

Reducing **microleakage** with Er,Cr:YSGG and/or Nd:YAG lasers

An evaluation

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Introduction

In endodontics, effective cleaning of the root canal system is essential for ensuring successful root canal therapy with long-lasting treatment outcomes.^{1–3} During endodontic instrumentation, various morphological changes occur on the root canal walls, including organic and mineral debris^{4–7} and smear layer formation.^{2,4,7} Therefore, not only are conventional cleaning and removal of debris and the smear layer important steps in endodontic procedures,^{1,2} but chemical irrigation is strictly recommended for use in conjunction with mechanical instrumentation in order to dissolve debris and the smear layer.^{8,9} In fact, the methods employed to clean and shape root canal spaces create a smear layer, which may harbour microorganisms that ultimately result in periapical pathosis.^{3,7} Many irrigant solutions, such as sodium hypochlorite and ethylenediaminetetraacetic acid (EDTA), are used. Sodium hypochlorite is effective in removing organic tissue remnants,⁸ while EDTA is effective in removing the inorganic portion of the smear layer.⁹ However, both irrigants are unable to remove the smear layer effectively.^{1,3,10}

A successful root canal therapy is based on a number of factors: reduction of microorganisms to the minimum, sufficient and proper root canal instrumentation and disinfection, as well as well-adapted root canal obturation.¹¹ A crucial disadvantage of irrigant solutions is that their bactericidal effect is limited to the main root canal. Because of the narrow diameter of the dentinal tubules and the high surface tension of the liquid solutions, they are able to penetrate only a small distance into the tubules. The penetration depth of chemical disinfection only reaches 100 µm into the adjacent dentinal tubules.^{12,13} However, the bacteria can penetrate over 1,000 µm from the canal lumen,¹² as described by Kouchi et al.¹⁴ and Ando & Hoshino.¹⁵ Therefore these bacteria are protected in the deeper layers of dentine. In this protected area, we find Gram-negative bacteria, which are characterised by their unusual migration qualities and their resistance to chemical irrigant solutions. They maintain their virulence against conventional endodontic techniques. And we find that, from this bacterial reservoir, the bacteria will spread

to the periapical areas of the tooth, causing inflammation and infection.¹² Since conventional root canal therapy is not always successful, new methods could perhaps enhance the long-term prognosis and overcome the shortcomings of conventional instrumentation methods.¹¹

Today, lasers are used in endodontics to dramatically improve the prognosis of root-filled teeth.¹² Laser irradiation produces different effects on the same tissue, and the same laser can produce various effects in different tissues. Er:YAG and Er,Cr:YSGG lasers have been reported to ablate dental hard tissue^{16–21} with minimum injury to the pulp and surrounding tissue.^{17–19,22–25} The Er:YAG laser has been reported to ablate enamel and dentine effectively, because of its highly efficient absorption in both water and hydroxyapatite,^{16,20,21} and the Er,Cr:YSGG laser, which uses a pulsed beam system, fibre delivery and a sapphire tip bathed in a mixture of air and water vapour, has been shown to be effective for cutting enamel, dentine^{18,20} and bone.¹⁸ Moreover, this specific property, combined with a water spray for both lasers, enables the effective removal of debris and the smear layer.^{23,26–31} The surface morphology of root canals can be altered by using a 1,064 nm Nd:YAG laser. Remaining soft tissue as well as the smear layer can be partially or completely removed, depending on the energy level used.¹¹

The Nd:YAG laser seems to be the laser of choice in root canal therapy. It is also the best-documented laser in the literature for root canal sterilisation. Most of the studies concerned with the Nd:YAG laser in endodontics deal with the quantitative evaluation of bacteria reduction.¹² Laser irradiation has been widely introduced in endodontic treatments as an aid to disinfection and the removal of debris and the smear layer from instrumented root canal walls and might be a solution for the various limitations and shortcomings of mechanical and chemical disinfection. Microleakage continues to be a main reason for failure of root canal therapy, where the challenge has been to achieve an adequate seal between the internal tooth structure and the main obturation material, gutta-percha.³² It has been found that approximately 60% of endodontic failures are due to inadequate obturation of the root ca-

