

Evaluation of the effectiveness of root canal obturation depending on the treatment methods

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Abstract

The aim of the study is a comparative quality evaluation of root canal adhesive filling by endodontic sealer and gutta-percha, using the standard treatment method, laser and LAI treatment methods. We studied 20 teeth removed with a diagnosis of chronic periodontitis treated according to traditional Protocol, using laser Er; Cr; YSGG 2780nm, LAI method, filled according to one Protocol using an epoxy sealer AH+ and gutta-percha using the method of continuous wave with the Calamus Dual (Dentsply Maillefer) device. The efficiency of tooth root filling depending on the type of treatment was studied by scanning electron microscopy.

Aim of the study - comparative quality evaluation of root canal adhesive filling by endodontic sealer and gutta-percha, using the standard processing method, laser processing and LAI method.

It was found that the highest density of the material obturation to the canal walls is obtained by laser treatment with a power of 1.5 W, which is confirmed by the absence of empty spaces between the material and dentin. It was not possible to achieve a tight fit of the material under the traditional Protocol, the size of the empty spaces was up to 13 microns. The results of this pilot study are the basis for further studies.

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Introduction

High prevalence of complicated tooth decay and the problems associated with its recurrence make this topic relevant, despite the success of modern endodontics. High-quality endodontic treatment provides a long-term positive prognosis of tooth preservation and its successful functioning. According to some authors, complications of endodontic treatment are caused by poor-quality tooth sealing and obturation of root canals.¹⁻⁸ When cleaning, formation and disinfection of the root canal are finished, it is essential to put airproof adhesive filling. Tooth filling material, adapted to the internal geometry of the prepared root canal, serves as a barrier preventing the growth of

bacteria and their metabolites, which can flow through tooth crown to the apex, and retrogradely when the penetration of tissue fluids from the periapical tissues occurs.

Tooth treatment and filling methods influence the quality of adhesive filling as much as anatomical organization of root canals. Nowadays, there are a lot of studies dedicated to the traditional Protocol of instrumental and therapeutic root canal treatment, also known as "Golden Standard", in which sodium hypochlorite is used as a therapeutic boring, and is effective against pathogenic flora.^{1, 5, 9} Sodium hypochlorite decomposes organic and non-organic tissues and annihilates bacteria but cannot sterilize root canals.¹⁰⁻¹² In this regard, lasers are of great interest to the dental community.

Elimination of debris and smear level leads to better sealing of root canal. Studies show that Er: YAG is a preferable option for intracanal elimination of dentine debris and smear level and competes with irrigants in that regard.^{13, 14} Erbium lasers eliminate smear level by activating water and, as a result, generating shockwaves and

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producing steam bubbles. In addition, erbium laser exposure leads to carbonization of root canal dentine, partial melting of dentinal tubules and occlusion of canal orifice in molten areas.¹⁵ Studies dedicated to disinfection using erbium lasers show that usage of these lasers can be effective for root canals and even more effective with the help of irrigants.^{16,17} However, there is information which reveals poor effectiveness of antibacterial tooth boring with the help of irrigant laser activation.^{13,18} On the other hand, there are practically no studies dedicated to airproof adhesive filling of root canal in correlation with methods of tooth treatment with the help of erbium lasers. Therefore, despite the modern success and increase in predictability of RCT, the problem of high quality tooth boring and, as a result, root canal filling remains highly relevant.

Aim of the study - comparative quality evaluation of root canal adhesive filling by endodontic sealer and gutta-percha, using the standard processing method, laser processing and LAI method.

Materials and methods

We studied 20 human teeth, removed with diagnosis "Chronic apical periodontitis". We used manually operated K-files and mechanical nickel-titanium files ProTaperUniversal (DentsplySironaEndodontics) for mechanical tooth boring. Root canals were treated minimally to the size ISO 35.04. We used laser Er,Cr:YSGG with wavelength of 2780 nm (WaterlaseiPlus, Biolase, USA) and radial endodontic RFT2 tip (200 µm in diameter, 25 mm in length), for LAI method we used RFT5 tip (400 µm in diameter, 14 mm in length).

