EFFECTIVENESS OF Er:YAG LASER IN CAVITY PREPARATION FOR RETROGRADE FILLING – *IN VITRO* STUDY

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SUMMARY – The purpose of this study was to determine the sealing quality of Super EBA cement in laser prepared root-end cavities in comparison with root-end cavities classically prepared with steel burrs. Two groups of three millimeter root sections were prepared. The first group was prepared with the Er:YAG laser and the second group with a steel burr mounted on a surgical handpiece. The sections were filled with Super EBA cement and tested for leakage with fluid transport techniques. The sealing quality of Super EBA cement in the classically prepared root-end cavities was better, but there was no statistically significant difference between the two preparation techniques. The possible reason for greater leakage in the laser prepared root-end cavities was probably the irregular shape of the root-end cavity.

Key words: *Root canal preparation; Lasers, solid state; Er:YAG laser; Apicectomy; Root canal filling materials; Super EBA cement; Retrograde cavity*

Introduction

Since the discovery of the laser in the 1960s, its application began in all branches of human activity. A laser is a device that generates a collimated, monochromatic and coherent beam of light[1]. Light is the portion of electromagnetic radiation that can be visible or invisible to the human eye. The basic operating principle of the laser is contained in the acronym LASER (Light Amplification by Stimulated Emission of Radiation) and is subjected to the laws of quantum physics. Electrons excited by energy from an external source transform into a higher orbital of the electron cloud of atom and on its return from the excited state, a photon is emitted. Photons are electromagnetic radiation, which influences the second atom. If second atom is excited, it will not absorb a photon, but it will emit a photon and there is a chain emission of photons that all have the same frequency, phase and direction of oscillation. The medium that produces the laser beam can be a gas, a liquid or a solid[2].

Over years, many types of lasers have been developed and tested for use in dentistry and maxillofacial surgery (excimer, KrF, XeCI, Argon, Diode, Nd:YAG, Tm:YAG, Ho:YAG, CO_2, Er:YAG, Er,Cr:YSGG)[3]. There are four possible effects of laser energy on living tissue, depending on its optical properties: transmission (the passage of laser beam through a biologic tissue without producing any effect on that tissue); reflection (the repelling of laser beam off the surface of the tissue without entering the tissue); scattering (dispersion of energy in contact with the tissue that causes secondary effects); and absorption of applied energy. Only absorbed and dispersed laser energy has the effect on the target tissue. Absorption of laser energy by the target is required to achieve tissue

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Received February 4, 2013, accepted April 15, 2014

removal and is the primary beneficial effect of laser energy. The amount of energy absorbed depends on the tissue characteristics, such as pigmentation and water contents, and on the laser wavelength and the emission mode[4]. Laser tests on biological tissues in the past failed to yield positive results because thermal damage of dental hard tissues occurred, such as carbonization of dentin or crack formation in enamel. With the development of Er:YAG (Erbium:Yttrium-Aluminum Garnet) lasers with a wavelength of 2.94 µm, its clinical application has become possible[3,5]. The coefficient of absorption by water and hydroxyapatite is approximately 10 times that for the CO_2 laser[3]. Since Er:YAG has the highest absorption in dental tissue of all of the infrared lasers, it allows ablation of hard tissue, e.g., bone, enamel, dentin and composite fillings. The ablation speed of the Er:YAG laser is higher in the carious tissue than in the healthy one, thus allowing the laser to be more selective and preserve more of the healthy structural tissue[5]. This specific laser, if used together with water spray, causes little temperature rise, or none at all, in the irradiated tooth surface during cavity preparation; neither does it cause carbonization of micro-cracks in the irradiated enamel and dentin[5,6]. Also, no difference in the dental pulp has been observed after cavity preparation when Er:YAG laser or a high-speed drill is used. Compared to rotary cutting instrumentals, Er:YAG laser cavity preparation takes more time, but its advantages include less noise and vibration than rotary instrumentation because of noncontact procedure and reduced need for local anesthesia[7,8]. Less pain felt by the patients is, for the most part, explained by a lower level of heat being produced and, consequently, less thermal injury to the pulp[5]. During the preparation of hard tissue with laser, the smear layer is removed and therefore leaves the cavity surface suitable for adhesive restorations[7,9]. It can be used in endodontic surgery for hemostasis and sterilization of the root-end apex and surrounding tissue due to its antimicrobial action[6,10]. The technology of Variable Square Pulse (VSP) provides electronic control of the laser pulse duration as well as its amplitude. It is reported that shorter pulses considerably increase the ablation rate of hard dental tissues and less energy is transformed into heat[9].