Group Number	Groups	Laser setting	Fibre/Tip size	Time of operation	Sample size
1	Conventional preparation & EDTA & Er,Cr:YSGG & Nd:YAG	Er,Cr:YSGG = (1.5W, 20 Hz), 140 μ s, [Waterlase MD]* Nd:YAG = (1.5W, 15 Hz) Pulse duration = 160 μ s [Fotona]**	Er,Cr:YSGG = 320 μ m Nd:YAG = 200 μ m	2 mm/sec Rotational	12
2	Conventional preparation & Er,Cr:YSGG & Nd:YAG	Same as * and **	Er,Cr:YSGG = 320 μ m Nd:YAG = 200 μ m	2 mm/sec Rotational	12
3	Conventional preparation & EDTA & Nd:YAG	Same as **	200 μ m	2 mm/sec Rotational	12
4	Conventional preparation & Nd:YAG	Same as **	200 μ m	2 mm/sec Rotational	12
5	Conventional preparation & EDTA				12
6	Conventional preparation				12
Total					72

Table 1: All groups of laser-irradiated root canals and control (n = 72).

nal system.^{33,34} Although gutta-percha is the most popular core material used for obturation, it cannot be used as the sole filling material because it lacks the adherent properties necessary to seal the root canal space. Therefore, a sealer and cement are always needed for the final seal.^{35,36} The Resilon/Epiphany system uses a new obturation material that bonds chemically with the internal tooth structure, thereby decreasing the possibility of microleakage.³²

The scientific investigation of fundamental problems plays a decisive role in understanding the mechanisms of action of exposing biological materials to laser irradiation and their consequences.³⁷ The purpose of this study is to analyse microleakage differences when removal of the smear layer is done conventionally, chemically (with and without EDTA) and with Er,Cr:YSGG and/or Nd:YAG laser irradiation and Resilon/Epiphany is used as the obturation material.

Materials and methods

In this study, 72 freshly extracted caries- and restoration-free single-canal bovine teeth^{38,39} stored in normal saline (0.9%) at 4 °C were used, after scaling with scalpels or hand instruments to remove residual tissue and calculus and rinsing thoroughly with tap water. Samples were randomly divided into six groups of 12 teeth each. The working lengths were established as 1 mm short of the apexes. The canals were hand instrumented with Kerr files (Maillefer) to the size of ISO 30 to this length in order to create an apical stop. The root canals were thoroughly rinsed with saline solution and gently dried using

paper points (Dentsply Sirona). Then Groups 1 to 4 were irradiated by laser, and EDTA (Produits Dentaires; 15 ml, LOT 6217 FL) was used to remove the smear layer for some groups, followed by a final rinse with saline solution (Table 1).

All 72 samples were prepared for obturation using the Resilon/Epiphany system. The canals were dried with absorbent paper points (Dentsply Sirona). A dry paper point was soaked with self-etching primer (SybronEndo; 6 ml, ref. No. 972-2007) and used to coat the root canal walls. The size of the Resilon master cones was then determined. An appropriate amount of the dual-polymerising Resilon sealer (SybronEndo; 4 ml) from the automix syringe was expressed on to a slab. The canals were coated with the sealer using the automix syringe, pre-measured Resilon master cones and a file. The viscosity of the sealer was modified by adding a drop or two of RealSeal thinning resin (SybronEndo, ref. No. 972-2006). Subsequent accessory points of Resilon core material were also coated with the sealer and inserted into the canal and compacted through lateral condensation. Once the obturation was completed, the coronal surface was light-polymerised for 40 seconds. The coronal portions of all samples were then restored.