Teeth were separated into 4 groups, 5 teeth in each group:

1. Control group, in which every tooth canal was treated according to the standard Protocol with the usage of 3% solution of sodium hypochlorite and 17% solution of EDTA as irrigant and passive ultrasonic activation (total volume of solutions in 20 ml for each root canal).

2. Teeth group, in which only saline solution was used as irrigant, and then root canal was treated by laser in following modes: power - 1 W, frequency - 20 Hz, water/air - 20/20, number of impulses - 20, tips 200 µm. We placed laser tip into the root canal to a depth of 1mm of operating length and helped forward with slow

spiral moves in coronal direction during 25 seconds. Laser tooth treatment was repeated 4 times, plunging root canal with saline solution during breaks.

3. Teeth were treated the same way, only the laser power increased to 1.5 W.

4. Group, in which every tooth was treated according to the standard way, with usage of 3% NaOCl and 17% solution of EDTA as irrigant and laser activation of irrigants (LAI). Laser activation of the solution was conducted with the help of RFPT5 tip, with external coating being removed chemically due to increase of collateral diffusion energy. Tip was plunged into the root canal 4-fold over a period of 5 seconds with 75 mJ, frequency of 20 Hz, power of 1.5 W, short of 5 mm to apex, plunging the root canal with fresh irrigant during breaks.

One tooth from each group was subjected to lateral split to evaluate the surface of root canal dentine using scanning electron microscopy (SEM) after different methods of tooth processing .

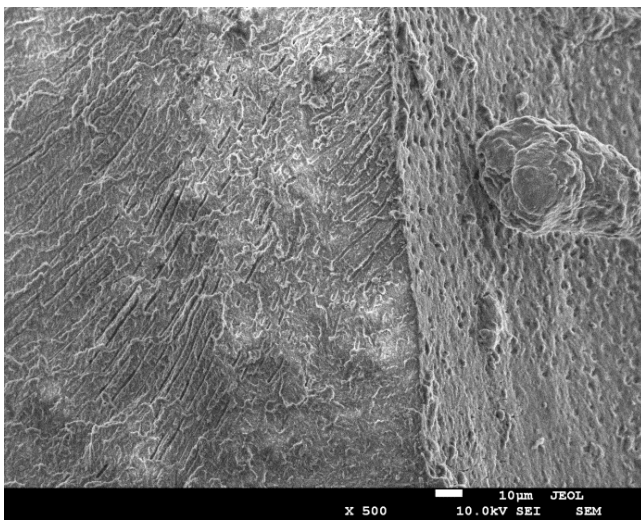
We used the same method for tooth filling with the usage of epoxy sealer AH+ and gutta-percha according to the method of continuous wave using CalamusDual (DentsplyMaillefer). To evaluate the quality of adhesive filling we conducted tooth cross sections of canal's middle and lower thirds by slicing and polishing on abrasive paper with silicone carbide abrasive grain with granularity of 1200 and 2400. SEM investigations were conducted in electron microscopy laboratory of SFU on SEM JEOL JSM 7001-F (Japan), equipped with EDS. Surface morphology was studied in secondary electrons with magnification of x70, x500, x2000. Quality and quantity elemental analysis of root canal surface sample was conducted according to the EDS method.

Small sample of criteria (pilot study format) did not allow to conduct full-value statistical data analysis.

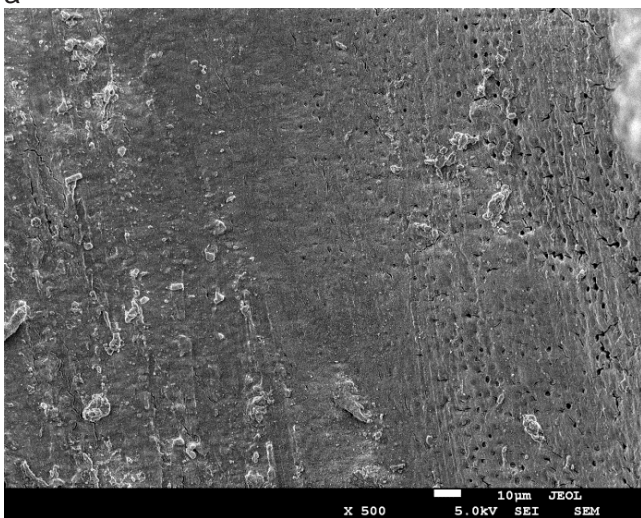
Results

SEM image of root lateral split treated according to the standard Protocol shows exposed dentinal tubules, debris and smear level (Fig.1 a,b).