Over years, many materials have been used to seal the root-end preparation, such as gold leafs, gutta-percha, titanium screws, polycarboxylate cement and Cavit, which are not recommended anymore. Amalgam was the most popular and most used material for root-end fillings. It is widely available and initially provides a relatively good apical seal and has other advantages including radiopacity, nonabsorbability, tissue compatibility and ease of application. However, amalgam has considerable disadvantages including slow setting, poor dimensional stability, the possible occurrence of leakage due to corrosion and discoloration of the surrounding tissue, so other materials have become a substitute for amalgam, like glass ionomer cement, poly HEMA, bone cements and composite resins[11]. Zinc oxide eugenol cements such as IRM (Intermediate Restorative Material) and Super-EBA (Super Ethoxybenzoic Acid cement) as well as MTA (Mineral Trioxide Aggregate) are the most commonly used materials for retrograde fillings, and both *in vivo* and *in vitro* studies have been reported[11,12].

The main goal of endodontic treatment is eliminating the etiologic factors of pulpal and periapical diseases providing a hermetic seal between the periodontium and the root canal system. When a conventional orthograde seal is not possible, periradicular surgery is indicated. This procedure includes exposure of the involved apex, curettage of the periapical pathosis, resection of apical end of the root, preparation of class I cavity and insertion of a root-end filling material to seal the root-end cavity[6,13]. The main objective of placing the retrograde filling material after apicoectomy is to provide an effective barrier that prevents the microorganisms and their products from the root canal penetrating into the periapical tissues[14]. After periapical surgery, the goal is to achieve periapical repair by deposition of the bone, cementum, and periodontal ligament cell attachment onto the resected root surface[6]. The success of the apical filling depends on the type of the filling material and careful preparation of the root-end cavity. An appropriate root-end cavity must be 3 mm deep, located at the center of the root, and parallel to the long axis of the root[15]. Failure of apicoectomy is generally attributed to an inappropriate marginal sealing of retrocavity[14,16].

Materials and Methods

A sample of twenty single-rooted premolar teeth extracted for orthodontic reasons were randomly assigned to two groups of ten each. The teeth were stored in 10% formaldehyde solution prior to preparation. After mechanical cleaning of the tooth, a 3-mm section of the tooth root apex was cut off with a diamond fissure burr perpendicular to the longitudinal axis. Another 3-mm thick segment of the resected tooth root was cut perpendicular to the longitudinal axis of the tooth, and later prepared using laser and surgical handpiece. The optimal laser beam parameters were chosen from previous research: a pulse of very short duration 100 μs, energy of 380 mJ and repetition rate of 20 Hz[3].

In the first group, a VSP Er:YAG laser device (Fidelis Plus, Photona, Ljubljana, Slovenia) was used to prepare root-end cavities. The Er:YAG laser emitted pulsed infrared electromagnetic radiation at a wavelength of 2.94 μm through a system of seven mirrors in a fully operating mobile arm. An RO04 handpiece with a focus of 940 μm from the same manufacturer was used for preparation. The experiment was carried out under constant water cooling.

In the second group, cavities were prepared with a surgical handpiece with reduction 4:1 (Intra 3614 N, KaVo, Biberach, Germany) and a round steel burr 1.5 mm in diameter. After the root-end preparation, the cavities were filled with Super-EBA cement prepared according to the manufacturer's instructions. The filling material was condensed and cured, and the samples were stored in sterile saline solution at 37 °C for 15 days.

The quality of the sealing material was evaluated using modified transmission fluid apparatus. The resected segment was connected to the capillary tube with air bubble, and apically to a pressurized plastic tube. Sealing ability was measured by movement of an air bubble in a capillary tube under the pressure of 120 kPa for 15 minutes. Each specimen was tested three times and the mean value was calculated.

Table 1. Results of descriptive measurements for the cavities filled with Super-EBA and measured fluid transport (in mL)

Technique of cavity preparation (group)	Material	Number of samples	Mean	Standard deviation
Laser	Super EBA	10	0.0460	0.0381
Conventional method	Super EBA	10	0.0169	0.0088

Data analysis was performed using the Student's t-test because the distributions did not deviate from the normal distribution.

Results

Descriptive measures of fluid transmission – cavities filled with Super EBA – laser and conventional method of preparation are shown in Table 1.

The mean leakage value in cavities produced by laser was 0.046 mL, and in the cavity prepared by the classic method it was 0.0169 mL.

At the 5% level of significance, there were no statistically significant differences when leakage in the cavities prepared by standard method was compared with those prepared by laser ($p>0.05$).

