ACTA ODONTOLOGICA SCANDINAVICA
2021, VOL. 79, NO. 2, 156–160
https://doi.org/10.1080/00016357.2020.1850855

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Temperature and time variations during apical resection

Ömer Ekici[a], Kubilay Aslantaş[b], Özgür Kanık[c] and Ali Keles[d]

[a]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey; [b]Department of Mechanical Engineering, Faculty of Technology, Afyon Kocatepe University, Afyonkarahisar, Turkey; [c]Department of Restorative Dentistry, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey; [d]Department of Endodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkey

ABSTRACT

Objective: The aim of this study was to investigate temperature and time variations during root-end resection.

Material and methods: Sixty human premolars were selected. The root canals were enlarged up to ProTaper X3 rotary instrument. A thermocouple was placed into the root canal 1 mm behind the resection line. The teeth were randomly divided into six groups according to the apical resection method: steel bur, tungsten carbide bur, Lindeman bur, diamond bur, laser and ultrasonic surgical piezo with a diamond tip. The root ends were resected 3 mm away from the root apex. The temperature of the root dentine during resection was recorded as maximum temperature, mean temperature and temperature change. The time required for apicectomy was recorded for each group. The Kruskal–Wallis method was used to analyse the differences between temperature changes during apical resections. The significance level was set at 5%.

Results: There was no significant difference between bur groups in terms of temperature increase. The maximum temperature in piezo surgery was significantly higher than the Lindeman, tungsten and steel burs ($p < .001$). In addition, the maximum temperature in laser surgery was higher than the Lindeman bur ($p < .05$). An increase in the temperature was mostly seen in piezo surgery and the least temperature change occurred in the Lindeman bur. Mean time stayed under 1 min in each group.

Conclusions: Although piezo caused the highest temperature increase, the measured temperature increase was within physiological limits in all tested techniques.

ARTICLE HISTORY
Received 8 April 2020
Revised 1 November 2020
Accepted 10 November 2020

KEYWORDS
Apical resection; temperature change; thermocouple; laser surgery; piezo surgery

Introduction

The apical root canal anatomy of roots is the most complex internal anatomy due to irregularities of the root canal system, showing isthmuses and accessory canals [1,2]. These anatomical challenges in the apical third of roots can constitute difficulties for root canal treatment procedures and be considered as a potential risk factor for the failure of treatment [3,4]. Usually an apical root end resection, which aims to remove the reservoir of persistent microorganisms in the complicated anatomy of the apical few millimetres is suggested in the case of failure of orthograde root canal treatment procedures. When the apical 3 mm of a root is resected, it has been reported that approximately 92% of irregularities of the root were removed [3].

During root-end resection, thermal changes may occur on the root dentine of the tooth in the surgical site, which may damage the periodontal ligament cells and alveolar bone [5]. To prevent damage to vital soft and hard tissues during apical resection, it is important to control abnormal temperature increases in the tissues. The threshold of damage to bone and periodontal ligaments is a temperature increase of 10 °C for more than 1 min [6]. Accordingly, heat increases of 10 °C in teeth are generally considered safe. Therefore, suitable cooling systems are designed for each method during tooth or bone tissue cutting.

In recent years, more biologically acceptable technologies, such as micro-instruments, ultrasonic piezo and laser, have entered endodontic surgery. These modern techniques have increased the success rates of all microsurgical procedures [7]. To the authors' knowledge, information on the thermal changes in the root dentine in the surgical site during apical resection with different techniques is lacking. The aim of the study was to examine and compare temperature increase in the root dentine and required time when using different root-end resection techniques and materials.

Materials and methods

Based on data from a previous study a sample size of 60 teeth, 10 samples in each group, was calculated using G*Power version 3.1.9.2 (Heinrich-Heine-Universitat, Dusseldorf, Germany; power 0.80, $a = 0.05$, effect size = 1.78) [8]. The study protocol was approved by the ethical board of a university (2019/10-316). Sixty human maxillary single root premolars were used for the study. Two rooted, broken, resorbed or curved roots were excluded. Roots were cleaned

CONTACT Ali Keleş alikeles29@yahoo.com Department of Endodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun 55280, Turkey

with curettes to remove soft tissue residues and stored in a 0.9% saline solution incubated at 37 °C. The access cavities were prepared with a diamond round bur (Frank Dental, Gmund am Tegernsee, Germany). Root canals were prepared with Ni-Ti files up to X3 (ProTaper Universal rotary system, Dentsply Sirona, Ballaigues, Switzerland). The root canals were irrigated with 1% NaOCl. After the last irrigation, root canals were dried with paper points. All these procedures were performed by the same specialist dentist. Teeth were stored in sterile distilled water at 37 °C and 100% humidity.