Laser tooth treatment with the power of 1 W leads to removal of smear level and occlusion of dentinal tubules almost on half the surface (Fig.2 a,b).

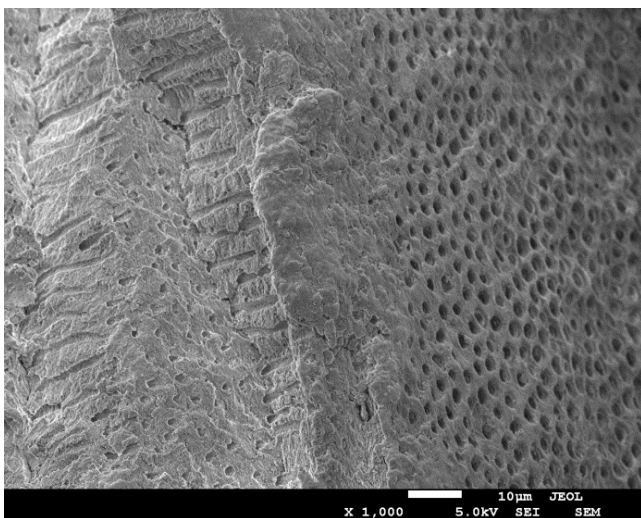


a

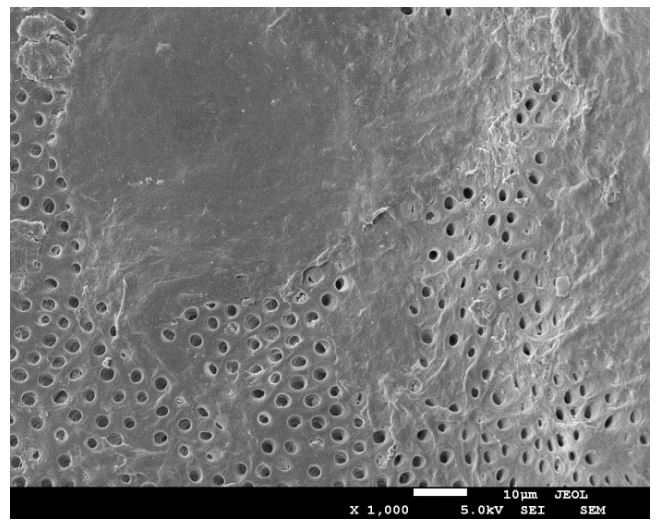


b

Figure 1. SEM images of canal surface treated according to the standard Protocol: a – tooth root lateral split; b – root canal.