Discussion

After the discovery of the laser, its use in oral and maxillofacial surgery has gradually increased. Tooth preparation and apicoectomy with Er:YAG laser has become an alternative to the classic preparation with surgical micro head handpiece[7]. The Er:YAG and the Er,Cr:YSGG lasers are considered an effective and safe technology for cavity preparation and have been granted US Food and Drug Administration approval for use on intraoral hard tissues[17]. However, the absorption of the Er:YAG laser light is much higher than that of the Er,Cr:YSGG, thus the efficiency of ablation is greatest for the Er:YAG laser[4]. For restorative procedures, laser use has increased patient acceptance related to the absence of pain, vibrations, whine of the drill, micro-fractures and heat production, although the cavity preparation takes more time[10]. The 'no-touch' characteristic of laser methods has several advantages including less chance for operating field contamination and a reduced risk of trauma to the surrounding tissues[7,9]. On the other hand, some authors consider noncontact procedure a disadvantage because of the lack of tactile feedback by the operator and the absence of a stable focus position during the cavity preparation[5,10].

This study examined the sealing quality in root-end filling cavities prepared with Er:YAG laser *versus* sealing quality in root-end filling cavities prepared with classic method. The study used the Er:YAG laser with a wavelength of 2.94 μm.

The success of apicoectomy with root-end filling depends on the shape of the root-end cavity. Removal of the last three millimeters of the root eliminates most of the apical deltas, isthmuses, and other canal irregularities. Consequently, the microorganisms harbored in these canals are removed, preventing the seepage of their byproducts to the periapical tissues[18]. An ideal root-end cavity preparation could be defined as a class I cavity at least 3 mm deep, with walls parallel to the course of the root canal[9]. Such shape is determined by the materials that are used for root-end fillings. Tooth sections perpendicular to the long axis of the tooth preserve the structure and decrease the number of sectioned dentinal tubules[19]. Failures in endodontic surgery are mainly caused by irregular cavity shape in vestibulo-oral direction and the inability to prepare the cavity to the sufficient depth of 3 mm[9]. Camargo Villela Berbert *et al.* showed that laser tips removed more dentin than ultrasonic retrotips and should be used with care to avoid overpreparation. Thickness of the remaining dentin is not of such a concern with laser preparation as it would be with ultrasonic or rotary instruments because there is no vibration or pressure exerted during root-end preparation that may produce cracks[6]. Dentin permeability decreased when the smear layer was found close to the apical third of the root canal[19]. Smear layer removal by laser preparation provides an irregularly shaped cavity[8,9]. Root-end resection performed with laser results in ablation of the exposed dentinal tubules, which may decrease microleakage and increase resistance to root resorption[18].

Root-end materials are in contact with the periradicular tissues, thus requiring biocompatibility as their main property[20]. Several studies have shown that MTA promotes regeneration of the periradicular tissues when placed in contact with the dental pulp or periradicular tissues[13,14]. Although MTA was found to have the highest estimated healed rate[21], the possibility of use in the presence of moisture and superior biocompatibility and sealing ability when compared to amalgam, IRM and Super-EBA[14,18], it is a costly material. It also has poor handling characteristics[22] and very slow setting time, all of which may contribute to a greater degree of leakage, surface disintegration and loss of marginal adaptation and continuity of the material. Super EBA and IRM showed better behavior than MTA regarding microleakage and marginal adaptation in the study conducted by Tobón-Arroyave[16,22]. However, microleakage with MTA was significantly less than that with amalgam, gutta-percha and zinc oxide eugenol in the study conducted by Otani, but microleakage of MTA has been reported to increase with time[23]. Despite the numerous carrier devices available to help in its clinical placement, doctors still find MTA difficult to use in certain surgical situations because of the location of the surgical site and the small size of the root-end preparation[22]. The thickness of 4 mm is more adequate for using MTA as a root-end filling material. In some cases, the preparation of 3 mm deep root-end cavities is not possible, therefore MTA is not indicated in these cases[14].

This study used the Super-EBA cement, an aluminum oxide reinforced form of zinc-oxide-eugenol based cement[16]. The eugenol contents can irritate periradicular tissues[13], so Super-EBA also contains o-ethoxybenzoic acid[6] allowing a decrease of eugenol in the material. Cement has a neutral pH value and low solubility, but it is also sensitive to moisture, radiolucent, and technique sensitive due to the fast setting. Another disadvantage is the inability to chemically adhere to dentin[13,16]. Numerous studies show that these ZOE containing materials are superior to amalgam in terms of sealability and biocompatibility[24].

