Neodymium-doped yttrium aluminum garnet laser \times self-etching primer: Association with mineral trioxide aggregate as retrograde root filling

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Abstract

Objective: The purpose of this study was to assess the effects of laser irradiation and self-etching primer on the microleakage of apicoectomized teeth retro filled with mineral trioxide aggregate (MTA).

Materials and Methods: A total of 60 bovine teeth were endodontically treated and had the apical 3 mm resected. Root-end cavities were prepared and the specimens were divided into five groups: Group 1 - control group, teeth only retrofiled with MTA; Group 2 - specimens treated with neodymium-doped yttrium aluminum garnet (Nd: YAG) laser on the inner walls of the root-end cavities; Group 3 - specimens treated as Group 2 added with Nd: YAG laser on the surface of the apical resection; Group 4 - teeth treated with self-etching primer on the inner walls of the root-end cavities, and Group 5 - teeth treated as Group 4 and in addition, treated with self-etching primer on the surface of the apical resection. All the specimens were retrofiled with MTA and sealed with varnish. The teeth were immersed in 2\% rhodamine B dye for 24 h. After this period, roots were washed, dried and resected. Marginal microleakage at material/root surface interface was evaluated quantitatively through linear measure in mm with the aid of a stereomicroscope and calculated by an image program.

Results: The mean values obtained were: Group 1 - 2.76 ± 0.60; Group 2 - 2.30 ± 0.84; Group 3 -2.21 ± 0.85; Group 4 - 1.04 ± 0.76, and Group 5 - 0.84 ± 0.40. ANOVA showed a significant difference among the groups ($P < 0.05$) and Tukey’s test revealed that Group 1, Group 2 and Group 3 were different from Group 4 and Group 5.

Conclusion: It was concluded that groups that used self-etching primer presented significantly lower degrees of marginal microleakage. Teeth treated with Nd: YAG laser presented same results as control group. The area of application did not reduce marginal leakage (for both laser and self-etching primer). Only MTA as a retro filling material was not sufficient to prevent marginal microleakage.

Keywords
Apoicectomy, lasers, retrograde obturation

Introduction

Endodontic therapy aims, among other factors, hermetic sealing of the root canals obstructing the change of fluids from the periapical tissues or from oral environment, avoiding microorganism proliferation, that could compromise the success of endodontic therapy.\textsuperscript{[1]}

Adequate endodontic treatment with the effective sealing of the root canals is of utmost importance in the maintenance of periapical health, blocking a new contamination by bacteria and their products derived from the apical region and lateral canals and dentinal tubules.

Conventional root canal treatment does not always result in clinical success. In cases where endodontic retreatment is not possible, periapical surgery is indicated.\textsuperscript{[2]} Among the surgical procedures, the apicoectomy with retrofiling is the standard of care. Several techniques and materials have been proposed aiming to provide the sealing of the root canal through...
a retrograde route and to promote tissue healing. The success of apical surgery depends on the perfect sealing of the canal system in order to obstruct the communication of tissue fluids, microorganisms and their metabolic products between the tooth and periapical tissues.[5]

The concept of complete obturation of the root canals system indicates the need of dentinal tubules and apical foramen sealing, aiming to block the bacterial invasion, however without periapical tissues irritation. With this purpose, several materials have been employed as retrograde fillings, including amalgam[4] composite resins,[5] zinc oxide and eugenol-based cements, such as intermediate restorative material (IRM) and Super-EB,[6] glass ionomer cements,[7] cyanoacrylate adhesives,[8] mineral trioxide aggregate (MTA),[9,10] and calcium enriched mixture (CEM) cement.[8] However, there is still a search for an ideal retropfilling material with suitable physical, chemical and biological properties.

MTA has been used since 1993 as a retro filling material due to its physical, chemical and biological properties. These properties include an antimicrobial effect and biocompatibility.[9,10]

Laser technology, especially the neodymium-doped yttrium aluminum garnet (Nd: YAG), has been used to occlude resected dentinal tubules, promoting fusion and recrystallization of the dentinal surface and presented good results.[11]

Dentin bonding agents have been used with the purpose of decreasing marginal leakage of retrofilings. Bampa and Vinha (1994)[12] observed decrease of marginal microleakage after the use of dentin bonding agent in teeth retrofilled with silver amalgam. According to Vignaroli et al. (1995)[13] dentin bonding agents, with silver amalgam or composite resins, are considered acceptable materials for retrograde procedures.

