Received: 28 September 2020 | Revised: 7 January 2021 | Accepted: 10 January 2021
DOI: 10.1002/jemt.23714

RESEARCH ARTICLE

MICROSCOPY RESEARCH & TECHNIQUE WILEY

Evaluation of surface roughness after root resection: An optical profilometer study

Ömer Ekici[1] | **Kubilay Aslantaş**[2] | **Özgür Kanık**[3] | **Ali Keleş**[4]

[1]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey

[2]Department of Mechanical Engineering, Faculty of Technology, Afyon Kocatepe University, Afyonkarahisar, Turkey

[3]Department of Restorative Dentistry, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey

[4]Department of Endodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkey

Correspondence
Ömer Ekici, Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar 03030, Turkey.
Email: dromerekici@hotmail.com

Review Editor: adi salomon

Abstract

The aim of this study was to evaluate the roughness of the apical surface after apical resection performed by six different methods with an optical profilometer. Sixty human single root premolar teeth were used in this in vitro study. After root canal preparation, root canals were filled with gutta-percha and AH Plus root canal sealers by lateral condensation technique. The teeth were randomly divided into six groups according to the apical resection method: steel fissure bur, tungsten carbide fissure bur, Lindeman bur, diamond fissure bur, laser, and ultrasonic surgical piezo with a diamond tip. The root ends were resected 3 mm away from the root apex and at a 90° angle. The time required for apicectomy was recorded for each group. After apical resection, the root surfaces were analyzed by an optical profilometer. The Kruskal–Wallis method was used to analyze the differences between groups. The significance level was set at 5%. The roughest surfaces were obtained by laser (25.54 ± 9.01 μm) and Lindeman bur (17.35 ± 6.03 μm), respectively. The longest mean resection times were recorded in piezosurgery and laser surgery (57 ± 14.39 s and 50.9 ± 16.86 s), respectively. Although the diamond-tipped piezo surgical cutting time is long, it has the best results in terms of surface roughness (5.50 ± 1.73 μm). The optical profilometer is a more convenient tool for evaluating the surface after apical surgery, as it provides an opportunity to evaluate objectively with both visual and numerical data.

KEYWORDS
apical resection, apical surface roughness, laser surgery, optical profilometer, piezosurgery

1 | INTRODUCTION

Endodontic surgery is a dental procedure to treat apical periodontitis in cases that did not heal after nonsurgical retreatment or, primary root canal therapy (Karabucak & Setzer, 2007). The endodontic surgery modalities include curettage, root-end resection, surgery with simultaneous root canal filling, and root-end filling (Bernardes, de Souza Junior, Duarte, de Moraes, & Bramante, 2009). Apical resection is a critical step in endodontic surgery. In apical surgical procedures, the smooth surface is very important to reduce the number of exposed dentinal tubules on the resected root surface and to minimize apical leakage (Del Fabbro, Tsesis, Rosano, Bortolin, & Taschieri, 2010). Because the presence of irregular and rough surfaces can act as irritants, accumulate debris, and stimulate resorption during the repair. Therefore, the method used during resection should provide a more uniform and smooth apical surface and minimize the displacement of obturation.

In the last decades, new technologies were introduced into endodontic surgery, such as the use of the microscope, microinstruments, ultrasonic tips, and more biologically acceptable root-end filling materials. These modern techniques increased the success rates, with outcomes for all microsurgical approaches of approximately 90% (Kim, Song, Jung, Lee, & Kim, 2008). Different tools and techniques are used for apical resection. Traditionally, burs of different sizes and shapes have been used successfully in endodontic surgery for many years. With the introduction of laser and ultrasonic devices in dental practice in recent years, the use of these new methods and technologies has started in apical surgery. The emergence of laser treatment in dentistry has led to its use in periradicular surgery to facilitate tubular closure during and after apicectomy and to reduce apical dentinal permeability. The most commonly used lasers for this purpose are CO_2, Nd: YAG, and recently used erbium: YAG lasers (Gouw-Soares et al., 2004). The introduction of ultrasonic activation has represented an important advancement in endodontic surgery (Nielson, Richards, & Wolcott, 1955). Surgical ultrasonic devices in dentistry are widely used in split osteotomies, orthognathic surgery, sinus lifting procedures, and dental implantology. The biggest advantage of ultrasonic devices is that it can be cut to the desired thickness and it does not damage soft tissues (Del Fabbro et al., 2010).

An optical profilometer is a device used to extract topographical data from any surface. Using the profilometer, it is possible to obtain surface morphology, step heights, and surface roughness. This can be done using a physical probe or by using light. An optical profilometer uses light instead of a physical probe. It is possible to make noncontact measurements by focusing light on the surface, which is the main component of this technique. Thus, it is easier to measure changes in the nanometer level on the surface. In the literature, a scanning electron microscope (SEM) was generally used in the studies to evaluate surface properties after apical surgery (Bramante et al., 2010; de Bruyne & de Moor, 2005). SEM permits only visual evaluation of surface properties in linear dimensions. The optical profilometer provides the opportunity to evaluate the roughness of the surface area, that is, topography, with both visual and numerical data. The studies evaluating the surface roughness with optical profilometer after resection are not in the literature as far as we know. The aim of this study is to compare the surface roughness after apical resection procedures in vitro environment with both traditional and modern techniques.

