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Application of Lasers for Treatment of Pulp Chamber Perforation

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Purpose: Pulp chamber floor perforations were created in extracted teeth, and dentin was pretreated using EDTA or Nd:YAG laser. Then, a microleakage test was conducted, and polymerization of light-cured composite resin using the argon laser or a halogen lamp was compared.

Materials and Methods: Thirty-six extracted teeth were divided into 6 groups, and after root canal preparation and filling in a conventional manner, a hole was artificially made in the pulp chamber floor. For dentin pretreatment prior to placing the filling material, 15% EDTA or Nd:YAG laser was applied. Either amalgam or light-cured composite resin was used as filling material. Either the argon laser or halogen lamp was employed as the light source for polymerization. The entire surface was coated using nail varnish, and the tooth was soaked in 1% rhodamine solution to assess dye leakage. Using stereoscopic and scanning electron microscopes, adhesion between the filling material and cavity margin, and dye penetration were observed. The results were statistically analyzed using a Kruskal-Wallis test.

Results: The microleakage test showed no statistically significant difference between dentin pretreatments with EDTA application and Nd:YAG laser application. However, when amalgam was used, dye leakage was seen in all cases regardless of the method of dentin pretreatment. SEM observation showed that when a light-cured composite resin was used, the volume of smear layer with Nd:YAG laser was less when compared to EDTA.

Conclusions: Pulp chamber floor perforations can be effectively treated by eliminating the smear layer using the Nd:YAG laser and polymerizing the light-cured composite resin using the argon laser.

Keywords: pulp chamber floor perforation, Nd:YAG laser, argon laser, dye penetration, smear layer, SEM.

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During root canal therapy, despite meticulous care and attention, accidental perforation of the pulp chamber wall by a cutting instrument may occur. Based on anatomical location, pulp chamber perforation can be roughly divided into gingival and periodontal membrane types. The periodontal membrane type is further divided into pulp chamber floor, apical, and lateral root canal wall subtypes.[1] Of these, perforation of the pulp chamber floor is extremely difficult to treat, and studies have shown that the prognosis is markedly worse when compared to the other types of perforations.[2-4] The basic treatment for pulp chamber floor perforations is to sterilize the affected area and form an airtight seal. In other words, the following 4 procedures should be employed: 1) infection control, 2) hemostasis, 3) cleaning, sterilizing, and drying, and 4) sealing of the perforation.[5]

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If a hole is made in the pulp chamber floor of a tooth with multiple roots, especially a molar, the roots are separated and restored at the end, but with maxillary molars, trisection can lead to the loss of one root. Therefore, when conditions permit, the perforation should be closed using a filling material. However, due to its location, pulp chamber floor perforation in molars cannot be treated by placing a filling material from the lateral aspect, as this requires a surgical procedure. Therefore, a filling material is often placed from inside the pulp chamber.[6] The prognosis is affected by the location, size, and treatment of perforation and the marginal seal of the filling material.[7,8] Poor marginal seal can lead to the loss of the filling material or infection due to marginal leakage.[9,10]

Cements, resins, and amalgam are often used to close perforated areas. For pulp chamber floor perforation, light-cured composite resin is often preferred due to its improved strength and biocompatibility. In Japan, amalgam is very rarely used today, but in various parts of the world, amalgam is still used due to its low cost, marginal seal that improves over time, and superior strength. Since esthetics is not an issue for the pulp chamber floor, the use of amalgam should be reevaluated in Japan.

With pulp chamber floor perforation, it is necessary to minimize leakage by packing a filling material as airtight as possible. Therefore, it is generally accepted that the debris and smear layer on the dentin surface should be completely eliminated. At present, chemicals, including EDTA, are often used to clean the wall surface through the chelate demineralization of inorganic materials. However, chemicals that remove the smear layer may weaken the healthy dentin underneath the smear layer.