Acid etching was done using a 35% orthophosphoric acid-etch gel for 15 seconds. After acid etching, all cavities were coated with a layer of primer (Syntac Primer, Ivoclar Vivadent), adhesive (Syntac Adhesive, Ivoclar Vivadent) and bonding agent (Heliobond, Ivoclar Vivadent) and light-polymerised (Translux, Kulzer) for 20 seconds. Then

Root third	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Apical	845 (Gr. 2)	950 (Gr. 2)	975 (Gr. 2)	582 (Gr. 2)	632 (Gr. 2)	483 (Gr. 1)
Middle	183 (Gr. 1)	512 (Gr. 2)	579 (Gr. 2)	517 (Gr. 2)	917 (Gr. 2)	821 (Gr. 2)
Coronal	380 (Gr. 1)	356 (Gr. 1)	504 (Gr. 2)	391 (Gr. 1)	718 (Gr. 2)	962 (Gr. 2)

Table 2: Graded average dye penetration depths (μm). Gr. = grade.

a composite (Ivoclar Vivadent; Shade A3) was used in increments to seal the coronal 2 mm of the roots and was light-polymerised for 40 seconds. For the dye penetration test, the samples were first coated with two layers of nail polish (Sally Hansen, Del Laboratories), except for the last apical 2 mm, which was left exposed so that the dye could only penetrate the canal via the apical region. The samples of each group were then kept in separate containers of distilled water and incubated at 37 °C for five days, to stimulate clinical conditions.

After incubation, the samples of each group, again in separate containers, were immersed in an aqueous solution of 2% methylene blue at 37 °C for seven days so that the root canals would be filled with dye solution by capillary action. After this time, the teeth were removed from the dye and rinsed under running water for 5 minutes and incubated again in distilled water at 37 °C for 24 hours. After incubation, the teeth were removed from the dye-containing solution, rinsed and dried. The samples were dehydrated in a sequence of alcohol solutions (70 % for 24 hours, 96 % for 24 hours and 100 % for 48 hours). Then they were kept in a histological cleaning agent (Histo-Clear II, National Diagnostics) for 2 hours and embedded in resin (K Plast, France) in groups in separate containers and stored in a water bath for four to seven days until the resin had set. The glass containers were broken to remove the resin-embedded samples, and Vaseline was applied into a self-made former container for each sample, to avoid sticking of acrylic to the container.

Dye leakage was assessed after immersion in methylene blue, by examining vertical and horizontal sections under a transmitted-light microscope (Leica DMRX with an integrated Hitachi HV-C20A camera, Leica Microsystems) at an objective lens magnification of 0.63x (optical lens magnification of 10x) by means of a computer programme (Diskus, Hilgers Technisches Büro). Then horizontal cuts of 500 μm in thickness were made, splitting the roots into three portions: coronal third, middle third and apical third. The horizontal sections were examined under the transmitted-light microscope at an objective lens magnification of 2x (optical lens magnification of 10x) by means of the same computer programme, to assess dye penetration, and the data was saved. It is necessary to note that the digital camera, which connects the microscope to the PC and software, will magnify the image, but the power of magnification is not easy to calculate. Therefore, the final magnification of the image that is shown on screen or printed out depends on the size of screen. That is why we only report objective lens and optical lens magnification in such cases.

Data analysis was performed using StatView software (SAS Institute Inc., USA), and the extent of leakage in each group was investigated in both vertical and horizontal cuts to gain a near 3D view. The scores were statistically evaluated by three calibrated examiners using the Kruskal–Wallis test to determine the statistical differences among the groups ($p < 0.05$), and comparison of paired groups was done using the Wilcoxon signed

