat generation.[12]

As far as our knowledge extends, there is currently no published literature comparing the temperature rise on the external root surface of teeth between the ProUltra tip number 6 and the newly introduced Cric Dental IR 3 ultrasonic tips, particularly at high and low power settings.

Hence, this study was conducted to evaluate temperature rise on the external root surface of teeth during retrieval of broken NiTi instrument using ProUltra tip number 6 and Cric Dental IR 3 ultrasonic tips at high and low power settings. The null hypothesis stated that there was no difference in mean temperature rise with the ProUltra tip and Cric Dental IR3 tip at different power settings.

MATERIALS AND METHODS

The study protocol was approved with the Institutional Ethical Committee (IEC no-353072020). This *in vitro* study is reported according to CRIS guidelines.

A sample size of 8 per group was determined based on data reported by previous studies (significance level-95%). Thirty-two freshly extracted permanent human mandibular molars with patent canals were included in this study. Teeth with root caries, fractures, dilacerations, cracks, immature apex, resorptions, and previously treated teeth were excluded from the study. The root surfaces were cleaned of calculus, debris, and tissue tags using ultrasonic scaler and randomly distributed into two groups.

- Group 1: 1A – Low power settings (*n* - 8)
  - (ProUltra tip) (Dentsply): 1B – High power settings (*n* - 8)
- Group 2: 2A – Low power settings (*n* - 8)
  - (Cric Dental IR3 tip) (Cric Dental): 2B – High power settings (*n* - 8).

The mesial root of mandibular molars was sectioned using diamond disk mounted on the mandrel with an air motor and straight handpiece (NSK) such that the length of the root is 12 mm and the root was mounted on casting vice for stability. Number10 K file was used to negotiate the canal to achieve glide path only in the mesiobuccal canal of the mandibular molar. Working length was determined by inserting the number 10 K file into the canal such that the file is seen at the apex and withdrawn 1 mm and confirmed by taking RVG.

Cleaning and shaping were done using number 15 and 20 K files initially, followed by using hand ProTaper Universal files till apex with size F1 hand ProTaper. 30-gauge side vented needle was used to deliver a total of 20 ml of 2.5% sodium hypochlorite and saline between each file to removed debris. Using a mini Endoblock, a mark was placed with an indelible marker on all F1 hand ProTapers, 4 mm from the tip of instruments, and was notched using diamond disk mounted on the mandrel, and the file was intentionally fractured in the middle third region in the mesiobuccal canal. Samples were randomly divided into the following groups as mentioned earlier.

Modified GG drills #3 and #4 were used to get straight-line access at the coronal level of ultrasonic tips using endomicroscope (ZUMAX, India), creating a staging platform. Ultrasonic tips were used according to the manufacturer's recommendation against the peripheral surface of the coronal part of the fragment in anti-clockwise motion under endomicroscope.

In Group 1A, ProUltra number 6 ultrasonic tip was used at low power setting, i.e. 2, and in Group 1B, ProUltra number 6 ultrasonic tips were used at high power setting, i.e., 6. In Group 2A, Cric Dental IR3 ultrasonic tip was used at low power setting-2 and in Group 2B, Cric Dental IR3 ultrasonic tips were used at high power setting-6. Using a thick layer of sticky wax, K-type thermocouple thermometer (Unitop Enterprise, India) [Figure 1] was attached on the external root surface in the middle third area approximately at the

junction of the tip and broken instrument and a second thermocouple thermometer was attached on external root surface at 1 mm from apical end of root and temperature was recorded at 0 s and 12 s using stopwatch while the procedure was being performed. The temperature measured at the start (zero seconds) was used as a reference point to calculate the overall rise induced by ultrasonic vibration by subtracting it from the temperature recorded at 120 s. The recorded data were subjected to statistical analysis.

Statistical analysis

Data analysis was done using Windows-based "MedCalc Statistical Software" version 19.0.1 (MedCalc Software bvba, Ostend, Belgium). Data for the temperature rise were expressed as means with standard deviation and standard error. Data of pain scores were tested for normality using the Shapiro–Wilk test. Since data were nonnormal, the comparisons were analyzed using the Kruskal–Wallis test with pairwise comparisons using Dunn's test. For individual pairwise comparison of temperature rises at the middle and apical third, two-way analysis of variance test was used. The significance level was set at 0.05.

RESULTS

Group 1 showed less heat generation when compared to Group 2 and the difference is statistically significant ($P < 0.00001$). Group 1A and Group 1B show statistically significant differences in results ($P < 0.05$) when compared to Group 2A and Group 2B [Table 1 and Figure 2a]. Maximum temperature rise is seen in the Cric Dental IR3 tip for both lower and higher power settings (Group 2A and Group 2B).

