Morphological Study on Apicoectomy by High-Powered Er:YAG Laser

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Purpose: In order to investigate the possibility of using the Er:YAG laser for apicoectomy and root-end sealing, the procedure time, dye penetration at the site of root-end sealing, and surrounding morphological differences were investigated.

Materials and Methods: In 48 extracted human mandibular second premolars, root canal therapy was performed in the conventional manner. The Er:YAG laser was used for apicoectomy at either 3, 5, or 7 W. After preparing a root-end cavity about 5 mm deep, root-end sealing was performed using amalgam or light-cured resin. For control, an engine-driven fissure bur was used. Next, the root apex was polished, and dye penetration was assessed at depths of 1, 2, 3, and 4 mm. Morphological observations were carried out by x-ray imaging, stereoscopic microscopy, and scanning electron microscope (SEM).

Results: When compared to the conventional rotary cutting device, the time required for 5- or 7-W laser apicoectomy was significantly shorter. The cut dentin surface in the laser application group was smooth, and carbonization, fissures, and marked evaporation were not seen. Dye leakage was only slight, with no significant difference between the laser and control groups ($p < 0.01$).

Conclusions: The time for apicoectomy using the Er:YAG laser was shorter when compared to apicoectomy using the engine-driven rotary cutting device, and the level of dye leakage was comparable to the conventional method. The cut surface for root-end sealing had no residual smear layer and was clean. Favorable results were obtained with 3-W laser application in terms of cut surface condition, therapy time, and sealant gap.

Keywords: Er:YAG laser, apicoectomy, root-end sealing, leakage test, treatment time, SEM.

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When the outcome of conventional root canal therapy is poor or when the root canal cannot be sufficiently enlarged down to the apical foramen, apicoectomy is performed to preserve teeth by simultaneously eliminating the apical lesions and the root apex, which is the source of infection.[1]

In general, on the cut apical surface following resection, a cavity is prepared from the apex towards the crown prior to root-end sealing.[2] The objective of root-end sealing at the apical area is to block the root canal from the periapical tissue. At present, carboxylate cement, glass-ionomer cement, super EBA cement, composite resin, amalgam and MTA are being used.[3] However, it is difficult to completely block leakage at the root end with any material, and the problems with leakage may remain.[4] The leakage after apicoectomy may depend on different sealants, but it may also be dependent on dentin cutting methods and cutting surface conditions.

For apical cutting and cavity preparation in apicoectomy, rotary cutting devices and ultrasonic tips are often used.[5,6] We have shown that, in apicoectomy, the use of an electric engine-driven steel bur likely causes dentin cracks, the vibrations are uncomfortable, and infection due to debris and residual smear layer is common.[7] Furthermore, it is difficult to use an electric rotary cutting device near the apex with missing bone within an extremely limited area.[8]

In recent years, lasers have been applied in various areas of dentistry, and studies have reported the use of different lasers in apicoectomy.[9-11] It has been shown that the heat generated during laser application can damage the pulp and surrounding tissue.[12] Because of its wavelength, the Er:YAG laser is readily absorbed by water, and since cutting is carried out under water irrigation during laser application, the effects of heat are lower when compared to the other lasers. Subsequently, studies have reported that when using the Er:YAG laser, apicoectomy can be performed without inducing heat damage to the periodontium.[13-15] Paghdiwala and colleagues performed apicoectomy using the Er:YAG laser and reported that the cut dentin surface was very smooth and clean.[16]
Therefore, we decided to use the Er:YAG laser not only for apicoectomy, but also root-end sealing, which is always performed following apicoectomy. The present study was conducted on the basis of a hypothesis that the time required to complete apicoectomy would be shorter, morphologically observed cut surfaces would be smoother, and dye leakage at the site of root-end sealing would be less than for conventional apicoectomy.