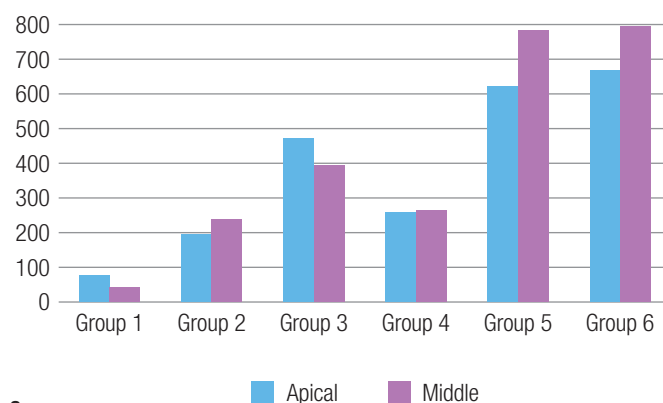
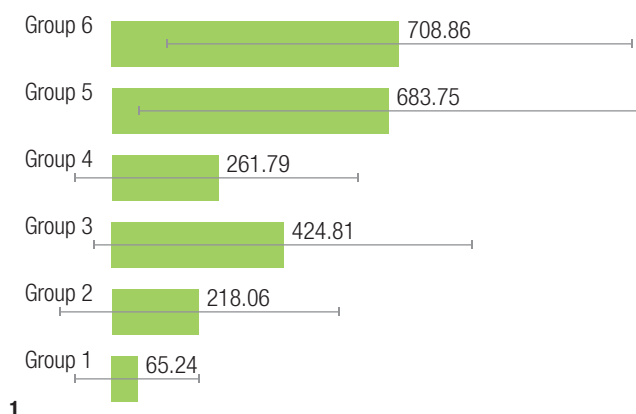
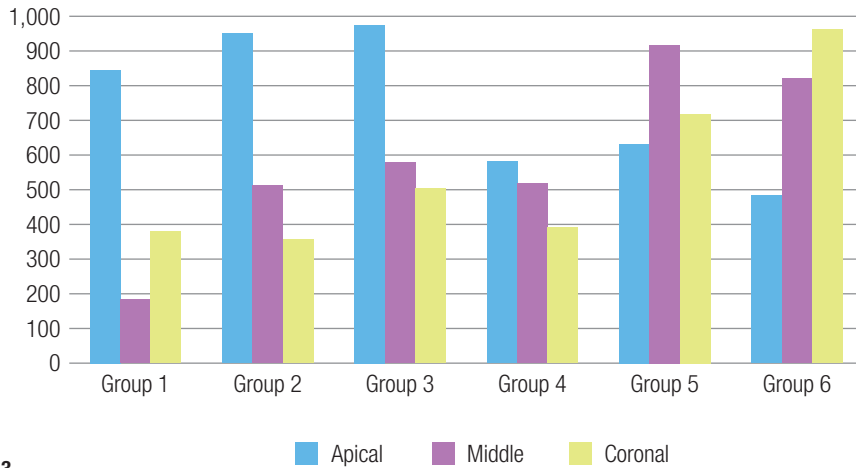
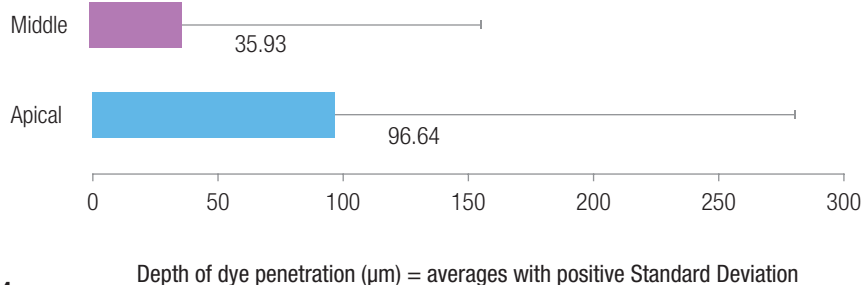


Fig. 1: Average dye penetration depth (μm) in all six groups. **Fig. 2:** Average dye penetration depth (μm) in all six groups based on the images of the vertical cuts of the roots.



3



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Fig. 3: Average dye penetration depth (µm) in all six groups according to the images that resulted from the horizontal sections. **Fig. 4:** The average dye penetration depth in the apical thirds was greater than in the middle thirds in Group 1, but the standard deviation shows that the difference could not be considered statistically significant ($p > 0.05$).

rank test ($p < 0.05$). The three examiners were unaware of the grouping of the teeth, and differences were reconciled by agreement. Since the magnification achieved by this technique was equal to 0.63x for the vertical cuts and 2x for the horizontal cuts, all the examiners could evaluate the samples at the same time with more comfort compared with using an optical microscope.

The extent of the leakage was scored as follows:

- 0: no penetration
- 1: penetration up to 500 µm
- 2: penetration up to 1,000 µm
- 3: penetration more than 1,000 µm.