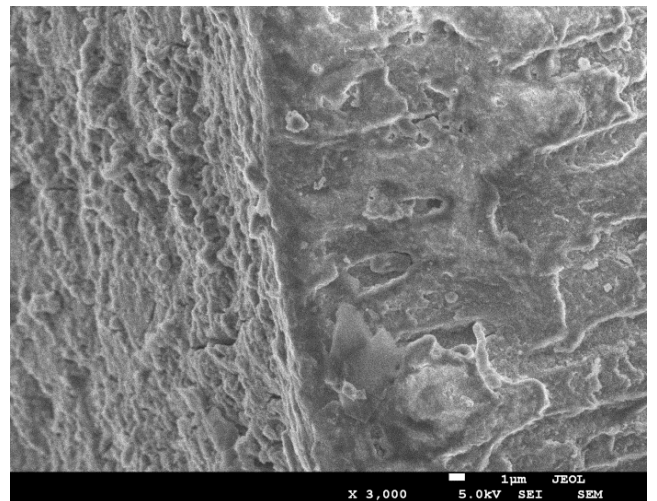


a

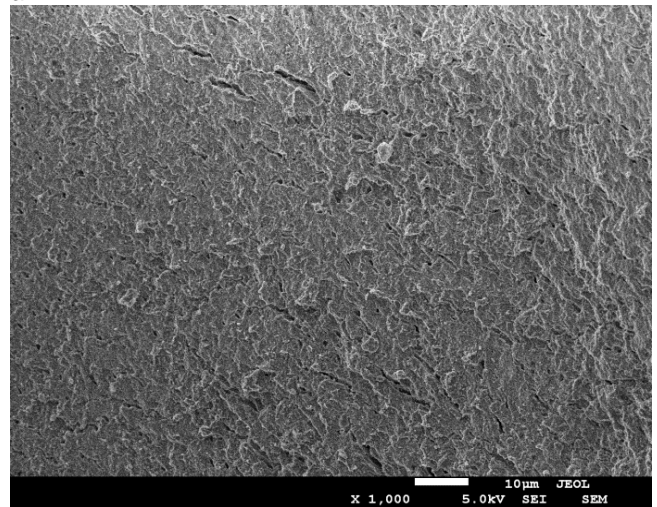


b

Figure 2. SEM images of canal surface treated by laser with the power of 1 W: a – tooth root lateral split; b – root canal.



a



b

Figure 3. SEM images of canal surface treated by laser with the power of 1.5 W: a – tooth root lateral split; b – root canal.

Laser tooth treatment with the power of 1.5 W leads to occlusion of practically all dentinal tubules, and to a significant depth of 10-15 microns (Fig.3 a,b).

LAI root canal treatment also leads to partial occlusion of dentinal tubules, however image shows incomplete sealing of dentinal tubules and almost half the tubules are exposed (Fig.4 a,b).

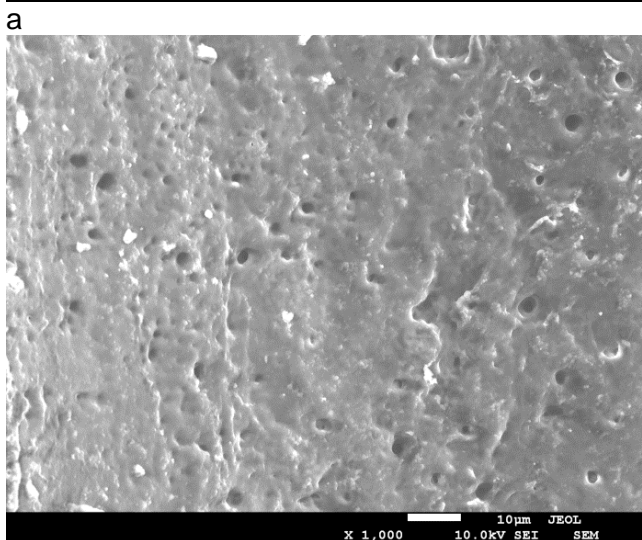
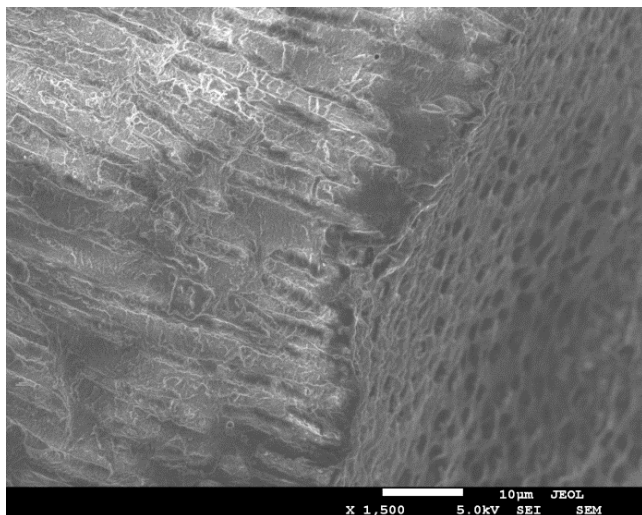


Figure 4. SEM images of canal surface treated with LAI method: a – tooth root lateral split; b – root canal.