Ever since Maiman applied the ruby laser for dental therapy, various lasers with different properties have been developed and introduced for dental treatment. Along with the carbon dioxide and Er:YAG lasers, the Nd:YAG laser has been widely used in dental offices all over the world. The Nd:YAG laser is an individual infrared laser with a wavelength of 1064 nm. Its absorbance by water and biological tissue is moderate, and when compared to the carbon dioxide and Er:YAG lasers, absorbance is lower. The absorption efficiency by black pigment is high, and blood coagulation is high because of high absorption by hemoglobins and heat-induced protein coagulation. Moreover, the pulsed Nd:YAG laser generates less heat in tooth tissue. Therefore, in the present study, we investigated the effects of dentin pretreatment of perforated areas using 15% EDTA, which has been shown to possess superior cleaning effects, or by irradiating perforated-area dentin using the Nd:YAG laser.[11-13]

For polymerization of light-curing composite resins, either a halogen or xenon lamp has been used for photopolymerization due to their wavelength characteristics. However, it takes 30 to several dozen seconds to achieve complete effects, and because the pulp chamber floor is surrounded by crown walls and is far from the irradiation tip, the possibility of casting a shadow is high, and the necessary amount of light may not reach the area. Subsequently, it was assumed that by utilizing a laser – which is a thermogenic source having a very narrow straight-line trajectory – resin can be cured using heat energy which can be controlled with an appropriate level of high output application.

The argon laser is a visible light laser with a wavelength of 488 nm. Therefore, its color tone is between blue and green and is similar to the conventional halogen light. While halogen light is blue due to the combination of multiple wavelengths, the laser has a coherent single wavelength. The absorption rate of the argon laser is high for hemoglobin, and it penetrates deep into soft tissue. In the present study, argon laser irradiation was used for curing resin.

In dentin perforation at the pulp chamber floor, the dentin is thin and the floor is wet, and since the floor is located at the bottom of a narrow pulp chamber, it is difficult to carry out therapeutic procedures. In the present study, in order to ascertain the effects of the above-mentioned two lasers on the marginal seal of the filling materials in pulp chamber floor perforation, extracted teeth were used to observe the microstructures of dye penetrated areas under a stereoscopic microscope (LEM) and scanning electron microscope (SEM).

MATERIALS AND METHODS

Subjects

The study was approved by the ethical review board of Showa University School of Dentistry (No. 2008-29). Thirty-six extracted human mandibular molars were used. All teeth had three root canals with two roots, and the area of the triangle connecting the three root canals ranged from 7 to 12 mm^2. The crown wall was prepared so that the pulp chamber floor would be surrounded by four 8-mm-high walls. In order to make the degree of collagen degeneration in hard tissues of the samples as comparable as possible, the teeth were soaked in 10% formaldehyde solution for 1 month and

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Table 1 Distribution of samples

Dentin pretreatment	Filling material	Polymerization light source
Group 1 (n = 6) EDTA	Resin	Halogen
Group 2 (n = 6) EDTA	Resin	Argon
Group 3 (n = 6) Nd:YAG	Resin	Halogen
Group 4 (n = 6) Nd:YAG	Resin	Argon
Group 5 (n = 6) EDTA	Amalgam	–
Group 6 (n = 6) Nd:YAG	Amalgam	–

then in distilled water (replaced daily) for 3 days to eliminate the chemical. The teeth were stored in a humid environment at 37 °C.

Sample Preparation

After mechanically eliminating the periodontal membrane and dental calculus attached to the teeth, pulp chamber perforation, soft tissue removal, root canal orifice identification, and root canal preparation were performed in a conventional manner. Root canal irrigation was performed as needed, and then the root canals were filled. During this time, 5% NaOCl and 3% H_2O_2 were used alternatingly to clean the root canal. After root canal filling, nail varnish was used to coat the entire tooth twice excluding the access cavity on the occlusal surface.

The size of the pulp chamber floor perforation was standardized by using a No. 2 round bar attached to a micromotor. A cavity was artificially prepared so that the pulp chamber floor cylindrically penetrated the center of gravity of the triangle formed by the three root canals.

Filling Materials and Lasers

The experimental group was randomly divided into 6 groups of 6 teeth each. The teeth were grouped according to the three treatment methods: pretreatment methods of perforated-area dentin, types of filling materials, and light sources used for resin polymerization (Table 1).

Pretreatment of perforated-area dentin

In order to treat the dentin surface of the chamber floor perforation prior to filling, a small cotton ball soaked in 15% EDTA (Morhonine, Showa Yakuhin Kako; Tokyo, Japan) was placed on the target area for 30 s, and then the treated area was washed with water. Air blowing the treated area for drying is contraindicated because of the risk of emphysema, and as a result, the area was just wiped using dry sterile cotton (groups 1, 2 and 5).