MATERIALS AND METHODS

Teeth and Experimental Groups

After obtaining approval of the ethical review board of Showa University School of Dentistry (approval No. 2008-30), 48 extracted human mandibular first and second premolars were used. All teeth had a single root. The teeth had been extracted due to periodontal disease, apical periodontitis, or orthodontic therapy, and all teeth were nonvital without past root canal therapy or curvature. According to our previous study, the circumference of the area 3 mm from the apical foramen was 10 ± 1 mm.[17]

Because the teeth were collected over a period of four months, to even the characteristics of soft tissue inside the root canal, the teeth were immediately soaked in 10% formalin solution and were placed in distilled water 7 days before the start of the study.[3]

After mechanically removing the periodontium and dental plaque attached to the teeth, the crown was sectioned so that the length of each sample would be 15 mm. After pulp cavity perforation, crown removal and root canal orifice identification were performed by the conventional method, root canal enlargement and preparation were carried out using a manual K file to a working length of 1 mm shorter than the root canal length. The final enlargement size was No. 40. During this time, the root canal was alternatively washed using 5% NaOCl and 3% H_2O_2 as needed, and after drying the root canal using a sterile paper point (Johnson & Johnson; New Brunswick, NJ, USA), the root canals were obturated by lateral condensation using a gutta-percha point (GC; Tokyo, Japan) and root canal sealing cement (Canals N, Showa Yakuhin Kako; Tokyo, Japan). After root canal filling, phosphate cement (GC; Tokyo, Japan) was used for temporary sealing, and radiographs were taken from the mesiodistal direction to confirm whether or not the root canal sealing matched the working length and was tight. In order to prevent dye leakage into dentinal tubules and medullary canal when the samples were soaked in a dye, the entire tooth was coated twice using nail polish.

Group Design

Forty-eight samples were randomly divided into 8 groups of 6 teeth each (Table 1). Root tip cutting, root-end cavity preparation and root-end sealing were performed using the Er:YAG laser and resin sealant (groups 1, 2, and 3) or using the Er:YAG laser and amalgam (groups 4, 5, and 6). For comparison, engine-driven fissure bur and resin sealant were used in group 7 and engine-driven fissure bur and amalgam were used in group 8. The output power of laser application was set at 3, 5, or 7 W. The details are shown below.

Apicoectomy

Apicoectomy was performed by an experienced researcher who was unaware of the study details, but was familiar with the instruments used. Apicoectomy was carried out at an angle of 90 degrees in relation to the tooth axis, under water irrigation at a rate of 10 ml per min at 3 mm from the root tip. For the laser group, the Er:YAG laser (Smart 2940D, DEKA; Florence, Italy) was used. The Er:YAG laser had a wave-

Table 1 Group design

Group	Irradiation Output	Filling Materials
1 (n=6)	3 W	Resin
2 (n=6)	5 W	Resin
3 (n=6)	7 W	Resin
4 (n=6)	3 W	Amalgam
5 (n=6)	5 W	Amalgam
6 (n=6)	7 W	Amalgam
7 (n=6) Control	–	Resin
8 (n=6) Control	–	Amalgam
(Total 48 samples)		

length of 2940 nm, maximum frequency of 20 Hz, pulse width of 80-700 µs, and maximum energy output on the irradiated surface of 700 mJ (output panel: 7.7 W). In the present study, instead of a cylinder-shaped sapphire tip, a light collecting mirror-type tip (Fig 1) was used with output of 3, 5, or 7 W.

The focal length from the lens to the irradiated body was set at 10 mm, and the handpiece was fixed so that the area of laser application on the tooth surface was as even as possible. By attaching a power meter (Laser power, Energy Monitor Model DGX, Ophir; Jerusalem, Israel) to the mirror-type tip, energy output at the tip was set beforehand.

For the control group, a No. 21 steel fissure bur was attached to the engine-driven handpiece (4500 rpm), and apicoectomy was performed using the same volume of water at the same site and angle as the laser group.

The cut surface of all samples was analyzed under a stereomicroscope (Nikon; Tokyo, Japan). Further, the time required to cut off the root tip was measured, and intergroup differences were statistically analyzed using Kruskal-Wallis and Fisher's PLSD tests.

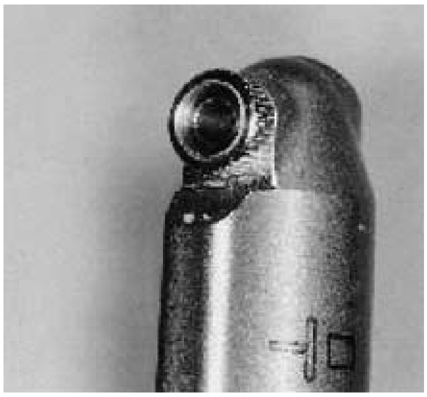


Fig 1 Mirror-type tip.