2 | MATERIALS VERSUS METHODS

The study was carried at the Faculty of Dentistry, Afyonkarahisar Health Sciences University, and Faculty of Technology, Afyon Kocatepe University, in 2019. This in vitro study was approved by the ethics committee of the Faculty of Medicine, Afyonkarahisar Health Sciences University (2019/10-284).

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, $a = 0.05$) (Antonio Hungaro Duarte et al., 2007). Sixty human mandibular single root premolar teeth were used for the study. Fractured, resorbed, curved and two rooted premolar teeth were excluded. The extracted teeth were stored in 10% formalin solution. Soft tissue residues on the tooth root surface were removed from the tooth. The access cavities were prepared with a diamond round bur (Frank Dental, 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. After root canal preparation, root canals were filled with gutta-percha and AH Plus root canal sealers by lateral condensation technique. 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 ($n = 10$) according to the cutting method as follows:

- 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, Germany).
- Group 3: Diamond fissure bur (a diameter of 1.8 mm, Frank Dental).
- Group 4: Lindeman bur (a diameter of 1.8 mm, Meisinger).
- Group 5: Diamond-tip piezosurgery (Ems Piezon Master Surgery, EMS Dental, Swiss) with diamond-tip (OTS7-4).
- Group 6: Er, Cr: YSGG laser (WaterLase, BIOLASE) with chisel-shaped sapphire tip (a diameter of 1.5 mm—0.5 × 1.5 mm at the distal end).

The teeth were placed in a tooth holder in a horizontal position with the roots facing out. The cutting process was performed by a single investigator and during the cutting process, another researcher recorded the duration of the resection in seconds. Each root was resected at a 90° angle at a distance of 3 mm from the apical under 0.9% NaCl irrigation. These procedures were repeated on each sample in all groups.

In the first four groups, a surgical physio dispenser was used (KAVO INTRAsurg 300, Kaltenbach & Voigt GmbH, Germany) at a rate of 40,000 rpm, with a torque of 55 Ncm, and a 40 ml/min water coolant (%9 NaCl, Kanfleks, Turkey). Diamond-tip (OTS7-4) piezosurgery (Group 5) was used at continuous operation mode, maximum output, 25 W, 24–32 kHz frequency range undercooling of 40 ml/min. 0.9% NaCl (Kanfleks, 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.

Resected teeth were stored at room temperature for drying and optical profilometry (S T400 model, Nanovea) was used for examination. The optical profilometer used scan both vertically and horizontally with 0.1 μm resolution and operates with the chromatic confocal technique (Figure 1a). The technique uses white light that passes through a series of lenses with a high degree of chromatic aberrations. Each wavelength will focus at a different distance creating the vertical measurement range. When a surface of interest is within the measurement range a single wavelength of the white light will be in focus while all others will be out of focus (ST400 - The Customizable Optical Profiler, n.d.). Prepared tooth samples are fixed to the device in an upright position (Figure 1b). The cutting direction is taken into account when scanning.

All dental specimens were screened under the same conditions and sensitivity by the single researcher. Then, 1 mm × 1 mm cut

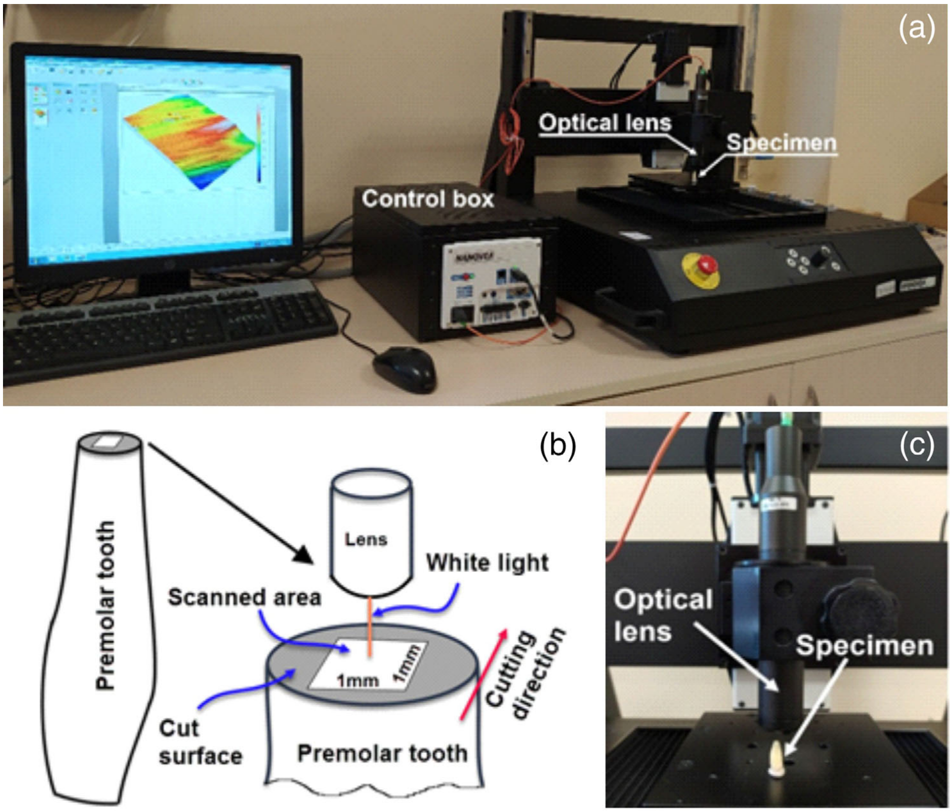

FIGURE 1 (a) Overview of the optical profilometer. (b) Schematic representation of the noncontact scanning of the cut tooth surface. (c) A closer view of the premolar tooth [Color figure can be viewed at wileyonlinelibrary.com]