The samples that were not treated with EDTA were irradiated using the pulsed Nd:YAG laser (Impulse Dental Laser, Denix; Tokyo, Japan). The wavelength of the present machine was 1064 nm, the maximum output 6 W, and N 5-100 PPS. In the present study, the laser was applied to perforated-area dentin intermittently (10 s of rest after 2 s of irradiation for a total of five times) with 2 W output, 15 pps and 10-s total application time (groups 3, 4, and 6).

Filling material

When using composite resin to fill the perforation area, a bonding agent (Clearfil, New Bond, Kuraray Medical; Tokyo, Japan) was applied before filling, but air blowing was not performed because it is considered risky in clinical settings. Light-curing composite resin (Silux-PLUS, 3M; St Paul, MN, USA) was filled in a single increment from the crown side as recommended by the manufacturer (groups 1 to 4). For the groups without a composite resin, amalgam (SPHERICAL-D, Shofu; Kyoto, Japan) was filled in a single increment according to the manufacturer's instructions (groups 5 and 6).

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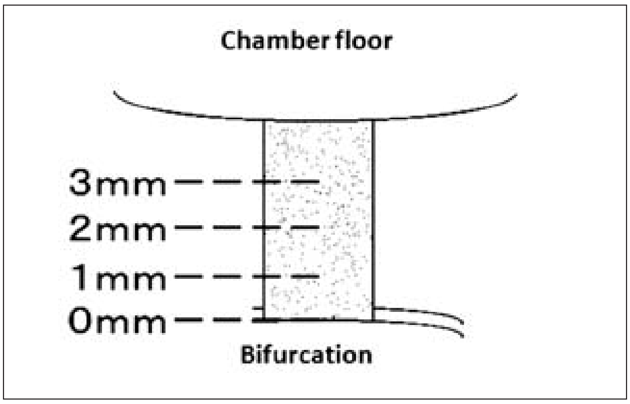

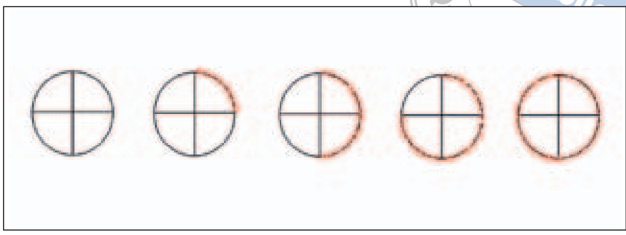

Fig 1 (left) Observed areas of pulp chamber floor perforation.

Fig 2 (right) Assessment methods and scores of the microleakage test.

Resin polymerization

For the groups with the light-curing composite resin, the argon laser (SPECTRUM Dental, HGM; Salt Lake City, UT, USA) was used for resin polymerization. The present device has a wavelength of 488 nm and generates successive waves with a maximum output of 4 W. In the present study, the output was set at 1.3 W, pulse width at 2.0 s, and four irradiations were administered in the single-pulse mode for a total of 8 s. A 320-mm fiberscope was used, and the argon laser was applied by moving the fiberscope 8 mm away from the illuminated surface (groups 2 and 4).

Alternatively, the halogen lamp Optilux 400 (Demetron; Danbury, CT, USA) was used to polymerize the resin composite. The light source for the machine had an overall wavelength (blue) of 375 to 505 nm (peak near 490 nm), and in the present study, the halogen light was continuously applied for 30 s from the crown side.

Assessment of Microleakage

After placing a filling material in the perforated area and temporarily sealing the area using phosphate cement, the occlusal surface of the tooth was coated twice using nail varnish and soaked in 1% rhodamine (1% rhodamine B, Muto Kagaku; Tokyo, Japan) at room temperature for 48 h. Then, the roots of the tooth were cut off, and the pulp chamber floor was polished up to 3 mm every 1 mm from the apical direction to the crown direction (Fig 1). At each millimeter, a stereoscopic microscope (Nikon; Tokyo, Japan) was used to observe dye leakage from the root apex direction. Based on the assessment standards shown in Fig 2, dye leakage was evaluated, and a Kruskal-Wallis test was used for statistical analysis. Then, the samples that were polished 3 mm from the pulp chamber floor were subjected to a series of alcohol dehydration, critical point drying, and platinum deposition in a conventional manner, and a scanning electron microscope (FE-SEM4700, Hitachi; Tokyo, Japan) was used to morphologically observe the dentin and filling material at areas with dye penetration in the cavity margin.