The teeth were randomly divided into six groups ($n = 10$).

Group 1: Steel fissure bur (a diameter of 1.8 mm, Ela, Thuringia, Germany)
Group 2: Tungsten carbide fissure bur (a diameter of 1.8 mm, Meisinger, Neuss, Germany)
Group 3: Diamond fissure bur (a diameter of 1.8 mm, Frank Dental, Gmund am Tegernsee, Germany)
Group 4: Lindeman bur (a diameter of 1.8 mm, Meisinger, Neuss, Germany)
Group 5: Diamond-tip piezo surgery (Ems Piezon® Master Surgery, EMS Dental, Nyon, Switzerland) with diamond-tip (OTS7-4)
Group 6: Er, Cr: YSGG laser (WaterLase, BIOLASE, Irvine, CA) with chisel-shaped sapphire tip (a diameter of 1.5 mm – 0.5 × 1.5 mm at the distal end).

An insulated K type thermocouple (model 5SRTC-TT-K-36-36, Omega Engineering, Manchester, UK) was used to measure temperature changes during apical resection. Root canals were filled with a heat-conducting paste. The tip of the thermocouple was extended into the root canal from the access cavity and placed in a 1 mm coronal area of the resection line and fixed with a removable adhesive (Patafix, UHU, Bühl, Germany). Thermocouples attached to the root canal were isolated with paraffin wax, which prevented outside temperature effects. The other end of the thermocouple was connected to the data logger (HOBO temperature data logger, Onset Comp., Bourne, MA). Temperature measurements were done using HOBOware data logging software (Onset Comp., Bourne, MA). The experimental setup used in the apical resection is given in Figure 1. The room temperature was maintained at 27 °C.

The teeth were placed in a fixing jaw in a horizontal position with the roots facing out. Each root was resected at a 90° angle at a distance of 3 mm from the apical under 0.9% NaCl irrigation. The cutting process was performed by a single investigator from the apex to the resection line. During the cutting process, another researcher recorded the temperature change for each tooth on a computer programme graphically (Figure 2). In addition, the duration of the resection was recorded in seconds. These procedures were the same in all groups.

In the first four groups, a surgical physio dispenser was used (KAVO INTRAsurg 300, Kaltenbach & Voigt GmbH, Biberach, Germany) at a rate of 40,000 rpm, a torque of 55 Ncm and a 40 ml/min water coolant (0.9% NaCl, Kanfleks, İstanbul, Turkey). Diamond-tip (OTS7-4) piezo surgery (group 5) was used at continuous operation mode, maximum output, 25 Watts, 24–32 kHz frequency range under cooling of 40 ml/min. 0.9% NaCl (Kanfleks, İstanbul, Turkey). In group 6, Er, Cr: YSGG laser used wavelength of 2.941 m, 3 W, 20 Hz, 50% water, 60% air, 300 mJ, pulse duration of 140 μs. Laser irradiation was performed with a chisel-shaped sapphire tip.

Temperatures during root-end resection procedures were calculated and compared in three ways:

1. Maximum temperature: It is the highest recorded temperature during the apical resection.
2. Mean temperature: It is the obtained average temperature during the apical resection.
3. Temperature change: It is the difference between the maximum temperature and the initial temperature before the apical resection.

