Evaluation of the influence of smear layer removal on the sealing ability of two different filling techniques

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ABSTRACT

Objectives: This study investigates the effects of Nd:YAG laser irradiation and 17% EDTA irrigation on apical seals with clearing technique, when used prior to two root canal filling techniques. **Methods:** Sixty freshly extracted human maxillary and mandibular canines and mandibular premolars, each with one root canal, were instrumented with ProTaper rotary nickel-TITanium instruments and then randomly divided into six groups according to the final irrigation solutions and Nd:YAG laser irradiation for smear layer removal and filling techniques employed: Group I: 2.5% sodium hypochlorite (NaOCl) and cold lateral condensation technique (CLC), Group II: 17% EDTA and CLC, Group III: Nd:YAG laser and CLC, Group IV: 2.5% NaOCl and thermoplasticized injectable gutta-percha technique (TIT), Group V: 17% EDTA and TIT, Group VI: Nd:YAG laser and TIT. After filling, the root surfaces were coated with a double layer of nail varnish, with the exception of the apical 2 mm, and placed in indian ink for 7 days. All samples were rendered transparent to measure the maximum linear dye penetration. **Results:** Group 1 showed significantly greater dye leakage compared with groups 5 and 6 (P<0.05). However, no significant difference was found between other groups (P>0.05). Canals obturated with TIT showed less mean dye leakage than canals obturated with lateral condensation. Groups, finally irrigated with 17% EDTA and irradiated with Nd:YAG laser, were showed lower mean dye leakage than control groups for both filling techniques. **Conclusions:** Under in vitro conditions, we found that smear layer removal improved the ability of the filling materials to prevent the fluid movement. Also, TIT showed less apical leakage than cold lateral condensation technique in the presence or absence of the smear layer.

Keywords: Apical leakage, Dia-Gun, EDTA, Nd:YAG laser, clearing technique

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INTRODUCTION

Besides proper cleaning and shaping of the root canal, the complete and hermetic filling of the root canal system is a major objective in root-canal treatment. For adequate apical sealing, the presence of smear layer and the filling technique to be used must be considered, among other factors. Studies have shown that mechanical instrumentation of root canals leaves a smear layer covering the dentinal walls.[1,2] This layer contains inorganic and organic material.[1] Despite controversy over maintaining the smear layer, it has been suggested by some authors that keeping the smear layer may block the dentinal tubules and limit bacterial or toxin penetration by altering the dentinal permeability.[3-5] In contrast, some experts believe that the smear layer must be completely removed from the surface of the canal wall because it can harbor bacteria and can be detrimental to effective disinfection of dentinal tubules by preventing NaOCl, calcium hydroxide, and other intracanal medicaments from penetrating into the dentinal tubules; and it can act as a barrier

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between obturating materials and the canal wall and thus interfere with the formation of an appropriate seal.[6-8]

Removal of the smear layer can be accomplished with the aid of chelating agents or laser devices. The most commonly used solution chelating agent is EDTA which reacts with the calcium ions in dentine and forms soluble calcium chelates. This solution is neither bactericidal nor bacteriostatic, but it inhibits the growth of eventually destroyed bacteria by the process of starvation. Also EDTA is generally effective at pH of 7.2.[9] Goldman et al[10] found that the use of a copious final flush with 17% EDTA, followed by NaOCl effectively removes the smear layer.

The effects of laser irradiation in endodontics have been investigated previously. Dederich et al.[11] observed root canal wall dentine after Nd:YAG laser exposure using scanning electron microscopy. They found melting and recrystallization of the dentine and speculated that the exposed dentine could have reduced permeability to fluids. Miserendino et al.[12] described how Nd:YAG laser irradiation reduced permeability due to the deposit of resolidified silica glass on the surface of canal walls. Harashima et al.[13] suggested that the Nd:YAG laser was useful for removing debris and smear layer and caused melting of internal structures on the instrumented root canal walls.