Typical SEM-image of a slice of tooth cross section, treated in a standard way is depicted on (Fig.5a). Elemental composition, determined according to the EDS method, shows precise boundaries between materials and dentine, which helped to determine density of sealer and gutta-percha to dentine (Fig. 5b, Table 1).

№ of spectrum	Chemical elements, atomic %												
	C	O	Na	Al	Si	P	S	K	Ca	Ti	Zn	Ba	W
Gutta-percha													
1	68.15	18.02					0.61				12.67	0.55	
Dentine													
2	32.02	35.49	0.68			12.47			19.35				
Sealer													
3	39.76	9.41							28.58				22.25
4	36.94	17.09		7.73	8.86		2.46	11.21	7.58				8.13

Table 1. Elemental composition of materials of tooth root canal cross-section after the sealing.

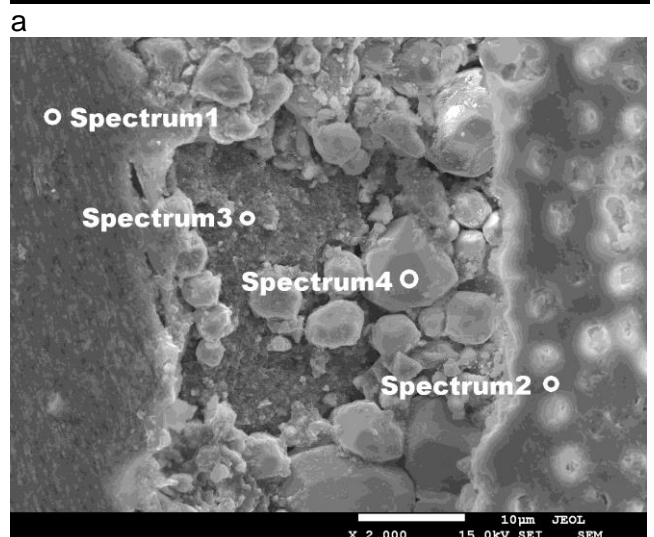
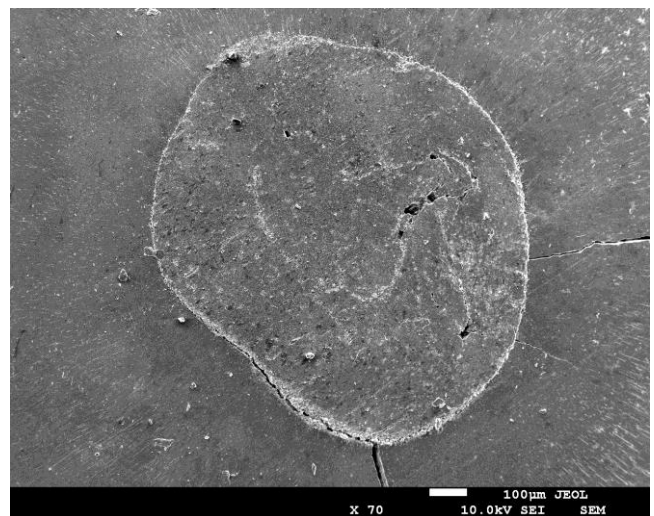
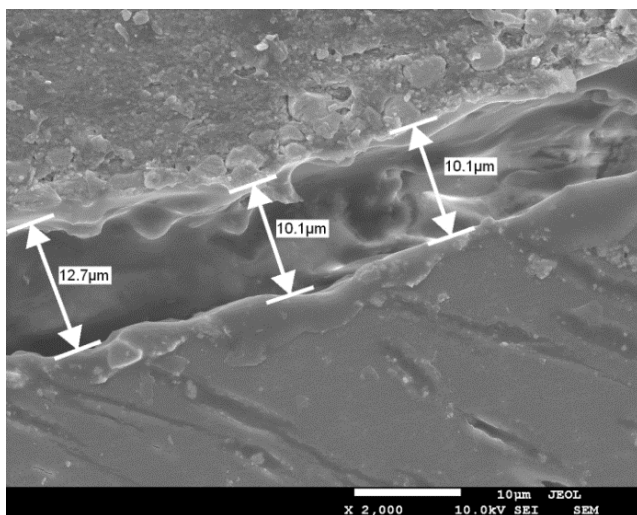


Figure 5. SEM images of a slice of tooth cross section (a), dentine structure, sealer and gutta-percha with spectrums' markers (b).