Root-end Cavity Preparation and Sealing

After apicoectomy using either the Er:YAG laser or the engine-driven fissure bur, root-end cavity preparation was carried out perpendicular to the cut surface using the same cutting device and output. Water was sprayed under the same conditions. During cutting with either laser or fissure bur, physical energy was concentrated at the center of the gutta-percha exposed on the cutting surface. When the gutta-percha was removed to a depth of 2 mm, the handpiece was rotated to disperse the focal point to the surrounding dentin to form an elliptical cavity with a long diameter of 5 mm and a depth of 5 mm. Then, radiographs were taken at the angle (mesiodistal direction) that was measured immediately following root canal filling.

After washing and drying the cut surface, a bonding agent (Clearfil New Bond, Kuraray Medical, Tokyo, Japan) was applied to the resin group (groups 1, 2, 3, and 7), and light-cured resin (Silux-PLUS Universal, 3M, US) was used for sealing. A halogen lamp (Optilux 400, Demetron; Danbury, CT, USA) was used to light cure the area from the apical side for 30 s. The light source of the lamp has a comprehensive (blue) wavelength ranging from 375 to 505 nm (peak near 490

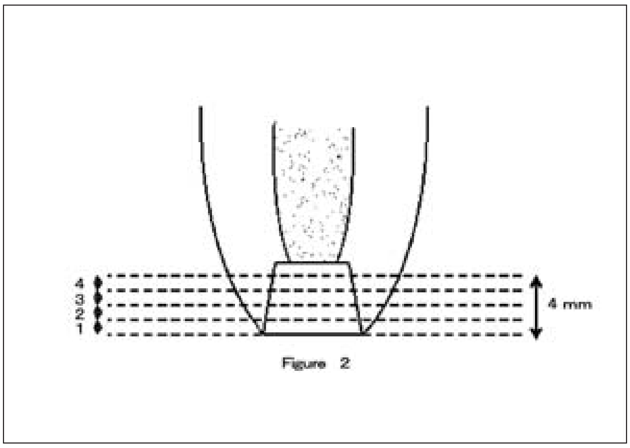


Fig 2 Analyzed layers of apical sealing.

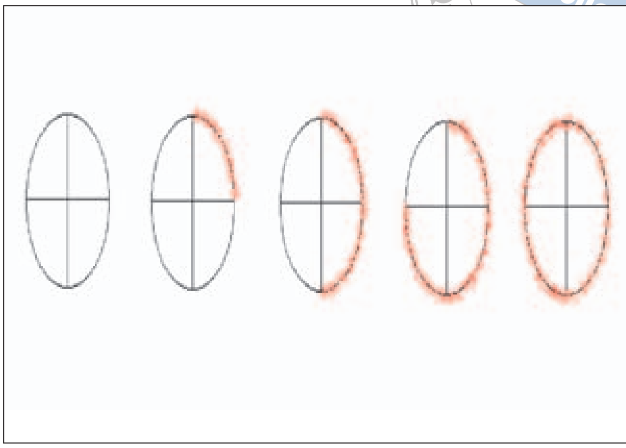


Fig 3 Assessment standards for the microleakage test. From the leftmost, 0 point, 1 point, 2 point, 3 point, and 4 point.

nm). In groups 4, 5, 6, and 8, amalgam (Spherical-D, Shofu; Kyoto, Japan) was used for sealing in a single step according to the manufacturer's instructions.

For the two control groups (cutting and cavity preparation using the fissure bur), in order to simulate clinical settings, a small cotton ball soaked in 15% EDTA (disodium edetate hydrate cetrimide, Showa Yakuhin Kako) was placed on the cut surface of each tooth as dentin pretreatment for 30 s, and the teeth were washed and then sealed.

Statistical Assessment of Microleakage

Five hours after root-end sealing, each tooth was soaked in 1% rhodamine B (1% rhodamine B, Musashi Kagaku; Tokyo, Japan) to a depth of 7 mm with the cut apical surface facing downwards using a fishing line and kept warm for 48 h in a constant temperature bath of 37°C. Then, the cut root surface of each tooth was polished every millimeter up to 4 mm in the apical-to-crown direction (Fig 2), and a stereomicroscope (Nikon; Tokyo, Japan) was used to observe dye leakage on the cut surface. According to the assessment standards shown in Fig 3, dye leakage was assessed using the worst score of each sample. In order to ascertain the relationship between leakage and sealants, a Mann-Whitney test was used to compare the laser (groups 1, 2, 3, and 7) and amalgam (groups 4, 5, 6, and 8) groups ($p < 0.05$). Furthermore, separately in the laser group and the amalgam group, a Kruskal-Wallis test ($p < 0.05$) was used to ascertain the statistical significance of laser outputs and their correlations to the control groups.