Several techniques have been developed to improve the seal of the prepared root canal. Currently, the most accepted and common technique is the cold lateral condensation of gutta-percha in combination with an insoluble root canal sealer. In many studies, this method served as a known standard to compare new filling techniques against.[14-16] However, the final root canal filling lacks homogenity and the lateral compaction of gutta-percha may also result in vertical root fractures if excessive condensation forces are used.[17-20]

To avoid such problems, different warm gutta-percha techniques have been introduced, and one of these is the high-temperature thermoplasticized injectable gutta-percha technique. This technique was introduced by Yee et al. in 1977 to improve the homogenicity and surface adaptation of the gutta percha and have been proved to significantly better than CLC in replicating root canal.[21] However, control of the apical extrusion of the softened gutta percha has been a major problem with these techniques.[22]

One of the most widely used methods for evaluating the sealing capacity of these materials in vitro is the study of apical leakage, where the tooth is immersed in a dying solution and quanTITative measurements are made of the degree of retrograde penetration observed. Different approaches have been described for accessing the root canal to visualize dye penetration, including longitudinal sectioning with a diamond disc,[23] clearing,[24] and cross-sectional techniques.[25]

The purpose of this study was to evaluate the effect of Nd:YAG laser irradiation and 17% EDTA irrigation on the apical leakage of obturated root canals with TIT and CLC.

MATERIALS AND METHODS

Selection and preparation of teeth

Sixty freshly extracted single-rooted maxillary and mandibular canines and mandibular premolars were used. All the teeth were radiographed to verify the presence of a single canal, mature apex, and absence of any resorption or endodontic obturation. Teeth with caries, cracks, and dilacerations were excluded. The external surface of the teeth was cleaned with curettes. The teeth were decoronated using a high-speed diamond disk with a cooling system to standardize the root length of 16 mm and stored saline solution until use.

Apical patencies were determined with a size #10 K file (Dentsply Maillefer, Ballaigues, Switzerland). The working length was established 1 mm short of the apical foramen. The specimens were shaped using ProTaper rotary instruments (Dentsply Maillefer) according to the manufacturer's instructions. Each instrument was only used for the preparation of five teeth. After using each file and before proceeding to the next, canals were irrigated with 2 ml of 2.5% NaOCl. Finally, the root canals were irrigated with 3 ml distilled water to avoid the development of NaCl crystals. The root canals were then dried with absorbent paper points. All teeth were divided randomly into six groups 10 teeth each. In group 1 and 4 (control groups), the root canals were irrigated with 2 ml 2.5% NaOCl followed by 3 ml distilled water. In groups 2 and 5, the root canals were irrigated with 2 ml 17% EDTA for 3 minutes followed by 3 ml distilled water. All the irrigating solutions were introduced into the canal using a 27-gauge stainless steel beveled needle. The needle was placed within 1 to 2 mm of the working length in each canal. The root canals were finally irrigated with 3 ml of distilled water to remove any precipitate that might have formed. In groups 3 and 6, the root canals were irradiated with a pulsed Nd:YAG laser (Smarty A10, Deka, Calenzano Firenze, Italy). The laser beam was emitted at a wavelength of 1064 nm and a flexible fibre delivery system was used. The parameter used was an output of 1.5 W, 100 mJ pulse and pulse frequency of 15 Hz. Throughout laser treatment, the fibre tip was applied with a spiral movement starting 1 mm above the apex and then moving coronally and five times for 3 seconds, interleaved with 30 seconds recovery intervals for each irradiation.

The root canals of groups 1, 2 and 3 were filled by means of the lateral gutta-percha condensation technique with gutta-percha cones and root canal sealer AH 26 (Dentsply De Trey, Konstanz, Germany) by one operator. AH 26 sealer was mixed according to the manufacturer's instructions and placed in the canal with a paper point to working length. The master cone was coated with AH 26 and gently seated at working length. Lateral condensation was then carried out using size 20 and 25 accessory gutta-percha cones with endodontic finger spreaders (Dentsply Maillefer) placed in the first instance to within 1 mm of the working length. The gutta-percha cones coated with sealer were laterally condensed until they could not be introduced more than 3 mm into the root canal.