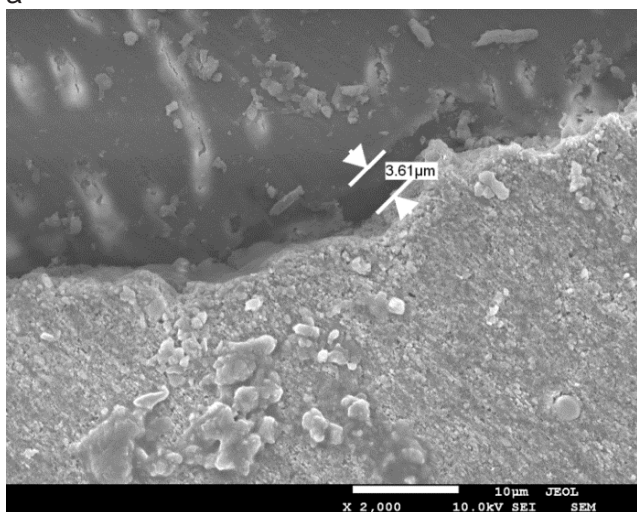
Elemental composition of gutta-percha is presented with data from spectrum 1, dentine - spectrum 2, sealer - spectrums 3, 4.

The research of teeth root slices, treated according to the standard Protocol revealed empty spaces between the filling and walls of the canal, their width varies from 10 μm to 12,7 μm , and also exposed dentinal tubules, opening into the empty spaces between dentine and gutta-percha (Fig.6a).

The study of the surface of tooth root slice, treated by laser with power of 1 W shows firm adherence of sealer and gutta-percha to dentine almost on the whole stretch, there are some insignificant empty spaces with max width of 3,61 μm (Fig.6b). Presumably it can be due to the fact that most of the dentinal tubules are sealed because of the specifics of laser processing and the sealer cannot flow into them.



a

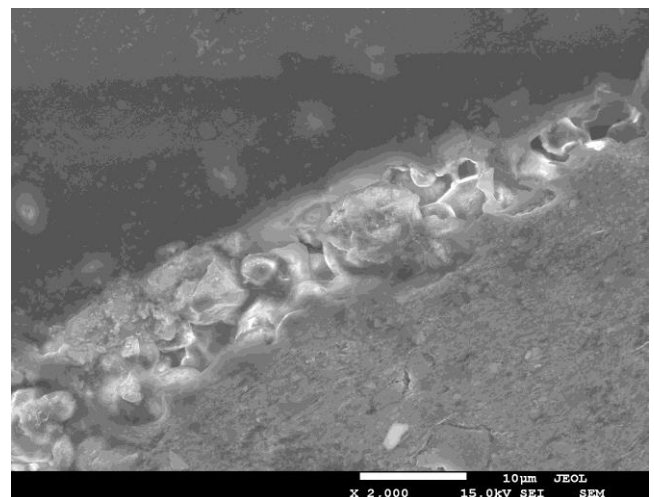


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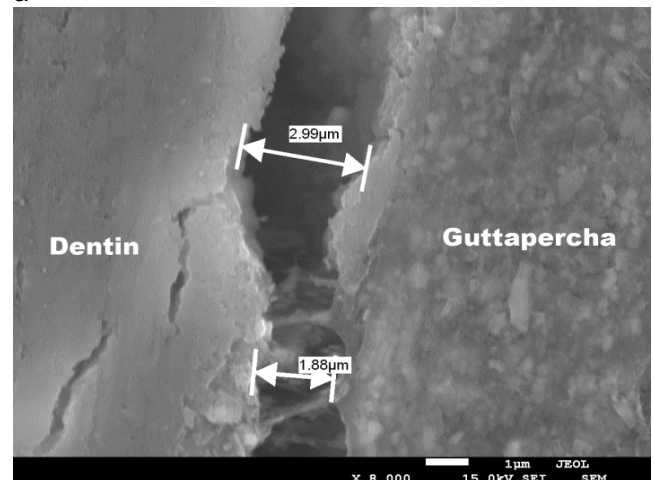
Figure 6. SEM images of a slice of tooth root treated: a – according to the standard Protocol; b – by laser with the power of 1 W.