surface area from the surface was taken into consideration during scanning operations. Scanning sensitivity was taken as 2 μm and scanning was performed at 1,000 Hz. Scanning with higher resolution increases the processing time. Therefore, some preliminary tests were carried out and the scanning frequency and sensitivity were determined. Similar surface roughness values were obtained at lower frequency (400 Hz) and resolution (1 μm). For this reason, all samples in the study were scanned at 1,000 Hz and 2 μm sensitivity. The total area scanned in the study is 1 mm^2. The data obtained from the optical profilometer was converted into three-dimensional (3D) images using the DigitalSurf (Nanovea Inc., Irvine, CA) software and the surface roughness was measured by using this software.

The surface roughness of the scanned area was measured as the areal average surface roughness (*Sa*). The data obtained were transferred to the Statistical Package for the Social Sciences (SPSS v.21.0 software; SPSS Inc., Chicago, IL) program and analyzed. Kruskal–Wallis test was used to compare the groups. A critical probability value (*p*-value) of <.05 and <.001 was used as the cut-off level for statistical significance.

3 | RESULTS

3.1 | Surface roughness values

The surface roughness values of each apical resection method measured with the profilometer are presented in Table 1. The roughest surfaces appear in laser surgery (25.54 μm), while the least rough surfaces are seen in piezosurgery (5.50 μm). According to the Kruskal–Wallis method, a significant difference was observed between laser surgery-piezosurgery ($p < .001$), laser surgery-tungsten bur ($p < .05$), and laser surgery-diamond bur ($p < .05$). The laser surgery produced rougher surfaces than these three methods. There was also a significant difference between Lindeman bur and piezosurgery ($p < .05$). Lindeman bur produced rougher surfaces than piezosurgery. There was also no significant difference in surface roughness between steel, tungsten, diamond burs, and piezosurgery. Similarly, there was no

TABLE 1 Surface roughness and resection time mean and *SDs* values of groups

	Surface roughness (μm)	Resection time (s)
	Mean ± *SDs*	Mean ± *SDs*
Steel bur	12.82 ± 5.77^{ab}	16.60 ± 5.23^{ab}
Tungsten carbide bur	9.97 ± 4.96^{a}	11.1 ± 2.64^{a}
Diamond bur	10.41 ± 5.28^{a}	12.9 ± 3.24^{a}
Lindeman bur	17.35 ± 6.03^{b}	9.6 ± 3.4^{a}
Piezo surgery	5.50 ± 1.73^{a}	50.9 ± 16.86^{b}
Laser surgery	25.54 ± 9.01^{b}	57 ± 20.04^{b}

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

significant difference in surface roughness between Lindeman bur and laser surgery.

3.2 | 3D surface views of the cut surfaces

3D surface images of the traces left by the tooth surface of each cutting tool used in the cutting process are given in Figure 2. The first thing that draws attention in Figure 2; the change of cutting method caused changes in the traces on the cutting surface. The scale given next to the 3D surface images shows the distribution of the height difference between the shallowest and the highest point of the surface. The larger the numbers on this scale, the higher the surface roughness. From this point of view, cutting marks on the surface can be easily seen in cutting processes using steel, tungsten, and diamond.

These marks are partially visible in the Lindman cutting technique. However, there are no cutting marks in piezosurgery and laser surgery. For this reason, traces such as those obtained in the steel and tungsten bur method were not observed. 3D surface images given in Figure 2 were selected from 10 samples. Similar traces were observed in other examples of each cutting technique. Figure 3, additional 3D surface images of each cutting technique are given without scale. As can be seen in Figure 3, cutting marks on steel and tungsten can be seen very clearly. While the cutting marks are partially seen in the