Considering the promising material and the properties provided by the Nd: YAG laser, the purpose of this investigation was to compare the use of MTA after a previous treatment with Nd: YAG laser or self-etching primer in the sealing of root-end cavities.

Materials and Methods

Selection and teeth preparation

Sixty freshly extract bovine incisive teeth with straight and complete roots were included in this study. After teeth extraction, they were cleaned and stored in distilled water until its use. The crown of each tooth was sectioned at the cementoenamel junction and the vestibular surface of each root was marked with a small furrow to make the identification easier.

Endodontic treatment of the teeth was performed in the following manner. The working length was established 1.0 mm less than the apical foramen. Each canal was prepared to a 50 K-file at working length and files to 80 K-file (Maillefer, Michigan, USA) were used in a step-back manner to complete the canal preparation. During all the instrumentation, teeth were irrigated with 1% sodium hypochlorite and the canals were dried with sterile paper points. The teeth were obturated with gutta-percha and sealer (Endofill-Dentsply Maillefer, North America, Tulsa Oklahoma) using a lateral condensation technique. The access openings were sealed with Cimpat (Septodont Spécialités, SP, Brazil). Then, all teeth had the apical 3 mm beveled at an angle of 90 degrees with a high-speed #56 carbide bur under constant water spray. The root-end cavities were prepared using a diamond bur (1014, KG Sorensen, Brazil) to a depth of 3 mm.

Division of the groups

After the procedures of apical sectioning and root-end cavity preparation, the teeth were randomly divided into five groups ($n = 12$): Group 1 - control group, teeth only retro filled with MTA; Group 2 - specimens treated with Nd: YAG laser on the inner walls of the root-end cavities; Group 3 - specimens treated as Group 2 added with Nd: YAG laser on the surface of the apical resection; Group 4 - teeth treated with self-etching primer on the inner walls of the root-end cavities, and Group 5 - teeth treated as Group 4 and additionally, treated with self-etching primer on the surface of the apical resection.

Pre-treatment with Nd: YAG laser or self-etching primer

Pre-treatment with Nd: YAG laser

Groups 2 and 3 were irradiated with Nd: YAG laser (Pulse Master 600IQ, American Dental Technologies) 1.2 W, 120 mJ/pulse and 10 Hz frequency. For laser application a point of 320 mm was used. The incidence on the surface of the apical resection was perpendicular to the surface and in the inner region followed a spiral course. For application on the inner walls of the root-end cavities, 3 applications (in contact) of 7 s were performed. For the irradiation of the external surface, corresponding to the resection of the root apical area, 3 applications of 7 s were performed in contact to the dental surface.

Pre-treatment with self-etching primer

Groups 4 and 5 were treated with Clearfil SE Bond, Kuraray Medical Inc., Okayama, Japan, according to the following procedures. First, self-etching primer were applied for 20 s and dried with air. Then, bond was applied, dried with air and light-cured for 10 s in the inner walls of the root-end cavity (Group 4), and in root-end cavity walls and surface of the apical section (Group 5), according to the manufacturer’s instructions.

After the pre-treatment, the cavities of all the teeth, including the control group, were sealed with MTA - Angelus, Londrina, PR, Brazil - (MTA) and stored in humidity at 37°C ± 1 for 7 days.

Marginal microleakage testing

After this period, all the roots were sealed with 3 layers of nail varnish except in the region of the sectioned apical surface and an area 1mm in width around the sectioned portion. Then, the
roots were immersed in a buffered solution of rhodamine B 2% during 1:30 h in vacuum environment (17 polHg) provided by a vacuum pump (Dia-PumpÔ - model CAL, type BF-172S, Fanen Ltda., São Paulo, Brazil). The specimens were kept into the dye solution for 24 h at 37°C ± ± 1 and relative humidity.

After the immersion in dye solution, the roots were washed in running water for 12 h, dried and the layers of nail varnish were removed. Roots were sectioned in the buccal-lingual plane. For this purpose, 2 grooves (buccal and lingual) were prepared in the external root surface and then the roots were cut with the aid of a chisel. Marginal microleakage evaluation was performed quantitatively through linear measurement (mm) at the dentine-material interface in the coronal direction.

