Effect of the Diode Laser on the Sealing Ability of Some Retrograde Filling Materials

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Purpose: The effect of diode laser treatment on the sealing ability of several retrograde filling materials was examined.

Materials and methods: One hundred eight bovine root sections, each 3 mm thick and with a central lumen 2.6 mm in diameter were prepared and divided in two equal groups of 45 specimens each; the remaining 20 roots served as positive and negative controls. The lumen of the first group was lased, and 15 specimens from each group were filled with amalgam, another 15 with glass-ionomer cement, and the rest with ZnO-eugenol cement. After setting, leakage was measured at 2 h, 3 months, and 6 months using a fluid transport model.

Results: More leakage was recorded on the lased specimens compared to the control group for all materials tested and for all time intervals with the exception of glass-ionomer cement specimens (of both subgroups), which showed no leakage at the first time interval (24 h).

Conclusion: Because of detrimental effects on apical sealing, diode laser should not be used to treat retrograde cavities in apicoectomies.

Keywords: diode laser, apical sealing, retrograde, leakage, sealing ability, amalgam, IRM, glass ionomer.

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Retreatment of failed endodontically treated teeth is the preferred approach and usually results in a successful outcome. When nonsurgical attempts prove to be unsuccessful, surgical endodontic treatment is needed to save the tooth.

Surgical removal of the root apex and the surrounding inflammatory tissues do nothing to eradicate the source of the infection from the root canal. A retrograde cavity and a very tight root-end filling are necessary to block both the remaining microorganisms and their toxic products from all portals of exit to periapical tissues.

A sufficient apical seal is a very important factor in achieving success.[1] Numerous materials have been used over the years as root-end filling materials, such as amalgam, composite, glass-ionomer cement, ZnO-eugenol cement, and (more recently) Mineral Trioxide Aggregate (MTA). To date, however, no material has been found with an ideal hermetic ability, but MTA shows the best results.[2] The leakage of the various retrograde materials has been investigated mostly by dye penetration methods, which cannot offer any information on the quality of the seal over a long period of time because the specimens are destroyed. In addition, for many other reasons, dye penetration techniques are questionable.[3]

Lasers have been suggested for a wide variety of applications in dentistry. The ability of lasers to vaporize, fuse, or otherwise seal dentinal tubules by recrystalization of the mineral component of dentin (glazing) has been reported, all with varying degrees of success. Dederich et al reported the melting and recrystaliza-

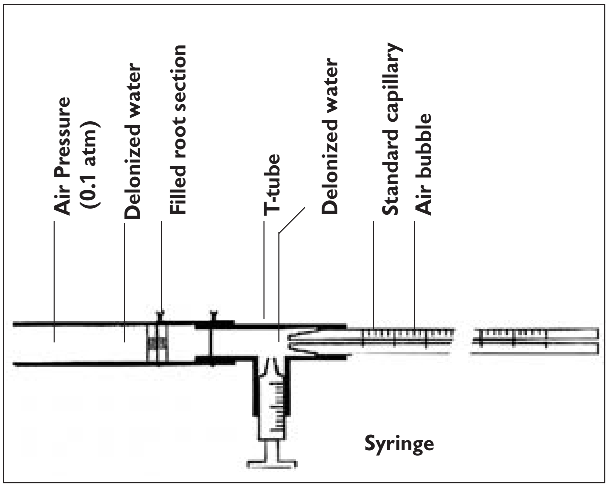

Fig 1 Fluid transport device.

tion of root-canal wall dentin following Nd:YAG laser exposure (wavelength 1064 nm).[4] Miserendino et al,[5] using a CO_2 laser (wavelength 1060 nm), observed similar phenomena. When the CO_2 laser was applied to patients given apicoectomies,[6] it did not improve the healing process. However, using extracted teeth in vitro,[7-10] the Nd:YAG laser was found to reduce the penetration of dye or bacteria through resected roots. In these in vitro investigations, the laser was used after root resection.

An in vitro study using the Er:YAG laser (wavelength 2940 nm) for root resection in extracted teeth[11] achieved excellent results with a smooth, clean resected root surface without any sign of charring. In contrast, in another in vitro study which used this laser for retrograde cavity preparation, no significant differences were reported between the teeth treated with Er:YAG laser and with the ultrasonic tools, as far as dye penetration techniques were concerned.[12] Diode laser has been reported to possess some interesting properties, such as a capability similar to that of the Nd:YAG to seal dentinal tubules[13] and the ability to destroy their microbial content.[14,15]

The purpose of this study was to compare the leakage of three commonly used retrograde filling materials in bovine dentin root sections treated with diode laser or not, using a transport fluid model.