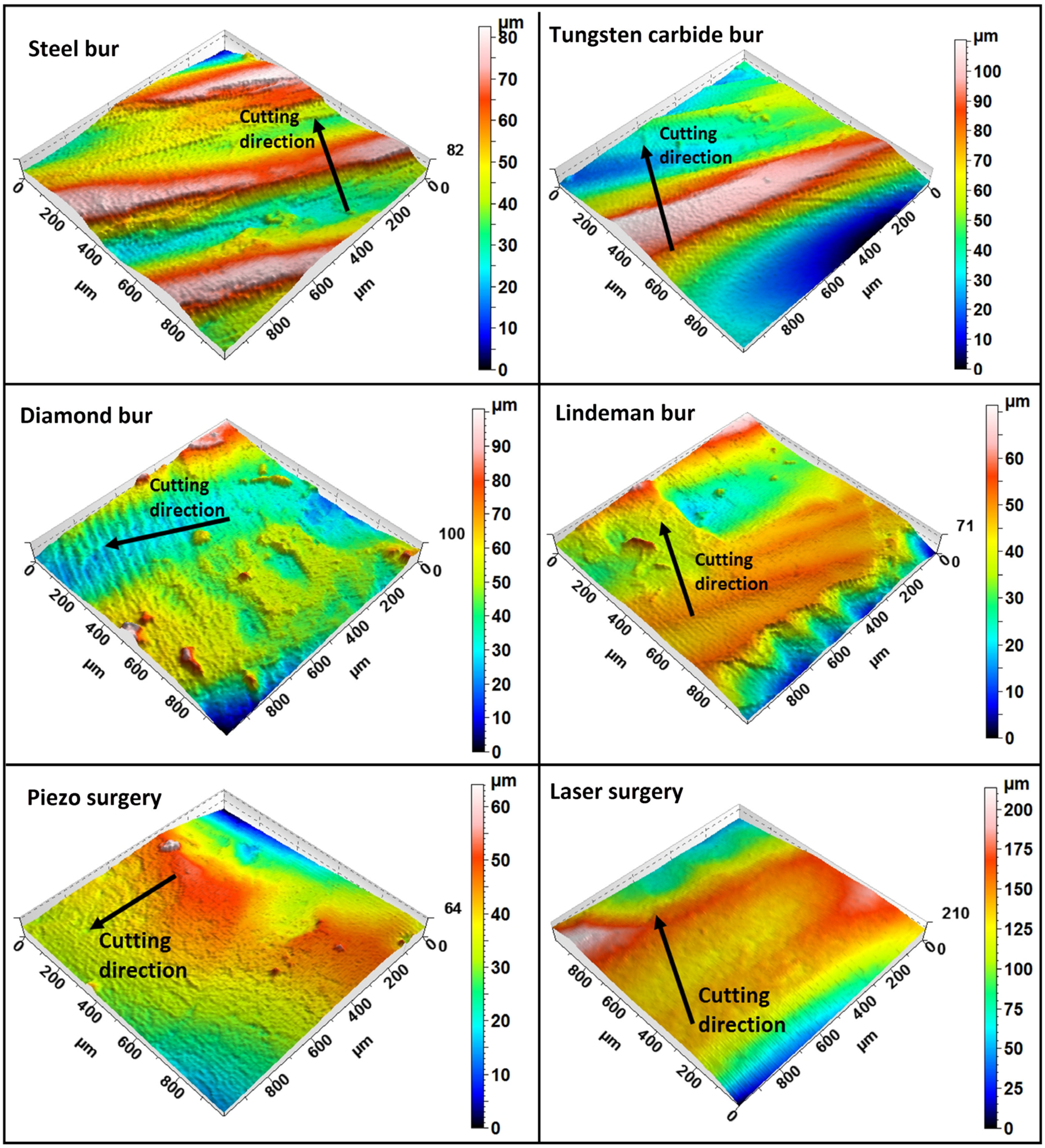

FIGURE 2 Three-dimensional (3D) topography images of the cut surfaces (first series examples) [Color figure can be viewed at wileyonlinelibrary.com]

diamond bur, cutting marks are not seen in piezo and laser surgery methods.

Figure 4 showed the variation of the 2D profile obtained along a line drawn by considering the cutting direction for each method. Regardless of the cutting method, changing the position of the line will caused by the profile to change. Therefore, the purpose of the 2D profile given in Figure 4 was to give more detailed information about the marks left by the cutting method on the surface. While the cutting marks were very clearly observed in the steel bur, there was a fluctuation on the surface that resembles sinus curves. Other methods in which cutting marks occurred, were the tungsten and the diamond bur, but those methods showed much less cutting markets compared to the case of the steel bur. In the diamond bur, the distance between the tracks was smaller than in the steel bur. In Lindeman, laser, and piezo methods, a fluctuation occurred instead of sequential traces. The increase in the difference between the shallowest and the highest point of this wave caused the surface roughness to increase.

3.3 | Apical resection time

The time spent in apical resection methods is given in Table 1, in seconds. Among these methods, the longest resection times are 57 and 50.9 s, respectively, in laser and piezosurgery. The fastest