Temperature measurements were recorded for every second during root-end resection. The Kolmogorov–Smirnov

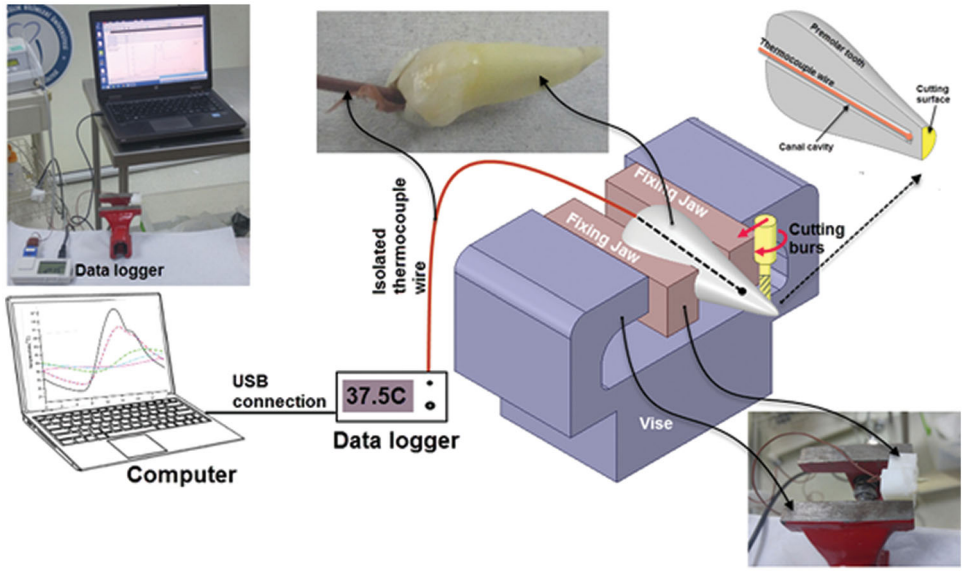

Figure 1. Experimental setup used in measuring temperature.

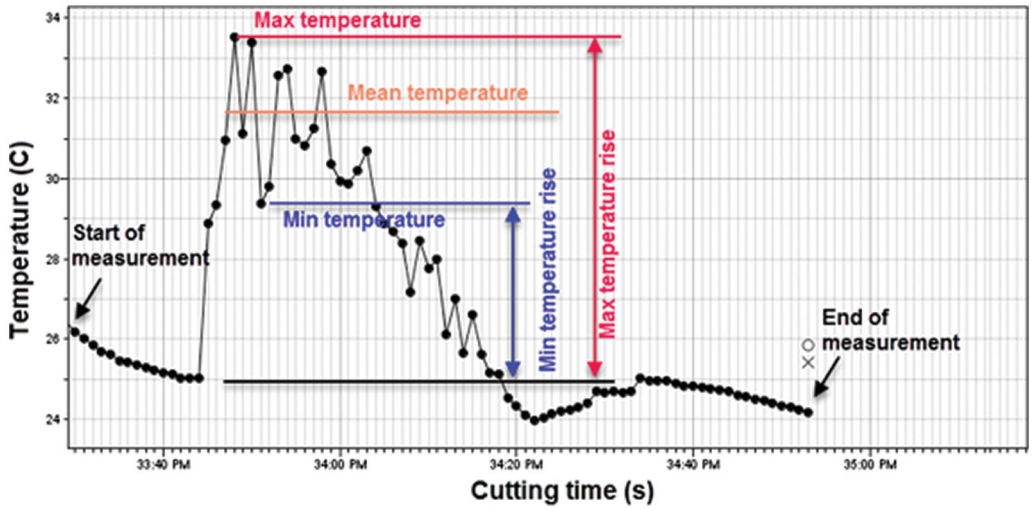

Figure 2. An example diagram for temperature measurement made during apical resection.

Table 1. Maximum temperature (°C), mean temperature (°C), temperature difference (°C), and time (seconds) mean and standard deviation (SDs) values of groups.

	Maximum temperature Mean ± SDs	Mean temperature Mean ± SDs	Temperature difference Mean ± SDs	Time Mean ± SDs
Steel bur	30.5 ± 2.68^{ab}	29.25 ± 1.83^{a}	3 ± 2.68^{ab}	20 ± 4.94^{ab}
Tungsten carbide bur	29.54 ± 1.22^{ab}	29.3 ± 1.09^{ab}	2.41 ± 1.22^{ab}	11.6 ± 2.71^{b}
Diamond bur	32.47 ± 2.53^{ab}	31.37 ± 2.04^{a}	4.97 ± 2.53^{ab}	14 ± 3.77^{b}
Lindeman bur	28.98 ± 1.25^{a}	$28.85 \pm 0{,}92^{a}$	1.79 ± 1.25^{a}	9.4 ± 4.08^{b}
Piezo surgery	40.41 ± 2.21^{c}	37.16 ± 2.63^{b}	11.15 ± 2.21^{c}	55 ± 14.39^{a}
Laser surgery	32.6 ± 2.01^{bc}	30.57 ± 1.8^{ab}	5.1 ± 2.01^{bc}	45.8 ± 19.9^{a}