The root canals of groups 4, 5 and 6 were obturated by TIT (Dia-Gun, North Fraser Way, Burnaby, BC, Canada) with AH 26 root canal sealer, according to the manufacturer's instructions. The master cone was coated with AH 26 and gently seated at working length. The Dia-Gun system was then set at 200°C and the applicator tip placed at the coronal third of the root canal. Tip of the device were then made contact with the upper part of the gutta-percha cone for 5 seconds and a hand plugger (Dentsply Maillefer) used to apply firm apical pressure to the gutta-percha. The remaining root canal space was obturated with backfilling technique. The gun tip was inserted into the root canal, the trigger was pulled slowly and gutta-percha filled in the root canal. After the excess gutta-percha was cut with a heated instrument, vertical condensation was performed to finish the filling.

After filling, the access cavities of all teeth were restored with Cavit (Espe, Seefeld, Germany). The teeth were radiographed in a proximal (mesiodistal) view to verify correct filling. In all cases, the sealers were allowed to set for 7 days at 37°C at 100% humidity. Then, the teeth were dried and coated with a two layers of nail polish, covering the whole tooth, including the coronal restoration of the access cavity, but leaving a 2 mm area around the apical foramen uncoated. After 1 hour of drying, all specimens were immersed in India ink (Pelikan, Hannover, Germany) for 7 days at 37°C. Then, the teeth were washed in water, and the nail varnish was removed with a scalpel. Teeth were demineralized in 5% nitric acid for 72 hours at room temperature (changing the solution every 12 hours), dehydrated in ascending concentrations of ethanol (80%, 90%, 96%), and stored in methyl salicylate at room temperature until they became clear.

Linear dye penetration was measured under a stereomicroscope (SMZ 800, Nikon, USA) at a 6X magnification. For each specimen, an average of three readings was taken. Apical leakage was measured as the distance from the anatomical apex to the deepest extent of dye penetration in a coronal direction (Figs. 1 and 2).

The results of the study were evaluated statistically using one-way ANOVA, Kruskal-Wallis and Mann-Whitney U tests. P values were computed and compared with statistical significance at the P=0.05 level.

RESULTS

The microleakage data for the different experimental groups are presented in Table 1. Group 1 showed significantly greater dye leakage compared with groups 5 and 6 (P<0.05). However, the statistical analysis revealed no significant differences in apcal leakage between the other experimental groups (P>0.05). Greater mean dye leakage was seen in groups obturated with the lateral condensation technique (groups 1, 2 and 3). Groups, finally irrigated with 17%EDTA and irradiated with Nd:YAG laser, were showed lower mean dye leakage than control groups for both filling techniques.

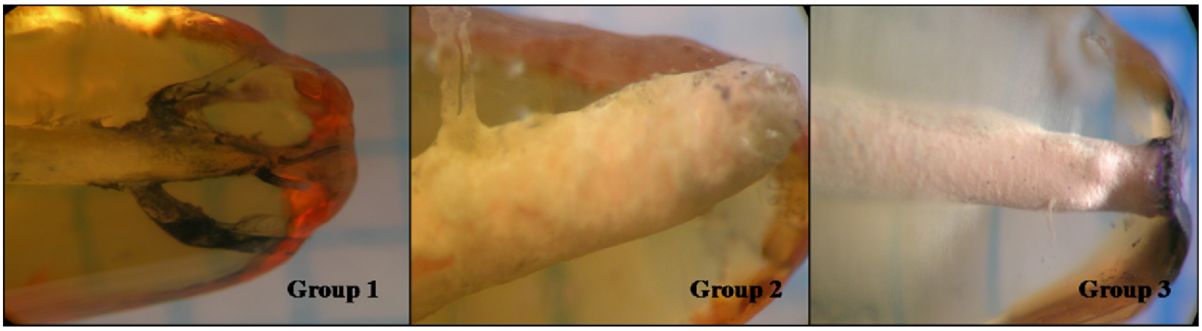

Fig. 1. Representative stereoscopic photographs from group 1 (2.5% NaOCl-CLC), group 2 (17% EDTA-CLC) and group 3 (Nd:YAG-CLC), original magnification 6X.