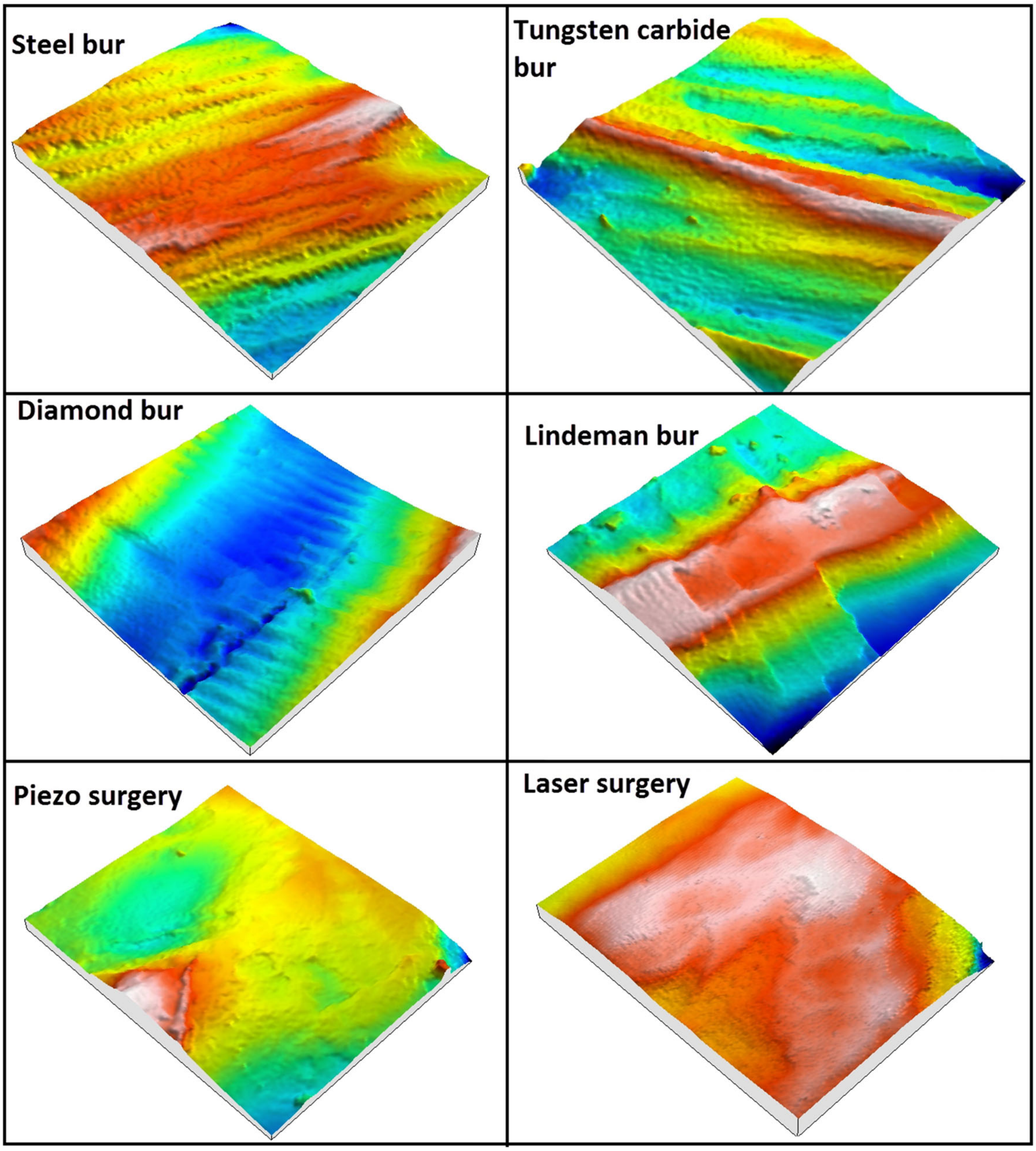

FIGURE 3 Three-dimensional (3D) topography images of the cut surfaces (second series examples) [Color figure can be viewed at wileyonlinelibrary.com]