All four groups showed statistically significant temperature rise ($P < 0.0001$) at both levels. Minimum temperature rise is seen in the ProUltra group at lower power settings (Group 1A) at the apical level and maximum temperature rise is seen in the Cric Dental IR3 group at higher power settings (Group 2B) at the middle third level [Table 2 and Figure 2b].

DISCUSSION

With the increasing practice of rotary endodontics, one of the most common procedural errors faced by endodontists is the separation of files. When this separated file persists in the root canal, it causes mechanical obstruction. Apical to separated files, bacteria and pulp tissue remains in the root canal and affects the outcome of treatment as it is difficult to perform biomechanical preparation and chemical disinfection.[2] Over the past few decades, various authors[13-16] have described many techniques and instruments which were used to retrieve the instruments. One of them being, the use of ultrasonics along with dental microscopes which have reported a good success rate.[17]

According to a retrospective study conducted by Patnana *et al*. found that highest percentage of file separation is seen in mandibular molars (7.4%).[18] In mandibular molars, mesiobuccal canal had maximum file fractures (31%).[19] Such high incidence could be attributed to the fact that

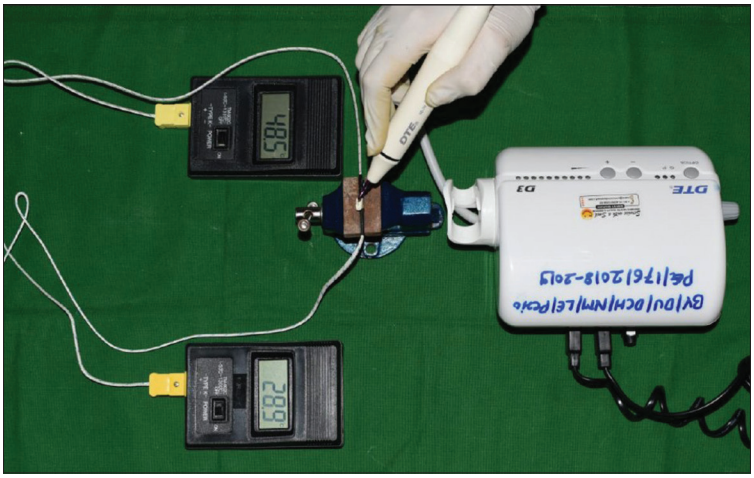

Figure 1: Measuring temperature using K-type thermocouple thermometer device

Table 1: Temperature rise while using Group 1 and Group 2 ultrasonic tips

Factor	Minimum	Median	Maximum	Test statistic	dF	Significa nce level	Intragroup comparison (*P*)
1A - ProUltra low power	2.1000	4.150	5.800	53.5806	3	*P*<0.000001	<0.05
1B - ProUltra high power	5.2000	6.300	8.700				<0.05
2A - IR3 low power	10.0000	14.150	18.500				<0.05
2B - IR3 high power	11.1000	16.550	22.800				<0.05

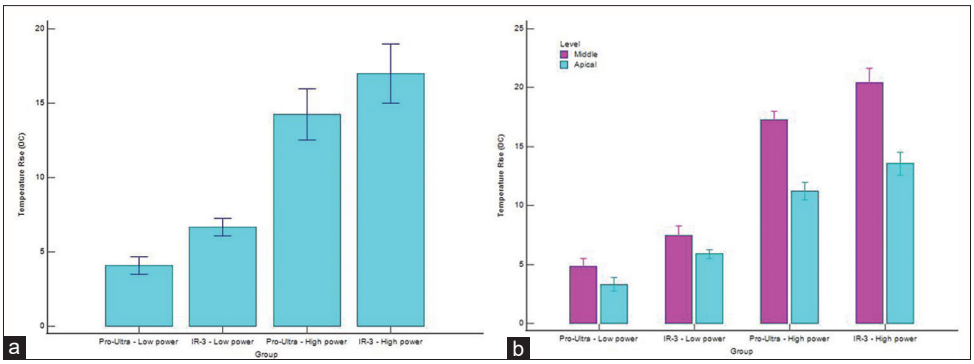

Figure 2: (a) Bar graph showing the temperature rise by both tips at low and high power settings. (b) Bar graph showing the comparison of temperature rise by both tips at low and high power settings at middle and apical third level

Table 2: Comparison of temperature rise at the middle and apical third level in the root

Factors	Mean difference	SE	*P*[a]	95% CI[a]
1				
2	−2.6000	0.3381	<0.0001	−3.5249–−1.6751
3	−10.1625	0.3381	<0.0001	−11.0874–−9.2376
4	−12.9062	0.3381	<0.0001	−13.8311–−11.9814
2				
1	2.6000	0.3381	<0.0001	1.6751–3.5249
3	−7.5625	0.3381	<0.0001	−8.4874–−6.6376
4	−10.3062	0.3381	<0.0001	−11.2311–−9.3814
3				
1	10.1625	0.3381	<0.0001	9.2376–11.0874
2	7.5625	0.3381	<0.0001	6.6376–8.4874
4	−2.7437	0.3381	<0.0001	−3.6686–−1.8189
4				
1	12.9062	0.3381	<0.0001	11.9814–13.8311
2	10.3062	0.3381	<0.0001	9.3814–11.2311
3	2.7437	0.3381	<0.0001	1.8189–3.6686