Morphological Observation of the Bonded Area

The samples that were polished to 4 mm were subjected to a series of alcohol dehydration, critical point drying and platinum evaporation in the conventional manner. The bonded area between the cavity dentin and sealant was morphologically observed with a scanning electron microscope (FE-SEM 4700, Hitachi; Tokyo, Japan).

RESULTS

In the present study, in order to gather basic data regarding the newly developed high-power Er:YAG laser, the time required for apicoectomy, the morphological changes due to resection and root-end cavity preparation, and dye leakage were analyzed using 48 extracted human mandibular first and second premolars. The results were as follows:

Time Required for Apicoectomy

The average time for 3-W laser apicoectomy (groups 1 and 4) was 46 s, 5-W laser apicoectomy (groups 2 and 5) 19 s, 7-W laser apicoectomy (groups 3 and 6) 10 s and fissure-bur apicoectomy (groups 7 and 8) 52 s.

Table 2 Treatment time for resection

Group	Number of samples	Resection mode	Mean Value (s)
1, 4	12	3-W Laser	46.06
2, 5	12	5-W Laser	18.86
3, 6	12	7-W Laser	9.50
7, 8	12	Control	51.84

* Statistically significant difference among 4 groups (Kruskal-Wallis test, $p = 0.001$).
* No statistically significant difference between 3-W laser and control (Fisher's PLSD test, $p < 0.05$).

Statistically significant differences were seen among the four groups (Kruskal-Wallis test, $p < 0.01$, Table 2), and except between 3-W laser and the control groups, the differences were statistically different (Fisher PLSD, $p < 0.05$, Table 2). In other words, the time required for apicoectomy was the shortest with 7-W laser, followed by 5-W laser, 3-W laser and fissure bur, in this order.

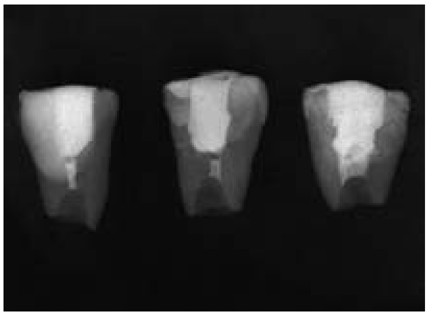


Fig 4 X-ray images following apicoectomy and root-end cavity preparation (From left, 3-, 5- and 7-W laser application).The bottom surface of the cavity of all samples was round and U-shaped, there was no deviation in the direction of formation, and the dentin was sufficiently thick.

Stereoscopic and X-ray Findings

Stereoscopic images immediately following root tip cutting were compared. In the laser group, the cut surface was smooth and flat under all irradiation conditions, and the cut surface was almost vertical to the tooth axis. Findings such as carbonization, microcracks or fusion were absent. In the control group, microcracks were seen around the cut dentin surface of some samples.

On x-ray images following root-end cavity preparation, the cut surface was mostly even along the root canal wall under all irradiation conditions, and there were no findings indicative of insufficient cavity preparation, thin root canal wall, marked evaporation, or labial or lingual deviation. Gutta-percha points were removed carefully (Fig 4). The laser was applied to prepare a root-end cavity with a diameter of 5 mm and a depth of 5 mm. Although the depth was 5 mm as planned, the diameter was larger at about 7 mm. The cavity was U-shaped with the tip at the center of the gutta-percha, and the cavity margin circumference flared inward and was larger than the bottom surface circumference. In additon, in one 7 W sample, the lateral wall of the cavity was wavy, and the bottom surface was wide at the cavity floor, but root canal wall thinning was not seen.

In the control group, the outer shape of the cavity was formed as planned, and a cavity having mostly parallel lateral walls was prepared, but in two teeth, the dentin wall near the cut surface was damaged.

Results of Dye Leakage Test

A dye leakage test was performed, and the Mann-Whitney test was used to assess the results according to the methods shown in Figs 2 and 3 ($p < 0.05$). A statistically significant difference was seen between the resin group (groups 1, 2, 3, and 7) and the amalgam group (groups 2, 3, 4, and 8) ($p < 0.05$). When using amalgam, the scores were the same for the laser and control groups. The Kruskal-Wallis test did not show any statistically significant difference ($p < 0.05$) (Table 3) between groups 1, 2, 3, and 7 and groups 4, 5, 6, and 8. Figures 5 through 10 show stereoscopic images with the worst scores first and with the best scores last.