Results

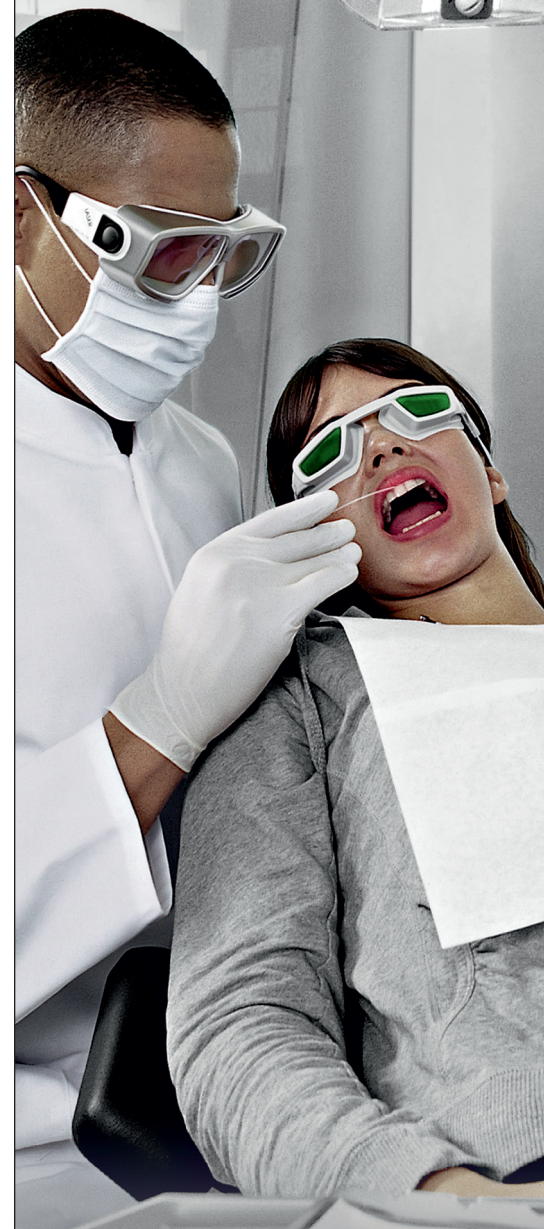
Figure 1 shows the average dye penetration depth in the various groups. In this graph, Group 4 shows a lower amount of dye penetration compared

with Groups 3, 5 and 6, but has a similar average to that of Group 2. As is seen in Figure 2, the general finding is that in Group 1 the apical thirds show more dye penetration, but in the other groups, we cannot state such an observation. The difference between Group 1 and Groups 5 and 6 was statistically significant ($p < 0.05$), but the differences between Groups 1, 2, 3 and 4 were not statistically significant ($p > 0.05$). In the vertical cross sections of the roots, besides the apical and middle thirds, the coronal thirds were examined as well (Fig. 3). In Groups 1 and 2, there was a greater average leakage in the apical thirds than in the middle and coronal thirds. Overall, there was no reportable difference between the coronal and middle thirds of all the roots. In the vertical cross sections, the apical, middle and coronal thirds were compared regarding the different kinds of laser irradiation and irrigation.