A modified fluid transport apparatus was used in the study because of its ability to test under dynamic loading as is the root-end restoration exposed after placement of the root-end cavity. Furthermore, it allows repeated measurements of the same specimen. Clinically, a root-end filling could be under pressure from the bleeding and swelling caused by surgery. The periapical pressure applied to a root-end filling may be considerably increased when the tooth is in chewing function. The samples in this study were prepared under clinical conditions, so we applied higher pressure with fluid transport apparatus to determine if there is difference in the quality of sealing in the cavities produced by laser and cavities made by the conventional method[9].

The results of this study showed no statistically significant differences in the quality of seal between the cavities produced by laser and conventional method. Çalişkan *et al.* also concluded that using the Er,Cr:YSGG laser had no advantages over conventional root-end cavity preparation methods; however, they used a composite filling material to seal root-end cavities[15].

The results obtained in our study are difficult to compare with the results from previous studies. Different authors investigated the properties of materials just by comparing them with previously known materials on the market while the preparation technique was ignored, or they investigated the properties of materials taking into account the preparation technique of cavity, and the tests were conducted on conventionally endodontic treated roots. Super-EBA can serve as a satisfactory retrograde root-filling material in periapical surgery with ultrasonic preparation, according to the study conducted by Wälivaara *et al.*[12].

In our study, traditionally prepared cavities showed less leakage than the cavities made with laser, although the differences were not statistically significant. The explanation for such results can be found in the fact that the three millimeter root sections that were used for testing are difficult to handle during preparation due to the problem of their stable fixation. Since the laser preparation used a noncontact mode, the sense of direction and the sense of preparation depth are lost. Such preparation produced an irregular shape of the root-end cavity that did not allow proper adhesion of the cement, which has consistency of the paste on the cavity walls. Such a cavity probably caused greater leakage in combination with Super-EBA cement. Also, super-EBA cement cannot bind to dentin, so there is no beneficial effect of removing smear layer by laser preparation.

In conclusion, root-end cavity preparation in root sections using laser did not show statistically better results compared to the classic technique of root-end cavity preparation. Root-end fillings in the laser-prepared cavities showed greater leakage than fillings in the classically prepared cavities, although the difference was not statistically significant. The higher leakage value could be correlated to the irregular shape of the cavity.

References

1. WILSON NHF. Minimally invasive dentistry – the management of caries. London: Quintessence Publishing Co., 2007.
2. HARRIS DM, PICK RM. Laser physics. Chapter 2. In: MISERENDINO LJ, PICK RM, editors. Lasers in dentistry. Chicago: Quintessence Publishing Co., Inc., 1995;27-38.
3. GRGUREVIĆ J, GRGUREVIĆ L, MILETIĆ I, KARLOVIĆ Z, KRMEK SJ, ANIĆ I. *In vitro* study of the variable square pulse Er:YAG laser cutting efficacy for apicectomy. Lasers Surg Med 2005;36:347-50.
4. De MOOR RJ, DELMÉ KI. Laser-assisted cavity preparation and adhesion to erbium-laser tooth structure: Part 1. Laser-assisted cavity preparation. J Adhes Dent 2009;11:427-38.
5. ANIC I, MILETIC I, KRMEK SJ, BORCIC J, PEZELJ-RIBARIC S. Vibrations produced during erbium:yttrium-aluminum-garnet laser irradiation. Lasers Med Sci 2009;24:697-701.
6. CAMARGO VILLELA BERBERT FL, de FARIA-JÚNIOR NB, TANOMARU-FILHO M, GUERREIRO-TANOMARU JM, BONETTI-FILHO I, LEONARDO Rde T, *et al.* An *in vitro* evaluation of apicoectomies and retropreparations using different methods. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:57-63.
7. ARISU HD, SADIK B, BALA O, TÜRKÖZ E. Computer-assisted evaluation of microleakage after apical resection with laser and conventional techniques. Lasers Med Sci 2008;23:415-20.
8. SOUZA-GABRIEL AE, CHINELATTI MA, PECORA JD, PALMA-DIBB RG, CORONA SA. Dentin microhardness and subsurface morphology after Er:YAG laser cavity preparation using different parameters. J Dent Child (Chic) 2009;76:58-66.
9. KARLOVIC Z, PEZELJ-RIBARIC S, MILETIC I, JUKIC S, GRGUREVIC J, ANIC I. Erbium:YAG laser *versus* ultrasonic in preparation of root-end cavities. J Endod 2005;31:821-3.
10. WALLACE JA. Effect of Waterlase laser retrograde root-end cavity preparation on the integrity of root apices of extracted teeth as demonstrated by light microscopy. Aust Endod J 2006;32:35-9.
11. ADAMO HL, BURUIANA R, SCHERTZER L, BOYLAN RJ. A comparison of MTA, Super-EBA, composite and amalgam as root-end filling materials using a bacterial microleakage model. Int Endod J 1999;32:197-203.
12. WÄLIVAARA DÅ, ABRAHAMSSON P, FOGELIN M, ISAKSSON S. Super-EBA and IRM as root-end fillings in periapical surgery with ultrasonic preparation: a prospective randomized clinical study of 206 consecutive teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:258-63.
13. VERZAK Z, CELAP B, MODRIC VE, SORIC P, KARLOVIC Z. The prevalence of idiopathic osteosclerosis and

condensing osteitis in Zagreb population. J Acta Clin Croat 2012;51:573-8.