Table 3 Dye leakage test scores

Group	Treatment?	0 mm	1 mm	2 mm	3 mm	4 mm	Total
1 (n=6)	3-W laser + resin	15	14	10	9	5	53
2 (n=6)	5-W laser + resin	15	15	12	9	6	57
3 (n=6)	7-W laser + resin	16	14	13	11	9	63
4 (n=6)	3-W laser + amalgam	24	24	24	24	24	120
5 (n=6)	5-W laser + amalgam	24	24	24	24	24	120
6 (n=6)	7-W laser + amalgam	24	24	24	24	24	120
7 (n=6)	bur + resin	16	14	12	7	7	56
8 (n=6)	bur + amalgam	24	24	24	24	24	120

Each number shows the total score of 6 samples. A statistically significant difference is recognized between groups 1, 2, 3, 7 (Resin groups) and groups 4, 5, 6, 8 (Amalgam groups). (Mann-Whitney U- test, $p < 0.05$). No statistically significant difference among groups 1, 2, 3, 7 (Resin groups) (Kruskal-Wallis test, $p < 0.05$). No statistically significant difference among groups 4, 5, 6, 8 (Amalgam groups) (Kruskal-Wallis test, $p < 0.05$).

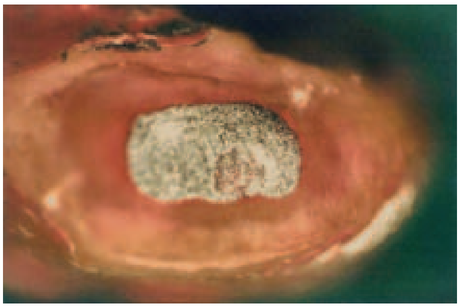


Fig 5 Representative LM image of group 6 (7 W, amalgam). Dye leakage was observed around the sealant. In order to avoid metal reflection, the images were taken by light microscopy with low light and long exposure. Score 4.

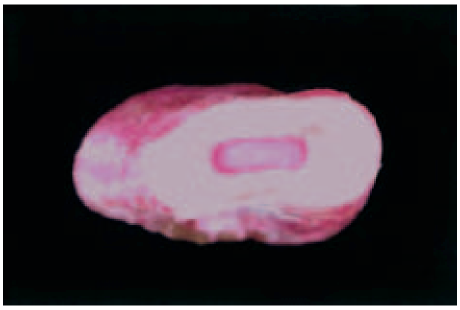


Fig 6 Representative LM image of group 7 (control, resin). Leakage was observed around the cavity. Score 3.

Fig 7 Representative LM image of group 3 (7 W, resin). Score 3.

Fig 8 Representative LM image of group 2 (5 W, resin). Score 2.

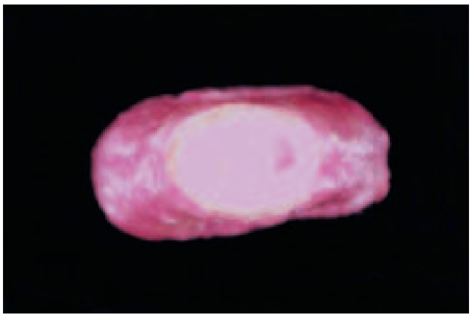


Fig 9 Representative LM image of group 1 (3 W, resin). Score 1.

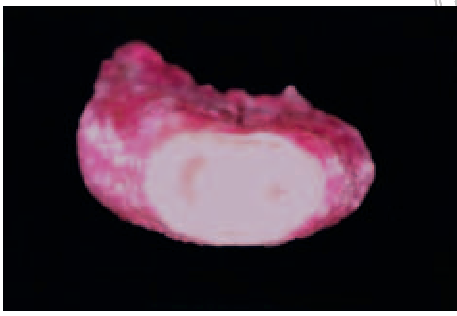
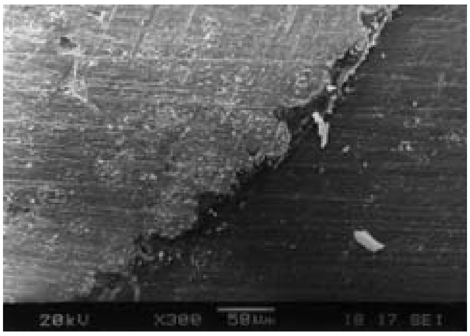
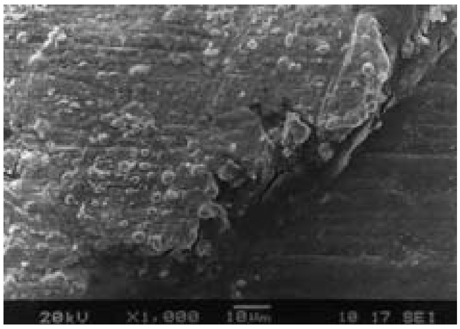


Fig 10 Representative LM image of group 1 (3 W, resin). Score 0. Most of the samples in this group demonstrated good results.