The results of the slices of tooth root cross section treated by laser with the power of 1.5 W show firm adherence of sealer to canal walls and gutta-percha (Fig.7a). Moreover, unlike previous processing methods, no empty spaces are observed, and due to the increased laser power the surface is restructured and the dentinal tubules are mostly sealed.

The study of the root cross-section surface showed a tight fit of the sealer to the walls of the canal and gutta-percha after using the LAI method. Small spaces with the width up to 2.99 μm were found (Fig.7, b). This method of canal treatment also seals dentinal tubules, which will not lead to the re-infection of the walls of the tooth canal. However, in contrast to the method, which includes only the laser, the obturation density is slightly worse due to the formation of more empty spaces.



a



b

Figure 7. SEM images of a slice of tooth root treated: a – by laser with the power of 1.5 W; b – with LAI method.

Discussion

Analysis of the results of electron microscopy examination of root canal cross-sections treated according to the standard Protocol, laser and LAI method, and sealed according to the same Protocol allows to make the following conclusions.

The traditional method of root canal treatment using sodium hypochlorite showed the presence of a large number of empty spaces between the sealer and the canal walls to 12.7 μm wide. Also, unsealed dentinal tubules which open to the empty spaces were found. These problems can contribute to the re-infection of the root canal.

Treatment of the root canal with laser with the power of 1 W showed tight fit of the obturation material to the canal walls, revealed a small number of empty spaces, the width of which were not more than 3.6 μm . In addition, because of the specifics of laser treatment of the root canal, the dentinal tubules were mostly sealed.

Treatment of the root canal with laser with the power of 1.5 W showed the best results on the fit density of the sealer to the canal walls, there were no empty spaces between the sealer and the canal walls. The specifics of the surface treatment of the root canal with a laser with this power allows us to seal almost all of the dentinal tubules opening into the lumen of the canal, allowing the sealer to make a sufficient layer, eliminating its leaking into the dentinal tubules.

Treatment of the root canal with LAI technique showed dense obturation but the width of the identified spaces reached 3 μm . The presence of non-fully sealed dentinal tubules, apparently, was due to the fact that the laser radiation in this method is indirect and not sufficient for the complete restructuring of the surface and sealing of the tubules.

The analysis of the results showed that the traditional method with sodium hypochlorite is less effective than the laser treatment method. The size of empty spaces (less than 12 μm) and dentinal tubules opening into these spaces prove the effectiveness of this method. The most effective of the laser techniques is laser treatment with a power of 1.5 W. The absence of empty spaces, completely sealed dentinal tubules – these factors exclude re-infection of the root canal and, as a consequence, the

occurrence of complications of endodontic treatment.

Conclusions

Finally, the laser root canal treatment with a laser power of 1.5 W can be recommended for further clinical studies as an alternative to the traditional Protocol, the results of this pilot study are partially confirmed by literature and are the basis for further research.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