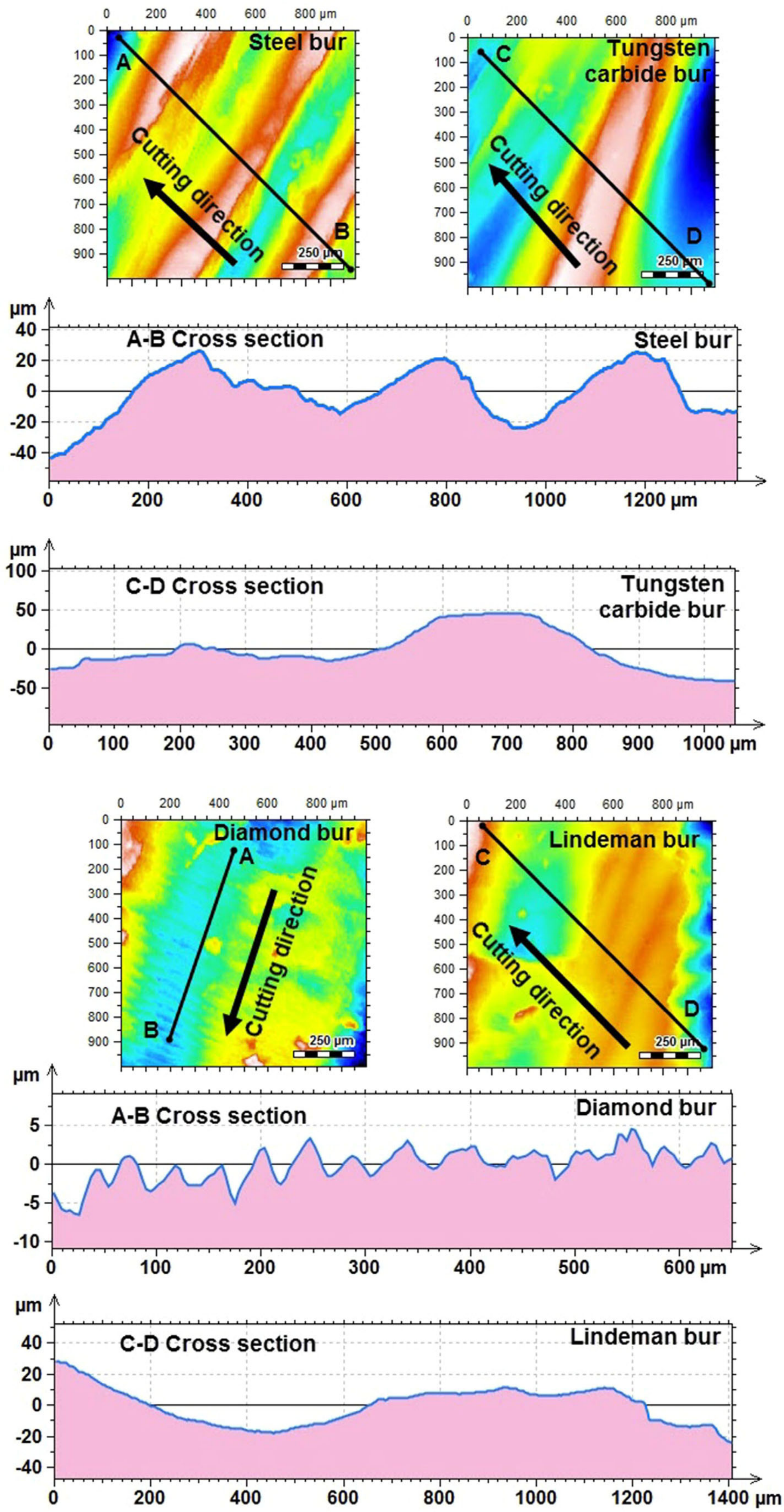

FIGURE 4 Variation of two-dimensional (2D) profile along the cutting direction for each cutting methods [Color figure can be viewed at wileyonlinelibrary.com]

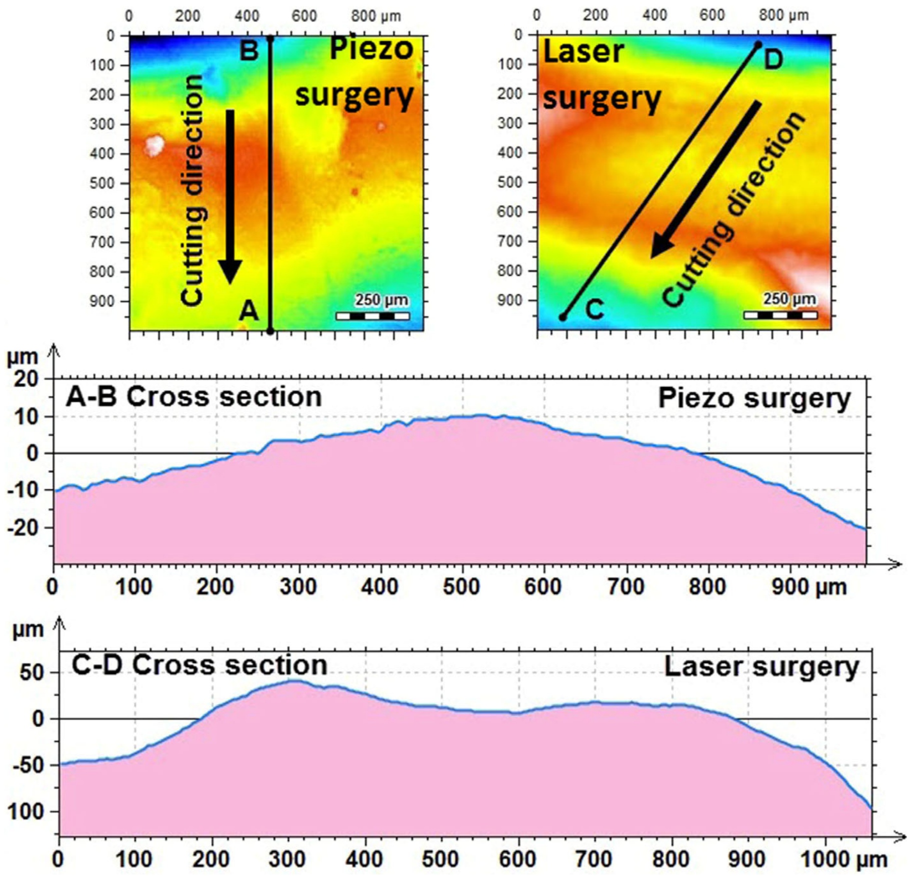

FIGURE 4 (Continued)

resection was performed with Lindeman bur (9.6 s). However, cutting times in piezo and laser surgery methods also differ among themselves. In laser surgery, while the maximum cutting time approaches 100 s, the minimum cutting time falls below 30 s. However, the difference between minimum and maximum cutting times in piezosurgery is less.

According to Kruskal–Wallis analysis, a significant difference was found between laser surgery-Lindeman bur ($p < .001$), laser surgery-tungsten carbide bur ($p < .001$), and laser surgery-diamond bur ($p < .05$). Similarly, there was a significant difference between piezo surgery-Lindeman bur ($p < .001$), piezo surgery-tungsten bur ($p < .001$), and piezo surgery-diamond bur ($p < .05$). As with laser, resection with piezo surgery was performed in a longer period than the other three methods. There was no significant difference in resection time between Lindeman, tungsten, and diamond burs. Similarly, resection time was similar between piezosurgery and laser surgery methods.

4 | DISCUSSION

Apical resection should be performed in such a way that a regular and smooth surface is obtained (Gutman & Harrison, 1991). For this purpose, various methods have been proposed in the literature. In this study, the most commonly used traditional methods in apical surgery and new technologies such as ultrasonic instruments and laser were compared for apical surface roughness. In the past, there are some studies evaluating apical surface roughness with SEM (Bernardes et al., 2015; Duarte, Domingues, Matsumoto, Padovan, & Kuga, 2007). This is the first study to evaluate surface roughness after apical resection with an optical profilometer in literature. Since the scanning is not along a line, the surface roughness of the entire area is taken into account. This method gives more realistic results than line scanning. Therefore, the surface roughness obtained after apical resection was quantitatively evaluated instead of subjectively. In addition, the 3D surface topography of samples cut using six different methods is presented for the first time in this study.