RESULTS

Dye Leakage Test

Based on the mean deviations for groups 5 and 6 in which amalgam was used as a filling material, there were statistically significant differences ($p < 0.01$) when compared to groups 1, 2, 3, and 4, in which a light-cured composite resin was used (Kruskal-Wallis test, $p < 0.05$). When using amalgam, no difference was seen between the two dentin pretreatment techniques (EDTA or Nd:YAG laser) (Figs 3a, 4a, 5a, 6a, and 7a).

Furthermore, the Kruskal-Wallis test did not show any statistically significant difference ($p < 0.05$) between any combination of groups among groups 1, 2, 3, and 4 (Table 2).

Morphological Observation by Stereoscopic Microscopy and SEM

Pretreatment of pulp chamber floor perforation

For groups 1, 2, 3, and 4, in which the light-cured composite resin was used as a filling material, the results

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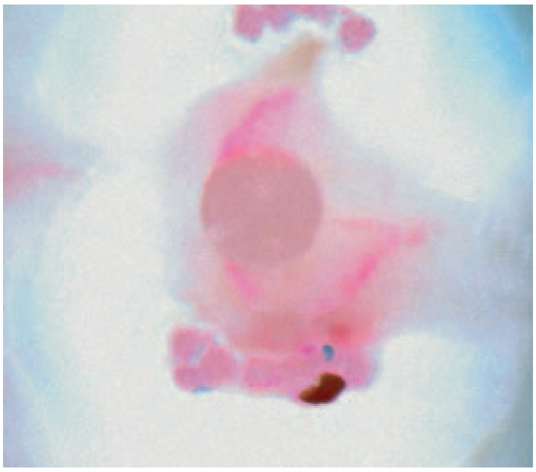

Fig 3a Representative light microscopic image of group 1 (EDTA, resin, halogen). Slight penetration of red dye is seen around the resin filling (score 1).

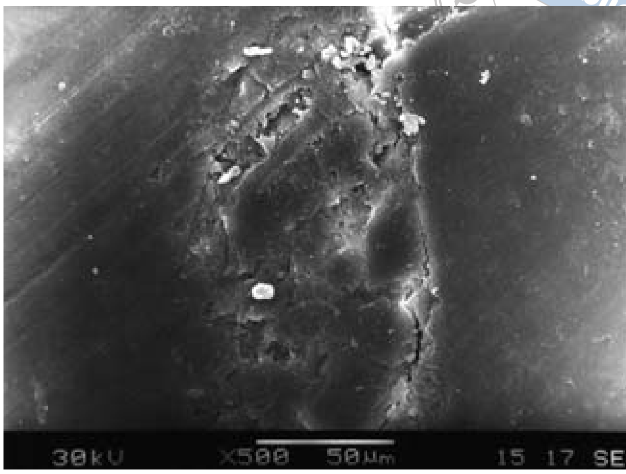

Fig 3b Representative SEM image (500X). Thick smear layer and debris are detected between resin and dentin.

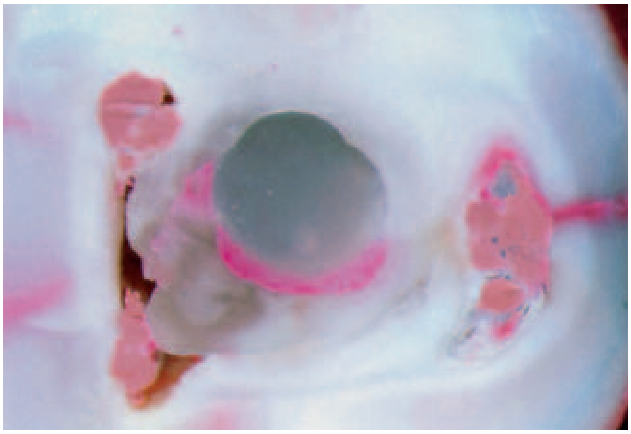

Fig 4a Group 2 (EDTA, resin, argon). After removing resin filling, leakage of dye is seen on the dentin surface of the perforated cavity wall (score 2). No carbonization is observed.