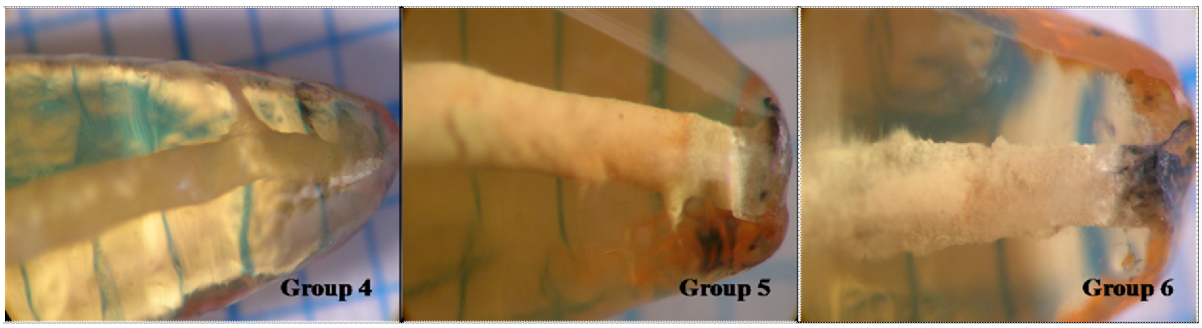

Fig. 2. Representative stereoscopic photographs group 4 (2.5% NaOCl-Dia-Gun), group 5 (17% EDTA-Dia-Gun) and group 6 (Nd:YAG-Dia-Gun), original magnification 6X

Table 1. Mean apical leakage and standart deviation values for each tested group (mm)

Groups	n	Mean (SD)
Group1 (2.5% NaOCl-CLC)[a-b,c,SS]	10	2.10 (1.64)
Group 2 (17% EDTA-CLC)	10	1.15 (1.02)
Group 3 (Nd:YAG-CLC)	10	1.45 (1.53)
Group 4 (2.5% NaOCl-TIT)	10	0.9 (0.61)
Group 5 (17% EDTA-TIT)[b-a,SS]	10	0.65 (0.52)
Group 6 (Nd:YAG-TIT)[c-a,SS]	10	0.55 (0.49)

CLC: cold lateral condensation; TIT: thermoplasticized injectable gutta-percha technique; SD: standart deviation; SS: statistically significant
a-b, SS (P: 0.041, $P<0.05$); a-c, SS (P: 0.031, $P<0.05$).

DISCUSSION

Assessment of linear dye penetration is a common method to explore apical leakage of root fillings after splitting the roots[14] or after clearing them.[15] In the present study, clearing technique was used to assess the apical leakage. The clearing technique was found to afford the largest volume of information on the morphology of the sealed canal, allowing three-dimensional visualization of the root canal, the degree of filling, and the possible condensation defects. The technique, moreover, facilitates the observation of lateral and accessory canals and clearly reflects the relation between the sealing material and apical foramen.[24] Although measuring the maximum linear dye does not provide information about the area of dye penetration, assessment of linear dye penetration provides sufficient data regarding apical leakage.[26]

In the present study, Nd:YAG laser and 17%EDTA were used for removal of the smear layer from root canals. Many reports have discussed apical leakage after laser irradiation. The use of the laser has certainly shown great promise in root canal therapy and main application is to remove the smear layer remaining on the instrumented root canal walls. Dederich et al.[11] first described how Nd:YAG laser exposure melted and recrystallized root canal dentine. They suggested that altered root canal dentine that appeared to be nonporous and continuous in nature could conceivably demonstrate reduced permeability to fluid. Miserendino et al.[12] also described reduced leakage to methylene blue dye after Nd:YAG laser exposure and they reported a bridge of glass-like material that partly occluded a lateral canal. Goodis et al.[27] have shown that direct Nd:YAG laser irradiation on dentine surfaces produced melting and recrystallization which, in turn, caused the dentine to be less permeable. Similar to previous studies, Park et al.[28], Carvalho et al.[29] found that the Nd:YAG laser irradiation appeared to improve significantly the quality of the apical seal and thus to reduce apical leakage following root filling.