In apical surgery, the size, shape, and material of the drill and the surface structure of the drill are among the important factors affecting the surface roughness. It is possible to obtain more uniform surfaces in the resection process with burs having a flat cutting surface such as fissure burs. Nedderman, Hartwell, and Protell (1988) comparing different burs at high and low speeds in their study found that fissure burs produce softer and more smooth surfaces. Morgan and Marshall (1998) first applied apical resection of the roots with the Lindeman and Zekrya bur and then smoothed the surface with multisurface carbide and ultrafine diamond burs. Researchers have demonstrated that Zekrya bur produces more regular and smooth surfaces than the Lindeman bur cutter. In the present study, similar to the results of the literature, with Lindeman bur rougher surfaces were obtained compared to fissure bur. This is because the shape of the Lindeman bur has a sharper and diagonal groove structure.

Besides the size and shape of the burs, as well as the properties of the material are also important. In this study, the surface roughness obtained with tungsten carbide is lower than the roughness values obtained with diamond and steel drills. In other words, a smoother surface was obtained in tungsten carbide drills. Bernardes et al. (2009) de Morais and Bernardia (2009) have achieved excellent results with high-speed Zekrya bur compared to diamonds and other burs. As in Morgan and Marshall's work, the multiface carbide bur process produced smoother surfaces than diamond bur. Bernardes et al. (2009) in the study of ultrasonic chemical vapor deposition coated bur compared with carbide bur found that carbide burs produce more regular root end surfaces. Similar results were reported by Duarte et al. (2007).

It has been found that the use of erbium YAG and CO_2 lasers alone or in combination with burs results in less dentinal permeability (Gouw-Soares et al., 2004). In the studies on the effects of retrograde obturations on the sealing, similar (Francischone et al., 2005) or even better (Oliveira, Gouw-Soares, Baldochi, & Eduardo, 2004) results were obtained with lasers compared to burs. Although the laser has positive effects on dentinal sealing, apical resections made by laser are quite poor in terms of surface roughness. In this study, the roughest surfaces were obtained by laser. In apical resection with laser, five times more rough surface was obtained than piezosurgery. This is related to the fact that each beat causes roughness on the surface during laser cutting. In addition, laser applications require preventive measures and the sounds produced by the device may cause uneasiness in the patient.

Ultrasonic piezo surgical instruments have been widely used in dentistry and maxillofacial surgery since this method improves the accuracy of the cutting and does not damage soft tissues. Procedures such as corticotomy, split osteotomy, a sinus lift can be performed more easily with these devices in maxillofacial surgery. The initiation of ultrasonic activation represents a significant advance in endodontic surgery because bone tissue management and root tip preparation can be performed with this device, thereby reducing the risk of damage to soft tissues (Nielson et al., 1955). When ultrasonic piezo devices are used in apiectomy procedures, a smoother cut and a smoother surface can be obtained. The results of the present study showed that diamond-tipped ultrasonic piezo resection produces the smoothest surfaces.

The time spent on cutting in apical resection is important as well as surface smoothness. Resection should be completed within a reasonable period of time so as not to exhaust the patient and the physician. In our study, the time spent in resection procedures with ultrasonic piezo and laser was found to be quite long compared to other bur methods. The reason for the fastest resection of the Lindeman bur is related to the crosswise aggressive groove structure of the Lindeman. With tungsten carbide burs, harder surfaces can be cut faster than steel burs. Although the hardness of diamond surfaces is quite high, the cutting speed on the tooth root surface is lower than tungsten carbide burs because diamond fissür burs do not contain significant grooves. Although steel drills have poor cutting on hard surfaces such as tooth enamel, they are better on the tooth root surface.

In conclusion, this study evaluates the apical surface with an optical profilometer after apical resection with six different tips and techniques and has demonstrated the advantages and disadvantages of different techniques and methods in terms of surface roughness, time spent for cutting. According to these results, tungsten carbide fissure bur can be considered as a more suitable method for apical resection when evaluated together in terms of both surface roughness and cutting process time. The worst results were obtained in terms of both surface roughness and cutting time in laser resection.

In this study, cuttings made by diamond-tipped ultrasonic piezosurgery gave the best results in terms of surface roughness. Ultrasonic piezo surgery can be recommended as an alternative to conventional resection methods such as tungsten carbide fissure bur. Piezosurgery reduces the likelihood of damaging soft tissues and it can be easily applied in clinics. Comparative studies evaluating other physical and biological parameters such as temperature, microcracks, and microleakage in the tooth should be performed in order to reveal the ideal method for apical resection.