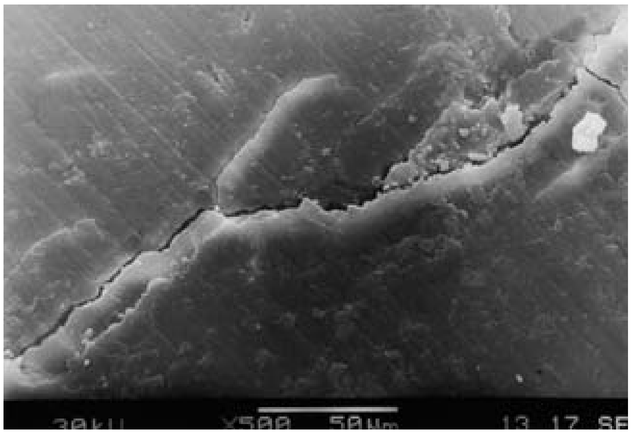

Fig 4b Smear layer is visible between resin and dentin.

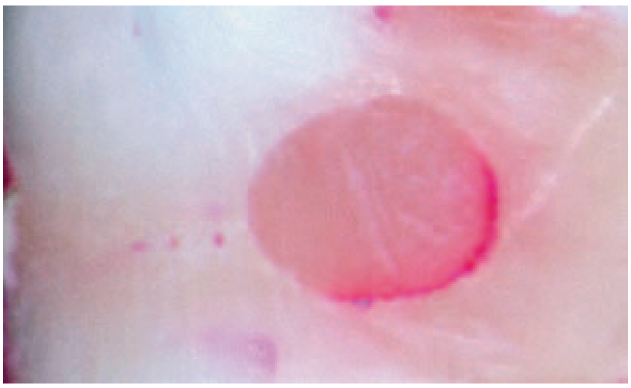

Fig 5a Group 3 (Nd:YAG, resin, halogen). Resin became pinkish, indicating insufficient polymerization (score 2). More than a quarter of the circumference is dyed by leakage.

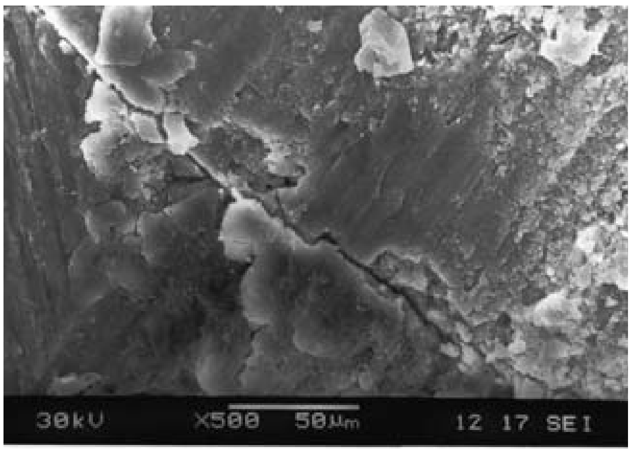

Fig 5b The gap is narrow but debris and smear layer are seen at the border.

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Fig 6a Group 4 (Nd:YAG, resin, argon). Resin filling is pinkish but no penetration is noted outside of the resin circumference (score 2).

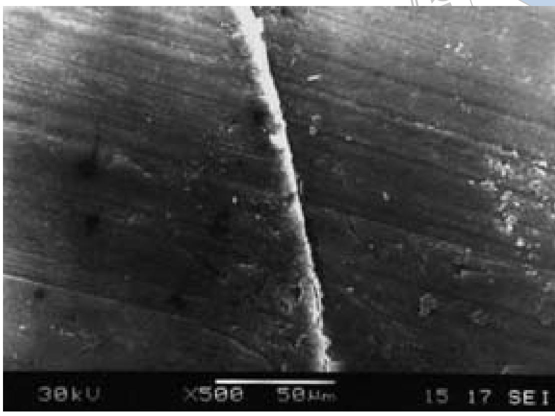

Fig 6b No smear later, debris, or gap is seen between the resin and dentin. In spite of this, a whitish layer which suggests resinous penetration can be recognized.

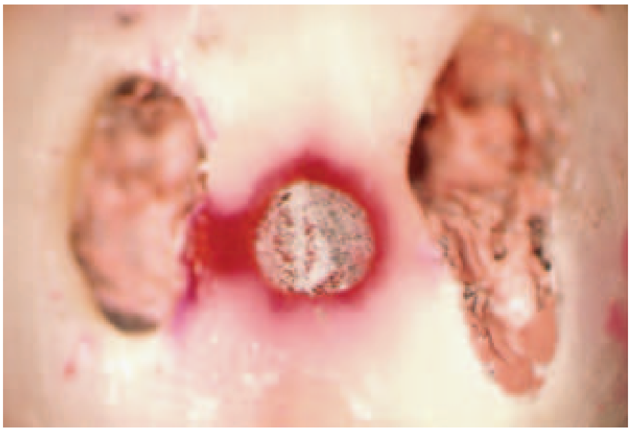

Fig 7a Group 5 (EDTA, amalgam). Very thick penetration around resin filling was seen in all the samples filled with amalgam (score 4).