Microleakage analyses were performed by two examiners using a stereomicroscope (MC80-DX, Carl Zeiss, Germany), considering the maximum microleakage observed in each specimen. The images were photographed by a digital camera and transported to a computer. Linear measurements correspondent to microleakage were calculated by Image Tool 3.0 program. The results of microleakage were compared using ANOVA (a = 0.05).

Results

Measurements of marginal microleakage of the different groups were submitted to descriptive statistical analysis (Table 1). Groups 4 and 5 presented the lowest measurements of microleakage. ANOVA showed a statistically significant difference amongst the mean of microleakage of the five groups (P < 0.05).

Tukey’s test (a = 0.05) was performed to observe the groups that differed statistically (Table 2).

Discussion

In apicoectomies, the apical sectioning causes exposure of thousands of dentinal tubules to the internal environment, leading to an important communication way between the canal system and the periapical tissues. Vertucci and Beatty (1986)\[14\] believe that this opening of dentinal tubules during apicoectomy can elevate the degree of marginal microleakage.

Table 1: Mean values (mm) and standard deviation of the maximum microleakage observed in the studied groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean value (mm)</th>
<th>Standard deviation</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>2.76</td>
<td>0.60</td>
<td>21.76</td>
</tr>
<tr>
<td>Group 2</td>
<td>2.30</td>
<td>0.84</td>
<td>36.40</td>
</tr>
<tr>
<td>Group 3</td>
<td>2.21</td>
<td>0.85</td>
<td>38.76</td>
</tr>
<tr>
<td>Group 4</td>
<td>1.04</td>
<td>0.76</td>
<td>73.03</td>
</tr>
<tr>
<td>Group 5</td>
<td>0.84</td>
<td>0.40</td>
<td>47.65</td>
</tr>
</tbody>
</table>

Group 1: Control, without any previous treatment, Group 2: Nd: YAG (inner walls of root-end cavities), Group 3: Nd: YAG (inner walls of root-end cavities+surface or apical resection), Group 4: Self-etching primer (inner walls of root-end cavities), Group 5: Self-etching primer (inner walls of root-end cavities+surface or apical resection), Nd: YAG: Neodymium-doped yttrium aluminium garnet

Gondim et al. (2005)]\[15\] reported that the better the marginal adaptation of root-end fillings, the fewer irritants would pass through the interface between the filling materials and the root canal wall. These observations justify the aim of the present study to evaluate the application of Nd: YAG laser or self-etching primer in the inner walls of the root-end cavities, and in the surface of the apical section. These procedures may lead to a better seal of the dentinal tubules in the apical region.

Apicoectomies were performed at 90° because such angle was the most frequently used and it would produce less microleakage than when apical resection is beveled. This angulation may have advantages like preservation of structure and decrease of the number of sectioned dentinal tubules.[9] Nowadays, studies demonstrated that when preparing an adequate retrograde cavity depth, the angle performed in the root-end will not enhance the microleakage.[16]

Authors have recommended the application of the MTA as a retrograde filling material, suggesting that a biological barrier at the apex can be obtained with this material.[10,13,17] According to Ruiz et al. (2003),[17] MTA is biocompatible and exhibits both osteoinductive properties and antimicrobial activity while promoting an adequate apical seal, since it is a hydrophilic material, and the humidity usually present during paraendodontics surgery does not affect the properties of this material. In relation to the indications of MTA, Torabinejad and Chivian (1999)[10] believe that it can be employed with success in cases of direct pulp capping, incomplete root genesis, repair of root perforations and as a retrograde filling material. Torabinejad et al. (1997)[18] reported that when MTA is used as a retrograde filling material, the formation of cement layers on the material can be observed. Moreover, Ferk Luketić, et al. (2008)[4] Torabinejad, et al. (1997)[18] Fischer, et al. (1998)[10] and Torabinejad and Chivian (1999)[10] asserted that the slight expansion of MTA in the presence of humidity can be considered a great advantage in relation to other retrograde filling materials, such as amalgam, Super-EBA and IRM, promoting better sealing.