ACKNOWLEDGMENT

This research is self-funded and has not received any external financial grants.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data available on request from the authors The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Ömer Ekici https://orcid.org/0000-0002-7902-9601

REFERENCES

Antonio Hungaro Duarte, M., Domingues, R., Akemi Matsumoto, M., Eduardo Marques Padovan, L., Carlos Kuga, M., & Paulo, S. (2007). Evaluation of apical surface roughness after root resection: A scanning electron microscopic study. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *104*, 74–76. https://doi.org/10.1016/j.tripleo.2007.07.012

Bernardes, R. A., de Souza Junior, J. V., Duarte, M. A. H., de Moraes, I. G., & Bramante, C. M. (2009). 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. *Journal of Endodontics*, *35*(2), 265–268. https://doi.org/10.1016/j.joen.2008.11.009

Bernardes, R. A., Húngaro Duarte, M. A., Vivan, R. R., Baldi, J. V., Vasconcelos, B. C., & Bramante, C. M. (2015). Scanning electronic microscopy analysis of the apical surface after of root-end resection with different methods. *Scanning*, *37*(2), 126–130. https://doi.org/10.1002/sca.21188

Bramante, C. M., de Moraes, I. G., Bernardineli, N., Garcia, R. B., Pidero, C. U., Ordinola-Zapata, R., & Bramante, A. S. (2010). Effect of sputter-coating on cracking of root-end surfaces after ultrasonic retrograde preparation—A SEM study of resected root apices and their respective impressions. *Acta Odontologica Latinoamericana: AOL*, *23*(1), 53–57 Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20645644

de Bruyne, M. A. A., & de Moor, R. J. G. (2005). SEM analysis of the integrity of resected root apices of cadaver and extracted teeth after ultrasonic root-end preparation at different intensities. *International Endodontic Journal*, *38*(5), 310–319. https://doi.org/10.1111/j.1365-2591.2005.00949.x

Del Fabbro, M., Tsesis, I., Rosano, G., Bortolin, M., & Taschieri, S. (2010). Scanning electron microscopic analysis of the integrity of the root-end surface after root-end management using a piezoelectric device: A cadaveric study. *Journal of Endodontics*, *36*(10), 1693–1697. https://doi.org/10.1016/j.joen.2010.06.028

Duarte, M. A. H., Domingues, R., Matsumoto, M. A., Padovan, L. E. M., & Kuga, M. C. (2007). Evaluation of apical surface roughness after root resection: A scanning electron microscopic study. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *104*(6), e74–e76. https://doi.org/10.1016/j.tripleo.2007.07.012

Francischone, C. E., Prado De Araújo Padovan, L. A., Marques Padovan, L. E., Húngaro Duarte, M. A., De Campos Fraga, S., & Prado Curvêllo, V. (2005). Apicectomy with the Er:YAG laser or bur, followed by retrograde root filling with zinc oxide/eugenol or sealer 26. *Photomedicine and Laser Surgery*, *23*(4), 395–398. https://doi.org/10.1089/pho.2005.23.395

Gouw-Soares, S., Stabholz, A., Lage-Marques, J. L., Zezell, D. M., Groth, E. B., & Eduardo, C. P. (2004). Comparative study of dentine permeability after apicectomy and surface treatment with 9.6 μm TEA CO2 and Er:YAG laser irradiation. *Journal of Clinical Laser Medicine and Surgery*, *22*(2), 129–139. https://doi.org/10.1089/104454704774076190

Gutman, J. L., & Harrison, J. W. (1991). *Surgical endodontics* (pp. 203–277). St. Louis, MO: Blackwell Scientific Publications.

Karabucak, B., & Setzer, F. (2007). Criteria for the ideal treatment option for failed endodontics: Surgical or nonsurgical? *Compendium of Continuing Education in Dentistry (Jamesburg, N.J.: 1995)*, *28*(7), 391–397 Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17687901

Kim, E., Song, J. S., Jung, I. Y., Lee, S. J., & Kim, S. (2008). Prospective clinical study evaluating endodontic microsurgery outcomes for cases with lesions of endodontic origin compared with cases with lesions of combined periodontal-endodontic origin. *Journal of Endodontics*, *34*(5), 546–551. https://doi.org/10.1016/j.joen.2008.01.023

Morgan, L. A., & Marshall, J. G. (1998). The topography of root ends resected with fissure burs and refined with two types of finishing burs. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *85*(5), 585–591. https://doi.org/10.1016/s1079-2104(98)90296-7

Nedderman, T. A., Hartwell, G. R., & Protell, F. R. (1988). A comparison of root surfaces following apical root resection with various burs: Scanning electron microscopic evaluation. *Journal of Endodontics*, *14*(9), 423–427. https://doi.org/10.1016/s0099-2399(88)80129-8

Nielson, A. G., Richards, J. R., & Wolcott, R. B. (1955). Ultrasonic dental cutting instrument: I. *Journal of the American Dental Association (1939)*, *50*(4), 392–399. https://doi.org/10.14219/jada.archive.1955.0077

Oliveira, R. G., Gouw-Soares, S., Baldochi, S. L., & Eduardo, C. P. (2004). Scanning electron microscopy (SEM) and optical microscopy: Effects of Er:YAG and Nd:YAG lasers on apical seals after apicoectomy and retrofill. *Photomedicine and Laser Surgery*, *22*(6), 533–536. https://doi.org/10.1089/pho.2004.22.533

ST400 - The Customizable Optical Profiler. (n.d.). Retrieved from https://nanovea.com/instruments/st400/

How to cite this article: Ekici Ö, Aslantaş K, Kanık Ö, Keleş A. Evaluation of surface roughness after root resection: An optical profilometer study. *Microsc Res Tech*. 2021;84:828–836. https://doi.org/10.1002/jemt.23714