MATERIALS AND METHODS

Preparation, Obturation, and Laser Treatment of Root Sections

One hundred eight specimens were prepared from root sections of freshly extracted bovine central incisors, each 3 mm high, using a low-speed diamond disk under tap water cooling. The root canals were machined to 1.3 mm in radius. The outer surface of the root sections was modified using a stone bur in a low-speed handpiece in order to obtain a smooth cylindrical surface, which would better fit the plastic tube of the fluid-transport device (Fig 1).

The central lumen of 54 root sections (Group 1) was treated with a Dentek diode laser (GaAlAs, wavelength 790 to 830 nm; FiberTech; Berlin, Germany), whereas Group 2 was left unlased. The laser fiber tip (200 nm in diameter) was gently introduced into the entrance of the central lumen. The laser fiber tip during irradiation was placed laterally in contact to the central lumen's wall and moved circumferentially at a speed such as to complete a full round in 1 s. The procedure was repeated 3 times. The laser parameters were set as follows: peak power at 4 W, frequency at 50 Hz, energy at 40 mJ/pulse, pulse duration 10 µs.

After irradiation, all lased root sections were checked for cracks and changes in diameter under an optical microscope, with negative results. Then the smear layer was removed from all specimens (lased and unlased). For the specimens to be filled with glass-ionomer cement, the smear layer was removed by using the dentin conditioner GC for 20 s (GC; Tokyo, Japan). In the specimens to be filled with amalgam or ZnO-eugenol cement, the smear layer was removed by successively rinsing with 5 ml of 2% NaOCl for 10 s, 10 ml of 40% citric acid for 30 s, and again 5 ml of 2% NaOCl for another 15 s.[11]

Each group was divided into 3 equal subgroups of 17 specimens each, leaving 3 specimens from each group to serve as positive control. Each experimental subgroup was obturated with either amalgam (Amalgam Logic, SDI; Australia), ZnO-eugenol cement (IRM, Dentsply-DeTrey; Konstanz, Germany) or glass-ionomer cement (Fuji II, GC; Tokyo, Japan). All test materials were mixed according to their manufacturer's instructions.

After filling the specimens with Fuji II, one surface was immediately coated with a thin layer of varnish (Fuji Varnish, GC), to protect the glass ionomer from drying out.

Table 1 Leakage of amalgam, glass ionomer, and IRM when used as retrofilling materials, in unlased and lased retrograde cavities at 24 h, 3-month and 6-month intervals

Time Interval		Unlased	Unlased	Unlased	Lased	Lased	Lased
	Leakage	NL	SL	GL	NL	SL	GL
24 h	Amalgam	5	6	4	3	4	8
	Glass ionomer	15	0	0	10	5	0
	IRM	8	7	0	4	6	5
3 months	Amalgam	0	1	14	0	0	15
	Glass ionomer	12	3	0	6	3	6
	IRM	1	5	9	0	3	12
6 months	Amalgam	0	4	11	0	0	15
	Glass ionomer	10	3	2	5	4	6
	IRM	1	4	10	0	2	13

NL: no leakage, SL: slight leakage (up to 20 µl/day), GL: gross leakage (leakage exceeded 20 µl/day).

After preparation and between measurements, all specimens were kept in 100% relative humidity (by means of moist sponge pieces) at 37°C.

Measurement of Fluid Transport

The 108 specimens were observed for leakage at 24 h, 3 months, and 6 months after filling. The method used to measure the fluid transport was described previously by Wu et al.[3] Each root section was connected with a plastic tube as shown in Fig 1. This connection was secured tightly by twisting an orthodontic stainless steel wire around it. The plastic tube on either side of the specimen was filled with deionized water.

A standard glass capillary was connected to the plastic tube at the outlet side of the specimen. Using the syringe, water was sucked back approximately 3 mm into the open end of the glass capillary tube.

The whole device was immersed in a water bath, and with the use of the syringe, the air bubble was adjusted to a standard position every time.