In each column, different superscripts indicate statistically significant difference between groups.

test was applied to check for data normality. (Kolmogorov–Smirnov test). The Kruskal–Wallis test was used to compare the maximum and mean temperatures, temperature change and time of apical resection among the groups. The significance level was set at 5% (SPSS version 21.0 software; SPSS Inc., Chicago, IL).

Results

Maximum temperature

Table 1 shows the maximum temperature values at the operation site during the cutting methods. The lowest maximum temperature was seen with the Lindeman bur (28.98 °C) and the highest maximum temperature was seen in piezo surgery (40.41 °C).

There was a significant difference between piezo surgery and Lindeman bur ($p < .001$), piezo surgery and tungsten bur ($p < .001$) and piezo surgery and steel bur ($p < .001$). Accordingly, the maximum temperature in piezo surgery was significantly higher than the other three methods. In addition, a significant difference was observed between laser surgery and Lindeman bur ($p < .05$) in terms of maximum temperature. The maximum temperature in laser surgery was higher than that with the Lindeman bur.

Mean temperature

Table 1 shows the mean temperature values at the tooth root during the cutting methods. When the mean temperatures were examined, the lowest temperature was found in the Lindeman bur (28.85 °C). Piezo surgery produced the highest temperature (37.16 °C).

A statistically significant difference was found between piezo surgery and Lindeman bur ($p < .001$), piezo surgery and steel bur ($p < .001$) and piezo surgery and tungsten carbide bur ($p < .001$). Accordingly, the mean temperature value in piezo surgery was higher than the other three methods. Apart from piezo surgery, there was no difference between the other methods with regard to the maximum temperatures.

Temperature change

Table 1 shows the temperature changes during apical resection. An increase in the temperature of the tooth root dentine was mostly seen in piezo surgery (11.15 °C). The minimum and maximum values of the temperature difference obtained in piezo surgery method were 3 and 24.15 °C, respectively. Although there was no significant difference between piezo and laser surgery ($p > .05$), piezo surgery produced significantly higher levels of temperature change than the burs ($p < .001$). Even though there was no significant difference among the burs ($p > .05$), the least temperature change occurred in the Lindeman bur (1.79 °C).

Time of apical resection

The mean time values of groups are given in Table 1. There was no a significant difference among bur groups ($p > .05$)

The longest mean resection times were spent in piezo surgery and laser surgery (55 and 45.8 s, respectively). Piezo and laser surgery were significantly different from Lindeman bur, diamond bur and tungsten carbide bur in terms of resection time ($p < .001$).

Discussion

Although it is possible that accessory canals and isthmuses are associated with persistent apical periodontitis when they have sufficient volume to harbour large numbers of microorganisms [9], an accurate identification of these structures is clinically impossible with the current imaging devices [10]. From a clinical perspective, an apical root-end resection, which aims to remove the reservoir of persistent microorganisms in the complicated anatomy may be performed on teeth with persistent apical periodontitis after root canal treatment. Numerous techniques and devices have been proposed in the literature to obtain the ideal method for apical surgery. Treatment results in endodontic surgery have improved in recent years with the development and introduction of microsurgical instruments that allow better management of root-end resection. It is important to have new methods to minimize adverse effects, such as angled root-end resections, cracks and smoothness of the resected apical surface [11]. In addition, the present methods should have appropriate cooling systems in the apical resection process so as not to cause a temperature rise beyond physiological limits in the tooth and surrounding vital tissues.