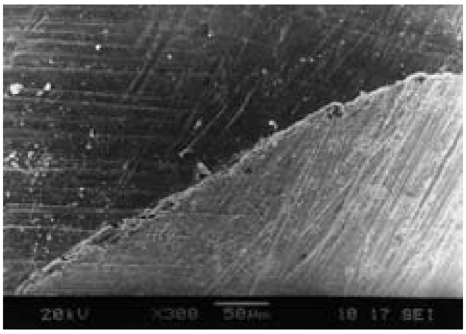
Figs 11 and 12 Representative SEM images of group 1 (3 W, resin). Low magnification (300X, left) and high magnification (1000X, right). The bonded surface was irregular like a coastline, but no gap was seen, and bonding was most favorable.

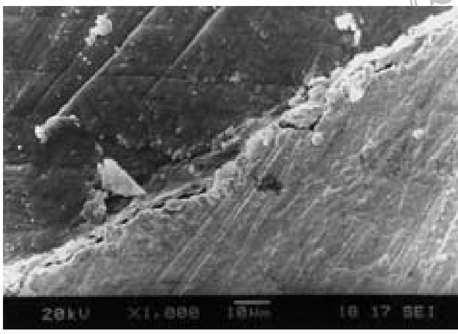
SEM Findings

The SEM results of samples polished up to 4 mm for the laser group are shown below. In group 1, where a 3-W laser was applied and resin sealant was used, no smear layer was seen on the bonded area, and gap formation was mostly absent (Figs 11 and 12). On the dentin side of the bonded area, roughness resembling a deeply indented coastline was seen, and the resin was closely adhered. Because gaps were not seen, there was no smear layer or debris on the bonded area. Like group 1, the results were the same for group 2, where a 5-W laser was applied and the resin sealant was used. In group 3, where a 7-W laser was applied and the resin sealant was used, there were no large gaps, but there was an intercalated layer between dentin and resin (Figs 13 and 14). This was not seen in group 1 (3 W + resin) or group 2 (5 W + resin). After cavity preparation using the engine-driven fissure bur, the superficial dentin layer was pretreated using EDTA and amalgam was used as a sealant (group 8), the smear layer existed in the bonded area, and a wide gap was seen almost circumferentially (Fig 15).

DISCUSSION

In teeth that cannot be treated by conventional root canal therapy, apicoectomy is performed as an auxiliary endodontic surgery.[18] At present, apicoectomy is performed mainly using a rotary cutting device in clinical settings, but there is a concern that the prognosis of these teeth may be affected by the friction heat during cutting and during rotation, cracks due to rotation-related vibrations, excessive dentin removal or residual fragments containing harmful substances.[19,20] Therefore, in the present study, Smart 2940D made by DEKA in Italy was used because its output is higher than the conventional Er:YAG laser.[21] It is a pulsed laser that has succeeded in increasing peak power per pulse, and it has the maximum pulsed output of 7.7 W.[22] Prior to clinical application, a study was con-





Figs 13 and 14 Representative SEM images of group 3 (7 W, resin). Low magnification (X300, left) and high magnification (X1000, right). A single-layered structure was seen in the bonded area, and there was a slight gap along the bonded area.

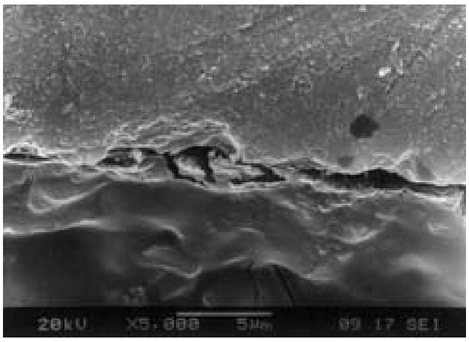


Fig 15 Representative SEM image of group 8 (control, amalgam). A high magnification image (5000X) showing the smear layer and debris in the gap. In the cavity margin of the dentin, defects were seen due to fissure-bur vibrations, and the gap was almost circumferential.

ducted to gather the basic data, and the above-mentioned results were obtained. The results are discussed below.