Finally, a pressure of 0.1 Atm was applied from the inner side to force the water through the voids along the filling, thus displacing the air bubble in the capillary tube. The experimental apparatus is shown in Fig 1. The observed movement of the air bubble inside the capillary tube expressed the volume of fluid transport. The displacement of the air bubble was recorded as fluid transport (Flux, F), the result of which was expressed in µl/day. Results were categorized as no leakage (NL) when no leakage was recorded, slight leakage (SL) when the observed leakage was up to 20 µl/day, and gross leakage (GL) when the observed leakage exceeded 20 µl/day.

One unfilled specimen from each group served as positive control, and one specimen from each subgroup, coated with two layers of acrylic nail varnish, served as negative control, thus leaving 15 specimens in which the retrograde filling would be challenged for leakage. On the positive controls, the air bubble moved too fast to record leakage time, and on the negative controls the air bubble did not move in any recording.

The results of the recorded leakage between the different subgroups and time intervals were analyzed statistically using a logistic regression model.

RESULTS

At all intervals, no leakage was recorded in the 12 negative controls, whereas in the 6 positive controls, gross leakage ($F > 20$ µl/day) was recorded.

Leakage of the three tested materials in lased and unlased sections measured at three time intervals is shown in Table 1.

Table 2 Logistic regression analysis of material, time and laser interaction

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Outcome variable: leakage

Covariate	Odds Ratio	Std. Err.	P>|z|	95% CI
Material				
1	24.111	14.229	<0.001	(7.584 to 76.656)
2*	1			
3	9.593	5.302	<0.001	(3.247 to 28.339)
Time interval				
1*	1			
2	5.368	1.947	<0.001	(2.637 to 10.928)
3	8.468	3.401	<0.001	(3.854 to 18.607)
Material/time interval interaction				
1 & 2	12.139	12.802	0.018	(1.536 to 95.914)
1 & 3	1.709	1.028	0.373	(0.526 to 5.558)
3 & 2	2.222	1.032	0.086	(0.894 to 5.524)
3 & 3	1.989	1.080	0.205	(0.686 to 5.764)
Laser				
0*	1			
1	5.123	2.246	<0.001	(2.169 to 12.099)

* Baseline category
Material 1: Amalgam, Material 2: G/I, Material 3: IRM
Time interval 1: 24h, Time interval 2: 3 months, Time interval 3: 6 months
Laser 0: no laser applied, Laser 1: laser applied

Logistic regression revealed that the application of the diode laser in the retrograde cavity on average increased the chance of a specimen to leak 5-fold ($p < 0.001$). As far as the retrograde filling materials, amalgam seems to be 24 times more prone to leak, and IRM 9.5 times more prone to leak compared to glass ionomer ($p < 0.001$ for both comparisons) (Table 2).

DISCUSSION

The nondestructive fluid transport model, originally designed by Pashley et al[17] and modified by Wu et al,[18] has been used in a few longitudinal leakage studies, including studies on retrograde materials. In this study, a pressure of 0.1 Atm (76 mm Hg) was used; because it was relatively low, it may have clinical relevance.[19]

Under the experimental conditions, amalgam, a commonly-used root-end filling material, leaked significantly more than the other tested materials at all time intervals.

These results are in agreement with those of other leakage studies using either the fluid transport model of the original design[20,21] or an electrochemical method.[22]

A continuous increase in leakage in the amalgam group was recorded for the first two measurements, followed by a reduction of leakage at the 3-month interval measurement, which may indicate the occurrence of corrosion.[23]

IRM, a ZnO-eugenol cement which has been used as an alternative to amalgam, showed less leakage than amalgam in this study, but more leakage than the glass-ionomer cement at all test periods. In a study by Kazemi et al,[24] continuous dimensional loss of the ZnO-eugenol materials was observed. This was caused by its solubility, which lasted for a few months and may explain the increase in leakage for IRM.

Glass-ionomer cements have attracted the attention of researchers. In this study, Fuji II retrograde fillings showed less leakage compared to amalgam and IRM at all time intervals, showing its potential to be used instead of the traditionally used materials.