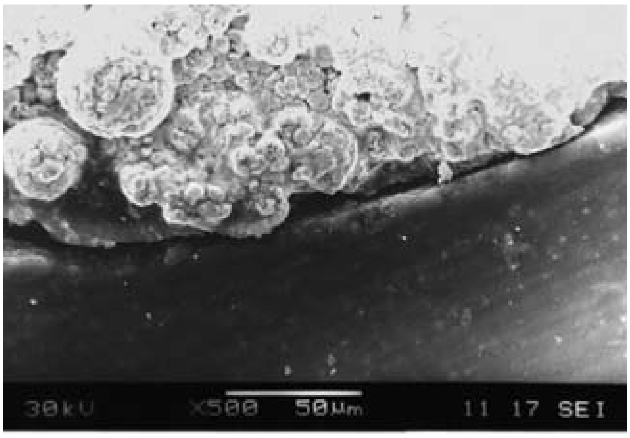

Fig 7b A wide gap is seen around the amalgam. Rough surface of amalgam indicates that mixing was not homogeneous.

Table 2 Dye leakage test (mean and standard deviation)

Group	0 mm	1 mm	2 mm	3 mm	Total
1	2.3	1.6	1.3	1.0	1.583 ± 0.717 (n = 24)
2	2.3	2.0	1.5	0.8	1.667 ± 0.816 (n = 24)
3	2.0	1.6	1.3	0.6	1.417 ± 0.830 (n = 24)
4	2.3	1.8	1.0	0.6	1.458 ± 1.021 (n = 24)
5	4.0	4.0	4.0	4.0	4.000 ± 0.000 (n = 24)
6	4.0	4.0	4.0	4.0	4.000 ± 0.000 (n = 24)

Units: mm, indicates the amount of abrasion from the lateral side of the pulp chamber floor.
Group 1 – 4; Kruskal-Wallis test ($p < 0.05$), $p = 0.6836$ (no significant difference).
Group 1 – 6; Kruskal-Wallis test ($p < 0.05$), $p = 0.0001$ (significant difference).

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of dentin pretreatment prior to root canal filling are shown. After artificially making a hole, the exposed dentin wall surface was pretreated using EDTA in group 1 (Figs 1a and 1b) and group 2 (Figs 2a and 2b). When compared to the groups 3 (Figs 5a and 5b) and 4 (Figs 6a and 6b) in which the Nd:YAG laser was used for dentin pretreatment, the volume of the smear layer in the junction between resin and dentin was greater for groups 1 and 2.

In groups 5 and 6, in which amalgam was used as the filling material (Figs 7a and 7b), no morphological differences were seen with respect to the pretreatment methods.

Amalgam and resin filling

In groups 1, 2, 3, and 4, in which a resin was used, although a gap was seen between resin and dentin, the gap formation in the junction was less pronounced compared to the amalgam group (Figs 3a, 3b, 4a, 4b, 5a, 5b, 6a, and 6b).

In groups 5 and 6, in which amalgam was used, larger gaps were seen between amalgam and dentin in all samples (Figs 7a and 7b). No sign of gap sealing due to amalgam erosion was seen. Moreover, the surface of the amalgam-filled areas was highly irregular, the degree of dye leakage was high, and leakage was intense all around the filling material. No morphological differences were seen in the filling material and cavity with respect to the dentin pretreatment before filling.

Polymerization method of resin filling material

Among the groups irradiated with the Nd:YAG as dentin pretreatment, the formation of a resin-impregnated layer was seen in the junction only for group 4, in which the argon laser was used for resin polymerization (Figs 6a and 6b), thus achieving tighter adhesion. There was no gap formation only in group 4, in which dentin was pretreated using the Nd:YAG laser and the argon laser was used for polymerizing the light-curing composite resin.

As far as the characteristics of dye penetration were concerned, in group 4, in which the argon laser was used for polymerization (Fig 6a), the dye penetrated into the resin filling material, but when the halogen lamp was used for polymerization (Fig 5a), the dye penetrated both resin and marginal dentin.