In addition to NaOCl, the use of a chelating agent has been advocated to rid the root canal system of the smear layer. Irrigation with EDTA alone can only remove the inorganic portion of smear layer. Therefore to eliminate smear layer completely, it should be combined with an organic solvent such as NaOCl.[30,31] On the other hand, using sodium hypochlorite alone for irrigation produces clean canal walls having the smear layer still present.[30] Yang et al.[32] showed that in removing the smear layer, there was no significant differences between saline irrigation and NaOCl irrigation. These results indicate that to remove the smear layer efficiently NaOCl (organic tissue dissolving activity) should be coupled with a chelating agent such as EDTA.

Similar to these previous studies, the results of this study showed that smear layer removal using 17% EDTA and Nd:YAG laser reduced apical leakage for both filling techniques. This reduced apical leakage might be due to the laser irradiation and 17% EDTA irrigation that made the canal wall more appropriate for canal filling, for example, reduction of smear layer and removal of debris.

In the current study, group 1 showed significantly greater dye leakage compared with groups 5 and 6 ($P<0.05$). However, no significant difference was found between the other groups ($P>0.05$). When mean apical leakage was compared between two filling technique, groups 4, 5 and 6 (filled with TIT) produced less mean apical leakage than groups 1, 2 and 3 (filled with CLC). CLC has proven to be a very popular gutta-percha technique. However, its ability to conform to the internal surface of the root canal has been questioned. Brayton et al.[33] reported voids, spreader tracts, incomplete fusion of the gutta-percha cones and lack of surface adaptation. Also, this technique relies on sealer to fill accessory canals. Peters[34] demonstrated that some sealer used in lateral condensation might resorb with time. This might decrease the effectiveness of the root canal filling.

TIT is used by many pracTITioners to backfill the root canal system after the down pack phase of the master cone. The rationale of using this technique is to obturate the apical portion while creating a plug, so that the injected gutta-percha by the thermoplastisized gutta-percha injection system will not extrude to the periapical tissues.[35,36] The Dia-Gun system, used this present study, was introduced to make root canal easier and less time consuming. This system provides controllable amount of heat to the gutta-percha in the canal and is used in a similar manner as the E&Q Master and System B/Obtura II techniques. In a previous study, Leonardo et al.[37] found that E&Q Master system demonstrated no significant differences from the cold lateral condensation technique. They suggested that use of TIT had a positive effect on apical seal. Xu et al.[38] found that sealing ability of the E&Q Plus system (this system has same protocol with E&Q Master system) and CLC. They found that both technique showed similar effect on apical leakage in the short term. But greater amounts of leakage were found for cold lateral condesation technique at longer times. In another study, Rajeswari et al.[39] found that there was statistically significant difference between CLC and TIT (Obtura

II). The results of these previous studies similar to this present study.

Even though tooth root tissues are a poor thermal conductor, the root canal filling with heated gutta-percha may be responsible for the outer root surface temperature.[40] In the present study, temperature rises at the root surfaces were not observed, however, some studies have demonstrated the temperature rises on the outer surface of roots produced by high-temperature TIT. Eriksson and Albrektsson[41] conducted a vital-microscopic study on temperature threshold levels for heat-induced bone tissue injury on rabbit. They found that bone tissue heating to 47°C (10°C above body temperature) for 1 minute caused bone remodeling and fat cell necrosis. Gutmann and et al.[42] in a mongrel dog showed no apparent periodontal tissues destruction after the injection of high-temperature thermoplasticized gutta-percha (Obtura, 160°C) into the root canal. The changes in the temperature of the external surface of the bone overlying the roots obturated with TIT were also recorded and the maximum temperature elevation over 60 seconds was found to be 1.1°C. Sweatman et al.[43] measured temperature changes on the outer root surface at 2, 4, and 6 mm from the root apex and found temperature rises from 5.27 to 6.23°C, and Barkhordar et al.[44] used single thermocouple to analyze the temperature in the central part of the root, and found an in vitro maximum mean temperature rise of 4.72°C.

CONCLUSIONS

The present study revealed that removal of the smear layer with 17% EDTA and Nd:YAG laser and obturated root canals with TIT reduced apical leakage.

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