14. de MARTINS GR, CARVALHO CA, VALERA MC, de OLIVEIRA LD, BUSO L, CARVALHO AS. Sealing ability of castor oil polymer as a root-end filling material. J Appl Oral Sci 2009;17:220-3.
15. CALIŞKAN MK, PARLAR NK, ORUÇOĞLU H, AYDIN B. Apical microleakage of root-end cavities prepared by Er,Cr:YSGG laser. Lasers Med Sci 2010;25:145-50.
16. TOBÓN-ARROYAVE SI, RESTREPO-PÉREZ MM, ARISMENDI-ECHAVARRÍA JA, VELÁSQUEZ-RESTREPO Z, MARÍN-BOTERO ML, GARCÍA-DORADO EC. *Ex vivo* microscopic assessment of factors affecting the quality of apical seal created by root-end fillings. Int Endod J 2007;40:590-602.
17. CARDOSO MV, COUTINHO E, ERMIS RB, POITEVIN A, Van LANDUYT K, De MUNCK J, *et al.* Influence of Er,Cr:YSGG laser treatment on the microtensile bond strength of adhesives to dentin. J Adhes Dent 2008;10:25-33.
18. SULLIVAN J, PILEGGI R, VARELLA C. Evaluation of root-end resections performed by Er,Cr:YSGG laser with and without placement of a root-end filling material. Int J Dent 2009;2009:798786.
19. POZZA DH, FREGAPANI PW, XAVIER CB, WEBER JB, OLIVEIRA MG. CO(2), Er:YAG and Nd:YAG lasers in endodontic surgery. J Appl Oral Sci 2009;17:596-9.
20. Al-HIYASAT AS, Al-SA'EED OR, DARMANI H. Quality of cellular attachment to various root-end filling materials. J Appl Oral Sci 2012;20:82-8.
21. von ARX T, PEÑARROCHA M, JENSEN S. Prognostic factors in apical surgery with root-end filling: a meta-analysis. J Endod 2010;36:957-73.
22. BORTOLUZZI EA, BROON NJ, BRAMANTE CM, GARCIA RB, de MORAES IG, BERNARDINELI N. Sealing ability of MTA and radiopaque Portland cement with or without calcium chloride for root-end filling. J Endod 2006;32:897-900.
23. OTANI K, SUGAYA T, TOMITA M, HASEGAWA Y, MIYAJI H, TENKUMO T, *et al.* Healing of experimental apical periodontitis after apicoectomy using different sealing materials on the resected root end. Dent Mater J 2011;30:485-92.
24. KIM S, KRATCHMAN S. Modern endodontic surgery concepts and practice: a review. J Endod 2006;32:601-23.

Sažetak

UČINKOVITOST Er:YAG LASERA U PREPARACIJI KAVITETA ZA RETROGRADNO PUNJENJE – *IN VITRO* STUDIJA

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Svrha ovoga rada bila je utvrditi kakvoću brtvljenja Super EBA cementa za retrogradno punjenje u laserom izrađenim kavitetima naspram kavitetima izrađenim mikromotorom klasičnom tehnikom. U tu svrhu korijenske sekcije debljine 3 mm preparirane su laserskim uređajem i čeličnim svrdlom montiranim na kirurški mikromotor. Kaviteti su ispunjeni Super EBA cementom i njihova propusnost je mjerena pomoću modificirane aparature za prijenos tekućine. Utvrđeno je da je brtvljenje ispuna u klasično izrađenim kavitetima bolje, makar razlika propuštanja prema laserski izrađenim kavitetima nije bila statistički značajna. Takav rezultat pripisuje se nepravilnom obliku kaviteta i nemogućnosti dobre adaptacije cementa na stijenke nepravilnog kaviteta.

Ključne riječi: *Korijenski kanal, preparacija; Laseri, solidni; Laser Er:YAG; Apikoektomija; Korijenski kanal, punila; Cement Super EBA; Retrogradni kavitet*