Findings indicative of carbonization of dentin

After dentin pretreatment at the pulp chamber floor perforation, findings indicative of carbonization were seen on the irradiated surface in 3 of the 18 samples where the Nd:YAG laser was used for dentin pretreatment. Carbonization and fusion were limited to the surface layer of the dentin, and undermining carbonization was not observed. Findings indicative of carbonization were not seen when EDTA was used for dentin pretreatment (groups 1, 2, and 5).

DISCUSSION

Root bifurcation perforation not only poses a problem for endodontic procedures, but also damages the periodontal membrane, induces epithelial proliferation, causes alveolar bone loss, or leads to tooth extraction. In most cases, such perforation is treated by nonsurgically filling the defect and attempting to regenerate the periodontal membrane.[6] When ascertaining prognosis following filling, the importance of marginal seal is well recognized.[7,8]

In recent years, the usefulness of composite resin, a restorative material with superior dentin adhesion, has been widely recognized, and the clinical application of light-curing composite resin systems, which use a visible light with a certain wavelength for polymerization, has expanded. However, problems such as areas of incomplete polymerization in deep parts of resin and contraction gaps between resin and dentin during polymerization and curing have been documented.[14] In particular, when treating the perforation inside the pulp chamber, pretreatment prior to filling and drying are difficult to perform, and factors such as longer time for restorative procedure, dentin and wound surface sterilization, disinfection, cleaning and hemostasis can complicate the therapy.[15] Therefore, in the present study, in order to overcome these problems, a laser was used to place a filling material on the chamber floor perforation and the marginal seal of the filling material was investigated. The above-mentioned results will be discussed below.

Pretreatment of the Chamber Floor Perforation

On the surface of abraded dentin, a layer of ground dentin, or so-called smear layer, is attached. The presence of a smear layer not only lowers the adhesion of a filling material to dentin,[18] but also carries the risk of

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harboring harmful substances and bacteria, and many reports have documented the necessity of smear layer removal.[19-22] When filling a perforated area, it is necessary to eliminate the smear layer, and especially in old perforations, this procedure is important as it affects the prognosis.

Koba and colleagues[11-13] applied the Nd:YAG laser after widening the root canal to sterilize and disinfect the root canal and eliminate the smear layer while treating an infected root canal, and this aided the healing of apical lesions because the smear layer containing organic components was reduced in volume. The cleaning effects of the Nd:YAG laser on the smear layer are thought to involve dentin transpiration. Generally, as the amount of laser irradiation energy increases, the effect of smear layer elimination increases. Next, the transpiration effects on the dentin underneath the smear layer are amplified, and dentin that is not sufficiently transpired forms a carbonized layer with the damage restricted to the dentin surface layer, thus resulting in multi-staged damage. In other words, excessive laser irradiation not only removes the smear layer, but also carbonizes the dentin surface layer, and the existence of a carbonized layer between dentin and filling material compromises airtight adhesion, resulting in gap formation. Therefore, the level of laser energy must be adjusted to avoid carbonization. In the present study, stereoscopic microscopy confirmed a carbonized layer in 3 of the 18 samples, and dye leakage was observed in all samples. In many cases, transpiration was limited to the dentin surface, and carbonization with marked undermining was not seen. Even when irradiation conditions were the same, transpiration was not seen at all in some samples, and even when irradiation energy was low, carbonization occurred. The reason for the varied results could be that because the laser was irradiated in a short period of time (2 s, five times), there were differences in the amount of absorbed laser energy. In addition, the degree of laser absorption could have been influenced by the differences in dentin color of the teeth, the amount of moisture content, the degree of calcification, and surface characteristics. However, as was the case with the present study, when the laser was irradiated while the root canal wall was dry, laser sparks may have caused dentin transpiration and carbonization. In other words, there may be a difference in the penetration of laser light between wet and dry states. In clinical settings, when laser is applied under the conditions set forth by the present study, it is not clear if transpiration and carbonization would occur in a comparable manner. For preventing carbonization and promoting the cleaning effect due to transpiration, it is necessary to develop a method to selectively stain the smear layer, lower pulse count by reducing peak power and continuously irradiate the area by increasing the irradiation interval, thereby suppressing temperature increase.