A previous study[19] on the sealing ability of various retrograde materials showed that glass-ionomer cement leaked less than amalgam and reinforced ZnO-eugenol cement (Super EBA), and that Super EBA leaked less than amalgam at all tested periods. These findings are in agreement with ours. Friedman reviewed results of 29 previous leakage studies involving retrograde filling materials, and on a cumulative basis, it appears that glass-ionomer cement leaked less than Super EBA, which in turn leaked less than amalgam without varnish.[25] These findings are also in agreement with our findings.

Based on the data of the control group of this study, it is not yet possible to make a recommendation about the material to be used. It should be borne in mind that these in vitro results are an indication about their potential capacity under the present experimental conditions. The purpose was to test the influence of a diode laser (Dentek) on bovine dentin wall and its effect on the sealing ability of various commonly used retrograde filling materials. Unfortunately, it was not possible to include MTA among the tested materials, because at the time of the experiment, this material was not available on the Greek market.

Leakage of all tested materials was greater in the lased specimens than the unlased ones, at all time intervals.

The melting and resolidification of dentin and the closure of dentinal tubules, even without dentin surface cracking, has been reported,[4,5] but the observed glazing zone may not be permanent, or even long lasting.[13] Indeed, the anatomical interpenetration between organic tissues and the tubules results in very high adhesion forces. Either due to the temperature increase or the photo-volatilization effect of laser, the observed dehydration may have decreased the interpenetration of pulpal tissues into the dentinal tubules and may have altered the mesh and adhesiveness of lased dentin. This altered lased dentin may be dissolved or removed by the applied pressure in transport fluid model.

On the other hand, in some in vitro studies, Nd:YAG laser was used after root resection of extracted teeth, in a manner similar to this study. It was found that the use of Nd:YAG laser reduced the penetration of dye or bacteria within resected roots.[8-10] However, the application of CO_2 laser on the surgical site of patients receiving apicoectomy did not improve the healing process.[12] It is not clear if this is due to the type of laser used, the damaging effect of laser, or the altered leakage.

Another parameter which should be taken into consideration is that the mechanisms of dye penetration are capillary action and diffusion. This means that capillaries or gaps are saturated by solutions. Saturation in porous materials is greater than in nonporous materials. A diamond, for instance, which is a nonporous material, presents a low surface tension and a drop of water does not expand its base as much as it would on a glass surface, which presents a higher surface tension.

Because of the glazing of lased dentin surfaces, dye penetration may be less than on unlased dentin surfaces. This may explain the different results of this study, because all specimens were measured by the use of the fluid transport model.

The observed reduction of leakage in unlased root sections filled with amalgam at the 6-month period was not observed in the respective lased group. Perhaps the corrosion products could not fill the gaps between the dentin walls and amalgam, as the glazed dentin may deteriorate and leave a bigger gap, or because the glazed dentin did not favor the genesis of corrosion products.

In fact it is not known whether the reported leakage in all groups is due to the alteration of dentin. If the dentin was glazed, the water could slip more easily through the existing gaps. If this hypothesis is accurate, the existing gaps in the lased specimens – despite being smaller in size – would allow greater leakage.

This assumption is supported by the fact that in the lased specimens of the amalgam group, the expected reduction of leakage was not noted. This could be attributed to the transportation of corroded material along the glazed nonporous surface of the dentin, that could not retain it in place under the applied pressure. It would be of great interest to analyze the transported fluid for amalgam by-products.

CONCLUSION

Based on our results, diode laser should not be used to treat retrograde cavities in apicoectomies because of the detrimental effects on apical sealing. However, it should be emphasized that these in vitro results are an indication of the potential capacity of laser treatment under the experimental conditions described here. It would be also interesting to test the leakage of the same materials after removing the lased zone of dentin or to use the laser energy not to glaze the dentin surface but only to kill the bacterial population of the dentinal tubules.

Of course, the glazing capability of some laser wavelengths would be very useful if we could find a material with better adaptation, based not on mechanical but on chemical retention with this nonporous glassy dentin.

Future studies should examine the adaptation of MTA to such surfaces.