Cutting Area and Time

In the present study, either the Er:YAG laser or engine-driven bur was used to cut teeth perpendicular to the tooth axis at a point 3 mm from the apical tip. With regard to the site of apical cutting, Sawada reported that 98% of root canal branches could be eliminated by cutting the root apex by 3 mm.[23] Moreover, regarding the cut surface angle, Vertucci reported that leakage following root-end sealing is related to the cut surface and dentinal tubule alignment,[24] and Chandler reported that dye leakage was milder when cut orthogonal to the tooth axis than when cut at an angle.[1] Based on the above report, apicoectomy was performed orthogonal to the tooth axis 3 mm from the apical tip in the present study, and the time required to complete apicoectomy was compared. The time for apicoectomy was significantly shorter with 5 or 7 W. When examined by x-ray, visual inspection, and palpation, the cut area was smooth without roughness. The reason for this was that in the present study, a light collecting mirror-type tip was used with a fixed focal distance (10 mm), output, and application time. In terms of methods for forming a box-shaped cavity such as using a fissure bur for the control group, the attached columnar sapphire tip with about 1.5 mm width could have been used, but a box-shaped cavity preparation was not done because resins and cements are mostly used for root-end sealing.

The above findings suggest that the dentin cutting performance of the present laser unit is sufficient, and the higher the output, the higher the cutting efficiency. However, in the present study, there were slight differences in the time for laser apicoectomy under the same output. The reason for this is that the focal distance from the lens was about 10 mm, but as cutting advanced, the focal distance changed, and while manually trying to keep the focal distance at 10 mm, there were slight displacements in angle and distance, resulting in differences in the amount of absorbed energy. Furthermore, there were differences in laser absorption with respect to the moisture content of teeth themselves, the degree of calcification, and surface properties.

Morphological Observations

The smear layer attached to the cut dentin surface is one of the causes for gap formation. While the clinical significance of the smear layer is not necessarily clear, the presence of bacteria and harmful substances in fragments created by mechanical cutting is disadvantageous, and many studies have reported the necessity of smear layer removal, especially in infected root canals.[25] It has also been reported that the smear layer lowers the sealant adhesion to dentin,[26] and the existence of the smear layer is believed to affect the prognosis. Due to the reasons above, it is necessary to remove the smear layer, and this is particularly important for previously root canal-treated teeth.

In the present study, stereomicroscopy was performed to analyze the cut surfaces, and SEM was used to analyze the sealant bonded areas; however, on the dentin surface that was cut using the Er:YAG laser, marked evaporation, fissure and carbonization were not observed, and there was not much smear layer on the bonded surface. The principle of hard tissue cutting by the Er:YAG laser is that instead of dissolving dentin, a few water molecules in a micro-area irradiated with laser vaporize by rapidly absorbing energy, and this force increases the internal pressure to cause a micro-explosion, thus physically destroying hard tissue.[27] During the series of cutting, the smear layer is also washed away by the water irrigation. Furthermore, the 2.94-µm oscillatory wavelength of the Er:YAG laser resembles the maximum absorption band of water, and the heat generated during laser application is lower when compared to the Nd:YAG laser or CO_2 laser.[28] In the present study, SEM findings suggest that the effects of heat stimulation were extremely low.

Additionally, because the Er:YAG laser is a pulsed wave, we thought that the morphology of the cut surface would be markedly wavy, but in reality, when compared to the cut surface for the rotary cutting device, the degree of roughness was lower, and the tendency was that the lower the laser output (from 7, 5 to 3 W), the smoother was the cut surface created orthogonally to the tooth axis. However, SEM of the sealant bonded area following root-end sealing showed more linear cavities with 7 W (Figs 13 and 14) when compared to 3 W (Figs 11 and 12), probably because the time required for cavity preparation was shorter with 7 W. It was noted that there was a gap and a sandwiched layer in the 7 W sample (Figs 13 and 14). It is not clear whether the inclusion is a resin impregnated layer or whether it is a layer that is fixed to the axial lateral wall following gutta-percha fusion, but in either case, a slight gap adjacent to the inclusion suggests a high incidence of leakage. In other words, when using the Er:YAG laser, the output of 7 W is too high for apicoectomy.