[a]Factors represent both retrieval tips at two different power settings. 1: ProUltra tip at low power setting, 2: ProUltra tip at high power setting, 3: Cric Dental IR3 tip at low power setting, 4: Cric Dental IR3 tip at high power setting, SE: Standard error, CI: Confidence interval

mandibular molars are very commonly indicated for root canal treatment and different root canal curvatures and configurations. Hence, the mesiobuccal canal of mandibular molars was selected for the study.

Dry field with different power settings is required while removing separated files from the root canal using ultrasonic tips as it improves visibility under the microscope and has less chance of procedural errors.[20] However, this might cause friction between the ultrasonic tip and dentin generating heat and leading to temperature rise.

To measure the temperature and rise on the external root surface, K-type thermocouple thermometer was used. It provides the widest range of temperature with 0.1°C sensitivity. It also has stable output, is cost-effective compared to other devices, and can function in rugged environmental conditions.[21]

Dentin is a poor thermal conductor which protects surrounding periodontal tissues whenever any procedure is performed where rise of temperature occurs.[22] However, this characteristic is subject to the thickness of dentin present which varies from coronal to apical third. In the case of file retrieval, staging platform is made where dentin is removed which reduces its thickness and temperature rises on the external root surface faster and even in the apical region, the thickness of dentin is less, hence two locations were used in this study to check the temperature elevation on the external root surface.

Power setting of the ultrasonic unit depends upon the maximum displacement amplitude of the ultrasonic tip which shows the chipping action. High power setting which maximizes chipping action by increasing longitudinal oscillations but high power settings are prone to cause thermal damage to periodontal tissues whereas low power settings have reduced chipping action and may require more time which might again cause temperature rise on the external root surface.[16] Hence, both power settings were used in evaluating the temperature rise on the external root surface.

In the current study, the file was fractured at the middle third level because according to Rambabu *et al*.,[23] the success rate of removing the broken instrument from the middle third is 67% whereas if the file fractures in the apical third, then there will be more dentin removal and there is less visibility, thus increasing chances of iatrogenic errors.[2]

In this study, ProUltra tip and Cric Dent IR3 tip at low and high power settings were compared at middle and apical levels and the difference was found to be statistically significant with $P < 0.0001$ thus rejecting the null hypothesis, which is similar to the study done by Madarati *et al*. As shown in Table 1, the temperature rise was seen higher in the high power setting compared to the lower power setting in both the groups with statistically significant results which is similar to the study done by Jadhav *et al*.[24,25]

As shown in Table 2, temperature rise was seen more at the middle third compared to the apical third which is in contrast to results reported by Jadhav *et al*.[24] This is most likely because

of the reduced dentin thickness in the middle third level as the staging platform is made and also because different ultrasonic tip ET20 was studied in the previous study.

Furthermore, a statistically significant temperature rise ($P < 0.001$) is seen when temperature was recorded at 0 s and 120 s. At the end of 120 s, maximum temperature rise is seen at higher power settings, which is similar in the study done by Hashem *et al*.[26] which states that the rise of temperature is a function of time.

This study's clinical relevance lies in its investigation of temperature changes on the external root surface during broken NiTi instrument retrieval, informing safer and more efficient endodontic procedures. By comparing various ultrasonic tips and power settings, it addresses concerns regarding patient safety by identifying methods that minimize thermal risks. Clinicians can utilize these findings to select the most effective tools and settings, optimizing instrument retrieval while mitigating the potential for thermal damage to surrounding tissues. In addition, the study aids in evidence-based decision-making, offering empirical data to guide treatment approaches. Ultimately, by promoting safer practices and enhancing procedural efficiency, this research contributes to improved patient outcomes and satisfaction in endodontic care.

The limitations of this study include its *in vitro* conditions, in which the study was performed and clinical studies with larger sample sizes are advised, which necessitate the need for more clinical studies. This study involves limited sample size and was done in only the mesiobuccal canal of mandibular molar teeth, but in day-to-day clinical situations, we encounter different root canal morphologies including curved roots.

CONCLUSION

Within the limitations of this *in vitro* study, it was found that there is a significant temperature rise seen when ultrasonic tips are used for retrieval of separated files, especially at higher power settings. The lowest temperature rise was seen with the ProUltra tip at lower power settings at the apical level. The highest temperature rise was seen with IR3 Cric Dental tip at higher power settings at the middle third level.

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Conflicts of interest
There are no conflicts of interest.

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