REFERENCES

1. Harty FJ, Parkins BJ, Wengraf AM: Success rate of apicoectomy. A retrospective study of 1016 cases. Br Dent J 1980;129:407-413.
2. Aqrabawi J: Sealing ability of amalgam, super EBA cement, and MTA when used as retrograde filling materials. Br Dent J. 2000; 188:266-268.
3. Wu MK, Wesselink PR: Endodontic leakage studies reconsidered. Part I. Methodology, application and relevance. Int End J 1993; 26:37-43.
4. Dederich D, Zakariasen K, Tulip J: Scanning electron microscopic analysis of root canal wall dentin following Nd:YAG laser irradiation [abstract]. J Endod 1984;10:428.
5. Miserendino LJ, Neiburger EJ, Walia H, Luebke N, Brantley W: The thermal effects of continuous wave CO_2 laser exposure on human teeth: an in vitro study. J Endod 1989;15:302-305.
6. Bader G, Lejeune S: Prospective study of two retrograde endodontic apical preparations with and without the use of CO_2 Laser. Endod Dent Traumatol 1998;14:75-78.
7. Stabholz A, Khayat A, Weeks DA, Neev J, Torabinejad M: Scanning electron microscopic study of the apical dentine surfaces lased with Nd:YAG laser following apicectomy and retrofill. Int Endod J 1992a;25:288-291.
8. Stabholz A, Khayat A, Ravanshad SH, McCarthy DW, Neev J, Torabinejad M: Effect of Nd:YAG laser on apical seal of teeth after apicectomy and retrofill. J Endod 1992b;18:371-375.
9. Arens DL, Levy GC, Rizoiu IM: A comparison of dentin permeability after bur and laser apicoectomies. Compendium 1993; 14:1290-1297.
10. Wong WS, Rosenberg PA, Boylan RJ, Schulman A: A comparison of the apical seals achieved using retrograde fillings and the Nd:YAG laser. J Endod 1994;20:595-597.
11. Ebihara A, Sekine Y, Takeda A, Suda H: Application of Er:YAG laser to apicoectomy. A preliminary study. J Japan Soc laser Dent 1997;8:23-30.
12. Ebihara A, Wadachi R, Sekine Y, Takeda A, Suda H: Application of Er:YAG laser to retrograde cavity preparation. J Japan Soc Laser Dent 1998;9:23-31.
13. Liu HC, Lin CP, Lan WH: Sealing depth of Nd:YAG Laser on Human Dentinal tubules. J Endod 1997;23:691-693.
14. Moritz A, Gutknecht N, Goharkhay K, Schoop U, Wernisch J, Sperr W: In vitro irradiation of infected root canals with a Diode Laser. Quintessenz Int 1997;3:205-209.
15. Moritz A, Gutknecht N, Doertbudak O, Goharkhay K, Schoop U, Schauer P, Sperr W: Bacterial reduction in Periodontal pockets through irradiation with a Diode Laser: A pilot study. J Clinic Laser Med Surg 1997;1:33-37.
16. Gutknecht N, Alt T, Slaus G, Bottenberg P, Rosseel P, Lauwers S, Lampert F: A Clinical Comparison of the Bactericidal Effect of the Diode Laser and 5% Sodium Hypochlorite in Necrotic Root Canals. J Oral Laser Appl 2002;2:151-157.
17. Pashley DH, Thompson SM, Stewart FP: Dentin permeability: Effects of temperature on hydraulic conductance. J Dent Res 1983; 62:956-959.
18. Wu MK: In vitro determination of leakage in Endodontic Research: PhD Thesis. Amsterdam 1993.
19. Wu MK, Kontakiotis EG, Wesselink PR: Long term seal provided by some root-end filling materials. J Endod 1998;24:557-560.
20. Derkson GD, Pashley DH, Derkson ME: Microleakage measurement of selected restorative materials. A new in vitro method. J Prosthet Dent 1986;56:435-440.
21. King KT, Anderson RW, Pashley DH, Pantera EA Jr: Longitudinal evaluation of the seal of endodontic retrofillings. J Endodon 1990;16:307-310.
22. Mattison GD, von Fraunhofer JA, Delivanis PD, Anderson AN: Microleakage of retrograde amalgams. J Endodon 1985;1: 340-345.
23. Ben-Amar A, Gardash HS, Judes H: The sealing of the tooth/amalgam interface by corrosion products. J Oral Rehabil 1995; 22:101-104.
24. Kazemi RB, Safavi KE, Spangberg LSW: Dimensional changes of endodontic sealers. Oral Surg Oral Med, Oral Pathol 1993; 76:766-771.
25. Friedman S: Retrograde approach in endodontic therapy. Endod Dent Traumatol 1991;7:97-107.

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