Microleakage Test

For evaluation of dye penetration test findings, an assessment method for cavity formation has been used in the laboratory, and it was also used in the present study because it facilitates statistical analysis.[16] A method in which teeth are soaked in 1% rhodamine solution for 48 h has been widely employed. Assessment was straightforward because the areas of dye penetration were clearly seen.[17]

No statistically significant difference existed between EDTA and Nd:YAG groups, and dye penetration was seen in both groups, because SEM showed a carbonized layer, residue from smear layer elimination, and dentin fragments. Dye penetration was extremely low in the areas where dentin pretreatment was favorably performed. In order to eliminate microleakage, it is necessary to sufficiently clean and develop a method to avoid formation of a carbonized layer or completely eliminate it.

No statistically significant differences were seen in the results of dye penetration between photopolymerization and argon laser. A previous study found that the polymerization time for the argon laser was shorter, and polymerization in deep areas was more likely to occur, thus agreeing with the results of the present study.[18]

As to the morphological characteristics of dye penetration, the dye can diffuse either towards dentin or filling material, and in the latter case, incomplete resin polymerization is suspected. When the dye diffuses towards dentin, dentinal tubules are opened and the smear layer is completely eliminated.

Resin Polymerization

The activation wavelength of camphorquinone, a catalyst for photopolymerization that is included in the light-cured composite resin, is in the blue section of the visible light spectrum (400 to 500 nm, maximum: 470 nm). The wavelength of the argon laser used in the present study was 488 nm, and it has been used to polymerize light-curing resins. However, there is also

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a concern for heat damage caused by irradiation. Kaneda[19] investigated the effects of visible light on the body and reported that active oxygen is produced in the gingival tissues which could somehow hinder cellular turnover. In the present study, because the purpose of argon laser irradiation was resin polymerization, 1.3 W was applied for 2 s for a total of four times with an irradiation distance of 8 mm. Hence, when compared to surgical procedures, the level of laser energy is much lower, and we believe that laser irradiation would not pose any problem.

While light polymerization using the halogen lamp took 30 s, that using the argon laser only took 8 s. Based on these observations, when placing a filling material into a perforated area where moisture exclusion is difficult and a meticulous procedure is required, polymerization over a short period of time using the argon laser would be more effective when compared to polymerization using a conventional lamp.

Clinical Application

When treating perforation in clinical settings, bleeding markedly affects the adhesion strength. In particular, gingival bleeding from the perforated area is difficult to control, thus making the subsequent procedures impossible or difficult to perform. So far, hemostasis has been achieved by alternatively applying hydrogen peroxide solution and sodium hypochlorite solution for irrigation, administering a protein coagulant such as formocresol (FC), applying a peripheral vasoconstrictive agent such as epinephrine, or coagulating peripheral vessels by electrocautery. However, the use of drugs may negatively affect wound surface treatment, and with electrocautery, electric current, albeit small, runs through the body, and the coagulation necrosis is thick. In the oral cavity, electrocautery could negatively affect underlying tissue, such as bone.

The Nd:YAG laser with a wavelength of 1064 nm has a small coefficient for tissue absorption, penetrates deep into tissue, and is capable of heat coagulation of capillary networks in tissue;[20] as a result, it also shows excellent hemostasis. When granulation tissue exists in a perforated area, hemostasis can be expected immediately after the transpiration and resection of the superficial layer of granulation tissue; the effects on the surrounding tissue are minimal and the recovery of microcirculation is favorable.[21] In the case of old perforation, if there is little soft dentin around the perforation, laser transpiration may occur, and this also sterilizes the area.[22-24] Therefore, the Nd:YAG laser is clinically very useful because it can do more than just improve adhesive strength.

CONCLUSIONS

In the present study, the argon and Nd:YAG lasers were applied for the treatment of chamber floor perforation, dye leakage in the adhesive surface between dentin and filling material was assessed, and the effects of laser application were investigated by morphologically observing the longitudinal sections of samples.

The results of the dye leakage test showed no statistically significant difference between dentin pretreatment by the Nd:YAG laser and that using EDTA. However, SEM showed that the Nd:YAG laser group had less smear layer in the adhesive interface, a resin-impregnated layer had formed, and the formation of contraction gaps was less pronounced. Additionally, in all samples with amalgam, dye penetration was seen from the root bifurcation towards the pulp chamber floor.

For the treatment of pulp chamber floor perforation using a light-cured composite resin, when compared to a conventional halogen lamp, the argon laser that achieved polymerization in a shorter time did not induce excessive resin contraction or lower physical properties. Further, dentin pretreatment using the Nd:YAG laser is comparable to that using EDTA, thus suggesting its usefulness in clinical settings.

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