Currently, the literature lacks a detailed examination of the temperature variation at the root end during apical resection with different materials and techniques. This study showed that the minimum temperature increase was realized in the Lindeman, tungsten carbide and steel fissure burs. This difference in temperature increase in these burs operated in the same physio dispenser system is related to the groove structure and sharpness of the cutting edge. The diamond fissure caused more friction and increased temperature due to the unclear groove structure of the bur. In the laser group, the temperature increase was found to be 5.1 °C, and this increase was within physiological limits. In this study, the highest temperature increase was seen in diamond-tipped ultrasonic piezo surgery.

Ultrasonic piezo is widely used in implant and bone surgery in dentistry. When used in bone surgery, it provides greater safety during surgery [12]. Ultrasonic retro tips have been reported to produce cleaner, mid-centred and more protective root-end cavities than those prepared with conventional burs. Ultrasonic techniques also significantly remove bacteria, thereby improving treatment quality [13]. Ultrasonic devices have been used more frequently in root-end cavity preparation than carbide or diamond burs [14]. For retrograde preparation with the ultrasonic surgical instrument, the use of constant vibration mode has been proposed [15]. In this study, a surgical ultrasonic instrument with a diamond tip in a 100% force level was used in constant vibrating mode. Although piezo surgery produced the greatest heat increase, temperature changes and duration were within the physiological limits during apical surgery in this study.

According to the results of this study, the time required for piezo and laser surgery was significantly higher than that required for apical resection using Lindeman, tungsten carbide and diamond bur. The findings of this study are in agreement with previous studies [16–18]. Lindeman, tungsten carbide, diamond and steel fissure burs performed apical resection within similar times. The faster time dispensed for the apical resection favoured a shorter surgical time [16].

The intraoral temperature is likely to change during the apical resection procedure, but it has been shown that the correct use of resection methods does not cause long-term temperature changes, does not increase above 47 °C and does not cause any irreversible thermal damage [6]. In our study, the highest temperature increase by piezo surgery was 11.15 °C and the mean time of apical resection was 55 s. Therefore, these results are slightly below the threshold indicated by Eriksson and Albrektsson [6] (irreversible resorption may occur in the alveolar bone tissue if the bone temperature increases by 13 °C for 1 min or 10 °C for 5 min). In methods other than piezo surgery, all temperature increases were below the 10 °C safety level. *In vitro* studies are not entirely like the *in vivo* environment. Clinically, root canals are filled by gutta percha and root canal sealers before root-end resection. Depends on their composition, root canal filling materials can act as an insulator or conductor [19]. Also, the *in vivo* environment is the less susceptible to thermal changes than the *in vitro* environment due to liquids, such as blood. Therefore, in the *in vivo* environment, heat dissipates more slowly than *in vitro* due to the isolation of blood in neighbouring tissues [20].

Within the limitations of this *in vitro* study, the temperature variations in the surgical site during root-end resection was investigated. It should be taken in the consideration that the root end resection is not the only reason that may cause heat generation during a surgical and non-surgical endodontic treatment. Root canal filling with warm vertical compaction [21,22], preparation of retrograde cavity [23], usage of lasers [24,25] and ultrasonic tips [8] in root canal may count as other reasons. Further studies are necessary, especially *in vivo* investigations, to determine the thermal change and its effects on periodontal tissue after the treatment.

Conclusion

Although the temperature increase was higher in piezo surgery than other methods, the temperature emerging in the root dentine of all apicectomy methods remained within the physiological limits. Further studies are needed to investigate heat increases in apical surgery and other dental procedures.

Disclosure statement

No potential conflict of interest has been reported by the author(s).

References

[1] Keleş A, Keskin C. A micro-computed tomographic study of band-shaped root canal isthmuses, having their floor in the apical third of mesial roots of mandibular first molars. Int Endod J. 2018; 51(2):240–246.

[2] Xu T, Fan W, Tay FR, et al. Micro–computed tomographic evaluation of the prevalence, distribution, and morphologic features of accessory canals in Chinese permanent teeth. J Endod. 2019; 45(8):994–999.

[3] Ordinola-Zapata R, Martins JNR, Niemczyk S, et al. Apical root canal anatomy in the mesiobuccal root of maxillary first molars: influence of root apical shape and prevalence of apical foramina – a micro-CT study. Int Endod J. 2019;52:1218–1227.

[4] Xu T, Tay FR, Gutmann JL, et al. Micro-computed tomography assessment of Apical Accessory Canal Morphologies. J Endod. 2016;42(5):798–802.