References

1. Swimberghe, RCD, Coenye, T, DeMoor, RJG, Meire, MA. Biofilm model systems for root canal disinfection: a literature review: *Int Endod J* 2019; 52: 604–8.
2. Bago, I, Plečko, V, Gabrić Pandurić, D, Schauerl, Z, Baraba, A, Anić, I Antimicrobial efficacy of a high-power diode laser, photo-activated disinfection, conventional and sonic activated irrigation during root canal treatment. *Int Endod J* 2013; 46: 339–7.
3. Romeo, U., Palaia, G., Nardo, A., Tenore, G., Telesca, V., Kornblit, R., Del Vecchio, A., Frioni, A., Valenti, P. and Berlutti, F., Antimicrobial Activity of KTP Laser in Endodontics. *Aust Endod J* 2015; 41: 17-23.
4. Bezgin, T., Ozgul, B.M., Arikan, V., Sari, S. MTA vs Gutta-percha/AH-Plus (Global corrections). *Aust. Endod J* 2016; 42: 73-81.
5. Gomes, B.P., Pinheiro, E.T. Extraradicular Endodontic Infections. In *Endodontic Microbiology: Chapter 6: A. F. Fouad (Ed.)* 2017; 129-148.
6. Balto, H.A. Obturation Techniques Allow Microbial Leakage Unless Protected. *J of Prosthodontics*, 2016, 25: 224-228.
7. Soo, WKM, Thong, YL, Gutmann, JL. A comparison of four gutta-percha filling techniques in simulated C-shaped canals. *Int Endod J* 2015; 48: 736– 746.
8. Irawati Siregar, Riza Permitasari, Kamizar, Anggraini Margono. Comparison of the Potential Genotoxicities of Resin-, Silicone-, and Bioceramic-based Root Canal Sealers against Human Lymphocytes. *Journal of International Dental and Medical Research*: 2019; 12 (1): 88-94.
9. Caffesse, RG, Echeverría, JJ. Treatment trends in periodontics. / *Periodontol* 2000 2019; 79: 7– 14.
10. Makeeva I.M., Franco A., Semenov A.M., Byakov of Page F., Novozhilova N. E., Dezhurko-Korol of VA. The research in vitro of efficiency of antiseptic substances for superficial disinfection of teeth, the inokulirovannykh of *Escherichia coli*. *Stomatology*. 2018; 97(4):8-10.
11. Flach, N., Böttcher, D.E., Parolo, C. C., Firmino, L.B., Malt, M., Lammers, M.L., Grecca, F.S. Confocal microscopy evaluation of the effect of irrigants on *Enterococcus faecalis* biofilm: An in vitro study. *Scanning*, 2016; 38: 57-62.
12. Mohammed, SA, Vianna, ME, Penny, MR, Hilton, ST, Mordan, NJ, Knowles, JC. Investigations into in situ *Enterococcus faecalis* biofilm removal by passive and active sodium hypochlorite irrigation delivered into the lateral canal of a simulated root canal model. *Int Endod J* 2018; 51: 649– 662.

13. Christo, JE, Zilm, PS, Sullivan, T, Cathro, PR. Efficacy of low concentrations of sodium hypochlorite and low-powered Er,Cr:YSGG laser activated irrigation against an Enterococcus faecalis biofilm. *Int Endod J* 2016; 49: 279–286.
14. Race, J., Zilm, P., Ratnayake, J., Fitzsimmons, T., Marchant, C. and Cathro, P. Efficacy of laser and ultrasonic-activated irrigation on eradicating a mixed-species biofilm in human mesial roots. *Aus. Endod J* 2019; 8.
15. Behnam Bolhari, DDS, MS, Sara Ehsani, DDS, Ardavan Etemadi, DDS, MS, Mohammad Shafaq, DDS and Ali Nosrat, DDS. Efficacy of Er,Cr:YSGG Laser in Removing Smear Layer and Debris with Two Different Output Powers. *Photomed Laser Surg.* 2014; Oct 1; 32(10): 527–532.
16. Dumani A, Tanrisever D, Sihay D, Kuzu SB, Yilmaz S, Guvenmez HK. Efficacy of calcium hypochlorite with and without Er,Cr: Yttrium, scandium, gallium, garnet laser activation on Enterococcus faecalis in experimentally infected root canals. *Niger J Clin Pract* 2019; Feb; 22(2): 215-220.
17. Akcay M, Arslan H, Mese M, Durmus N, Capar ID. Effect of photon-initiated photoacoustic streaming, passive ultrasonic and sonic irrigation techniques on dentinal tubule penetration of irrigation solution: a confocal microscopic study. *Clin Oral Investig.* 2017; Sep; 21(7):2205-2212.
18. `Dunia Alhadi, Farah M. Jaber, Manaf Taher Agha, Musab Hamed Saeed. The Effect of Diode Laser Irradiation on Root Canal Dentin. *Journal of International Dental and Medical Research:* 2019; 12 (1): 49-53.