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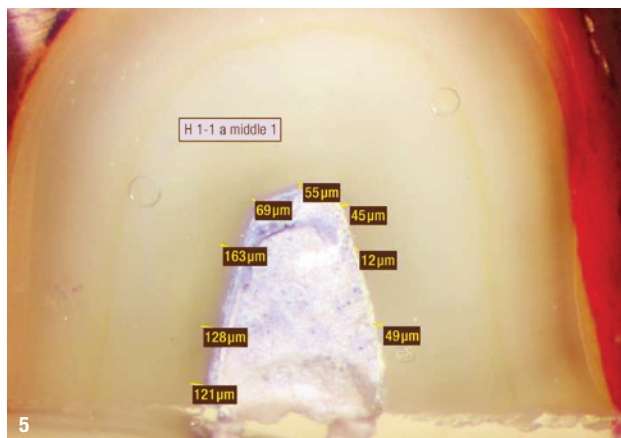
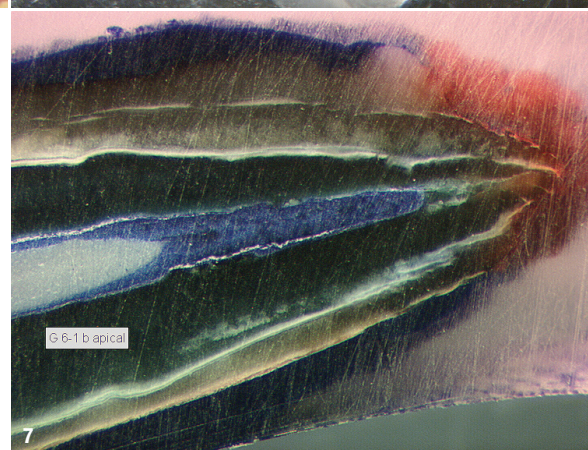
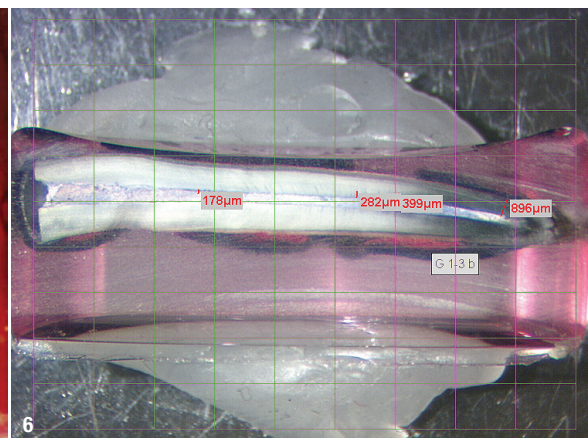


Fig. 5: A sample of cross-section cuts under the microscope. Dye penetration depth was measured by a computer programme. **Fig. 6:** A sample of vertical cuts of roots. Measurements are not as accurate as for horizontal views. **Fig. 7:** The apical region can be seen with more detail in vertical cuts, but even so, the measurements could not be done as accurately as for horizontal cross sections.



For better understanding of these findings, the depth of penetration was categorised as is shown in Table 2. The middle thirds of Group 1 show the lowest amount of dye penetration. The difference between the groups was not statistically significant ($p > 0.05$). However, the comparison between the apical thirds of the first three groups with the middle or coronal thirds of the same groups showed a statistically significant difference ($p < 0.1$). This result was narrower in Group 1. Therefore, the most valid result is that in Group 1, for which both lasers were used, the lowest penetration depths were reported. In this group, the apical thirds showed significantly higher dye penetration depths compared with the middle and coronal thirds (Fig. 4).

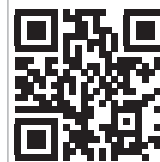
Discussion

No study has reported on the combined use of laser and Resilon. In studies that used Resilon as a filling material, a similar efficacy to that of gutta-percha was observed. Thus, the concern of the current investigation was to determine whether Resilon would show an acceptable integrity with the dentinal walls after laser therapy. The graphs and standard deviation overlaps of the six groups show that only the group treated with both lasers plus EDTA had a statistically significantly lower amount of leakage. The difference between the apical thirds and middle thirds of the same group was not statistically significant. As the average dye penetration depths in various areas in each cross section were reported as the resulting raw data of that slide, the horizontal images show more accurate and more reliable results (Fig. 5). But, as is seen in Figures 6 and 7 in vertical section imaging, the depth of penetration is not as easy and clear to measure as it is in horizontal samples. Therefore, for future studies, the use of horizontal cross sections only is recommended.

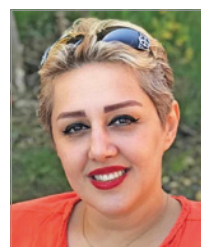
Conclusion

Resilon as an adhesion-based filling material shows good results in combination with EDTA and both Er,Cr:YSGG and Nd:YAG lasers according to the criteria of this study.

Literature



about the author



Dr Mina Mazandarani holds a DDS and an M.Sc. in Lasers in Dentistry from the Aachen Dental Laser Center at RWTH Aachen University in Germany. She is a PhD candidate in the Clinic for Dental Conservation, Periodontology and Preventive Dentistry at RWTH Aachen University hospital.

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