In groups 5 and 6, where 5- or 7-W laser was applied and amalgam was used, the cut dentin surface was wavy, and a clear gap was formed circumferentially (Fig 15). While the bonded surface on the dentin side was linear, the dentin margin was missing. Vibrations due to the fissure bur led to microcrack formation. However, when using amalgam, metal oxidation occurs with time and the gap is filled by rust formation, and because resin does not absorb water, the probability of bacterial invasion through the gap or sealant should be low in the long term. In the present study, the preparation for morphological observations started only after 2 days of sample preparation, and long-term leakage was not compared.

Dye Leakage Test

The results of the dye penetration test were evaluated using the assessment methods for cavity preparation previously employed by our department.[29] These assessment methods were employed for the ease of statistical analysis. A method where teeth are soaked in 1% rhodamine B solution for 48 h has been widely used for a long time, and it was also employed in the present study, and areas of dye leakage could easily be identified. In the present study, no statistically significant difference was seen between the Er:YAG laser group and the control group with resin sealing, and dye leakage was seen in both due to the formation of contraction gaps as seen by SEM. The reason for this was that in both the control and Er:YAG laser groups, dye leakage was mild at areas without gaps.

In the present study, no statistically significant difference was seen, but the tendency was that the lower the laser output, the lower the dye leakage. Although further investigations are needed to analyze the details, when eliminating microleakage, it may be effective to cut and eliminate the root tip at high output, form a root-end cavity at high output and then treat the dentin surface by applying low output laser to the cut surface.

With regard to the morphological characteristics of dye leakage, the dye diffused in either the dentin direction or the sealant direction (Figs 5 to 10). The latter may be explained by the presence of unpolymerized resin sealant, but in the former, the reason was that dentinal tubules were open and the smear layer was removed. In the present study, on 4-mm polished surfaces, the reason for dye diffusion to the dentin and resin directions was incomplete resin polymerization or vacuolization.

Clinical Application

When using the Er:YAG laser in clinical settings, apicoectomy can be performed in a short time, and there is not much smear layer. Furthermore, procedures such as EDTA application, washing and drying, are not needed, and there is no risk of demineralization of the healthy dentin underneath the smear layer by a treatment agent. Hence, the Er:YAG laser is useful for apicoectomy requiring quick management.

However, with high-output application, the cut surface was highly irregular, and the fragile heat-denatured layer formed on the dentin surface layer may lower adhesion. When performing resin sealing as a preventive measure, it is effective to apply low-output laser twice to the healthy dentinal tubules for resin tag formation and hybridization.

In the present study, a halogen lamp was used for resin polymerization, and areas that appear to be unpolymerized were seen in the deep region. To solve this problem, it is desirable to apply the argon laser for a short period of time.[30] Moreover, when moisture exclusion is difficult and quick procedures are required, it is necessary to perform root-end sealing by combining various lasers for hemostasis and apical cavity sterilization, disinfection and drying.

With the past methods, sterilization, disinfection, and drying were not often adequately performed, but many studies have documented that the Er:YAG laser sterilizes and inactivates endotoxin.[31,32] Since laser application can not only sterilize, disinfect and dry, but also make teeth acid resistant, the clinical significance of combining laser application is high in patients whose teeth require moisture exclusion, disinfection, or sterilization.[33,34]

CONCLUSIONS

In the present study, in order to gather basic data for high-powered Er:YAG laser, morphological changes due to apicoectomy and dye leakage at the site of root-end sealing were investigated, and the following conclusions were obtained:

1. Apicoectomy was performed using the Er:YAG laser, and when compared to the electric engine (4500 rpm), the time required was significantly shorter at 5 or 7 W.
2. Cut surfaces were observed by stereomicroscopy, and although findings such as carbonization, cracks, and fusion were not seen in the dentin of the laser group, debris, smear layer, and fissures were seen in the samples cut using an engine-driven fissure bur.
3. X-ray imaging was performed to observe the morphology of root-end cavities created by the Er:YAG laser, and the cavities were U-shaped without labial or lingual deviation.
4. A dye leakage test showed that the degree of leakage for the resin group was significantly lower when compared to the amalgam group. No statistically significant difference was seen between the Er:YAG and control groups. However, the tendency was that the lower the output, the smaller the leakage.
5. SEM showed hardly any smear layer between the sealant and the cavity made by the Er:YAG laser. The tendency was that the higher the energy output, the greater the cavity margin roughness.

The above findings suggest that the use of the Er:YAG laser in apicoectomy is clinically effective.

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