[5] Stropko JJ, Doyon GE, Gutmann JL. Root-end management: resection, cavity preparation, and material placement. Endod Topics. 2005;11(1):131–151.

[6] Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. J Prosthet Dent. 1983;50(1):101–107.

[7] Setzer FC, Kohli MR, Shah SB, et al. Outcome of endodontic surgery: a meta-analysis of the literature - Part 2: comparison of endodontic microsurgical techniques with and without the use of higher magnification. J Endod. 2012;38:1–10.

[8] Madarati AA, Qualtrough AJ, Watts DC. Factors affecting temperature rise on the external root surface during ultrasonic retrieval of intracanal separated files. J Endod. 2008;34(9):1089–1092.

[9] Arnold M, Ricucci D, Siqueira JF. Infection in a complex network of apical ramifications as the cause of persistent apical periodontitis: a case report. J Endod. 2013;39(9):1179–1184.

[10] Tolentino E de S, Amoroso-Silva PA, Alcalde MP, et al. Accuracy of high-resolution small-volume cone-beam computed tomography in detecting complex anatomy of the apical isthmi: *ex vivo* analysis. J Endod. 2018;44(12):1862–1866.

[11] Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. J Endod. 2006;32(7):601–623.

[12] Angiero F, Benedicenti S, Signore A, et al. Apicoectomies with the erbium laser: a complementary technique for retrograde endodontic treatment. Photomed Laser Surg. 2011;29(12): 845–849.

[13] de Lange J, Putters T, Baas EM, et al. Ultrasonic root-end preparation in apical surgery: a prospective randomized study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104(6): 841–845.

[14] Tsesis I, Rosen E, Schwartz-Arad D, et al. Retrospective evaluation of surgical endodontic treatment: traditional *versus* modern technique. J Endod. 2006;32(5):412–416.

[15] Del Fabbro M, Tsesis I, Rosano G, et al. Scanning electron microscopic analysis of the integrity of the root-end surface after root-end management using a piezoelectric device: a cadaveric study. J Endod. 2010;36(10):1693–1697.

[16] Bernardes RA, de Souza Junior JV, Duarte MA, et al. Ultrasonic chemical vapor deposition-coated tip *versus* high- and low-speed carbide burs for apicoectomy: time required for resection and scanning electron microscopy analysis of the root-end surfaces. J Endod. 2009;35(2):265–268.

[17] Duarte MA, Domingues R, Matsumoto MA, et al. Evaluation of apical surface roughness after root resection: a scanning electron microscopic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104(6):e74–e76.

[18] Komori T, Yokoyama K, Takato T, et al. Clinical application of the erbium: YAG laser for apicoectomy. J Endod. 1997;23(12): 748–750.

[19] Keleş A, Ahmetoğlu F, Şimşek N, et al. Heat conductive properties of set root canal sealers. Acta Odontol Scand. 2013;71:751–755.

[20] Schütz S, Egger J, Kühl S, et al. Intraosseous temperature changes during the use of piezosurgical inserts *in vitro*. Int J Oral Maxillofac Surg. 2012;41(11):1338–1343.

[21] Diegritz C, Gerlitzki O, Fotiadou C, et al. Temperature changes on the root surface during application of warm vertical compaction using three different obturation units. Odontology. 2020;108(3): 358–365.

[22] Viapiana R, Guerreiro-Tanomaru JM, Tanomaru-Filho M, et al. Investigation of the effect of sealer use on the heat generated at the external root surface during root canal obturation using warm vertical compaction technique with System B heat source. J Endod. 2014;40(4):555–561.

[23] Bodrumlu E, Keskiner I, Sumer M, et al. Temperature variation on root surface with three root-end cavity preparation techniques. Srp Arh Celok Lek. 2013;141(9–10):597–601.

[24] Strakas D, Franzen R, Kallis A, et al. A comparative study of temperature elevation on human teeth root surfaces during Nd: YAG laser irradiation in root canals. Lasers Med Sci. 2013;28(6): 1441–1444.

[25] Arslan D, Kuştarcı A. The effect of the KTP laser on smear layer and temperature change: an in vitro study. Lasers Med Sci. 2018; 33(1):149–157.