Table 2: Results of Tukey’s multiple comparison test performed for comparison among the groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean values</th>
<th>Homogeneous groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>2.76</td>
<td>A</td>
</tr>
<tr>
<td>Group 2</td>
<td>2.30</td>
<td>A</td>
</tr>
<tr>
<td>Group 3</td>
<td>2.21</td>
<td>A</td>
</tr>
<tr>
<td>Group 4</td>
<td>1.04</td>
<td>B</td>
</tr>
<tr>
<td>Group 5</td>
<td>0.84</td>
<td>B</td>
</tr>
</tbody>
</table>

Similar letters indicate no significant differences, Group 1: Control, without any previous treatment, Group 2: Nd: YAG (inner walls of root-end cavities), Group 3: Nd: YAG (inner walls of root-end cavities+surface of apical resection), Group 4: Self-etching primer (inner walls of root-end cavities), Group 5: Self-etching primer (inner walls of root-end cavities+surface of apical resection), Nd: YAG: Neodymium-doped yttrium aluminium garnet
Based on these characteristics, MTA was chosen as the retrograde filling material in this study. It was observed that MTA alone was not enough to block the marginal microleakage. The association of an adhesive system, for instance, provided better sealing.

Although this study was performed in 3 mm deep cavities, in some cases, this deep is not possible to be executed in vivo, due to difficult access. Thus, in cases of difficult access to make retrograde cavities and there is a potential need for endodontic surgery, other biomaterials could be used in an orthograde manner, like MTA and CEM.

Valois and Costa (2004) suggested that the thickness of 4 mm is more adequate for using MTA as a root-end filling material. Therefore, it is important to evaluate other materials, such as Castor Oil Polymer, with a capacity to promote sealing of smaller cavities since MTA is not indicated in these cases.

Vignaroli et al. (1995) indicated the use of adhesive systems to seal sectioned root apex, as they observed significant reduction in the apical microleakage when four different dentinal primers were applied directly on the sectioned surface, without root-end cavity preparation. In this study, the lowest values of microleakage were observed when the self-etching primer was employed. It might have occurred because the self-etching was used before the retro filing with MTA. This adhesive is a material that prevents excessive conditioning of dentine or cement, since a single step conditions and permeates the dentin avoiding demineralized areas not impregnated. McDonald and Dumsha (1987) verified significant reduction in the apical microleakage when dentinal primer was used as retrofiling material together with composite resin. These authors also attributed these results to the sealing of dentinal tubules provided by adhesive system employed. These observations are in accordance to the results obtained in the present study. The placement of a dentin bonding agent is difficult to control, and the material could partially or completely block the apical preparation, thus, it is important to apply a thin layer of the adhesive system in order to avoid compromising the sealing ability of the retro filling material.

The effects of laser on dentinal and marginal permeability of apical surfaces of apicoectomy and retrofitted teeth have been analyzed. Lange-Marques et al. (1995) related that laser is characterized by presenting a wavelength that propagates in the space and time, maintaining the capacity of concentrating in a tiny point great quantity of energy. In clinical practice, lasers with high density of power more frequently used for hard tissues are Nd: YAG, Argonium and Er: YAG.

Nd: YAG is absorbed by phosphates and carbonate hydroxyapatite, disorganizing crystal structures by thermochemical ablation, while dentin converts into an ionizing gas free of debris, occluding tubules, thus, reducing the dentinal permeability.

CO₂ laser is also used and promotes irradiated root surfaces with craters and carbonized layer, similarly to cementum and no dentinal tubules.

Er: YAG promotes accurate apical resection by vaporization, hemostasis, minimal pain, no vibration and nor discomfort, shorter application time and minimal pain, in comparison to burs. Angiero et al. (2011) found that 86,15% of 65 teeth in a study in vivo demonstrated no complications, and concluded that laser-assisted surgery with erbium laser increases the possibilities of therapeutic approaches in cases of retrograde endodontic treatment.

According to Myers and Myers (1985), Miserendino, Levy and Miserendino (1995) and Lage-Marques et al. (1995) the application of Nd: YAG laser causes modifications in the canal dentinal surfaces due to the fusion that changes morphology and decreases dentinal permeability. Dederich et al. (1984) evaluated the effects of Nd: YAG laser irradiation on the root walls and observed that dentinal walls of the canal seem to be crystallized, non-porous, glazed and continuous. These characteristics may probably make it less permeable to the fluids. In the same way, Pashley et al. (1992) and Kinney et al. (1996) observed that application of laser promotes recrystallization of hydroxyapatite and, consequently, causes an increase in the resistance, microhardness and reduction in the capacity of dentine demineralization. However, in the present study, a better marginal seal and consequently reduction of permeability of the dentine exposed to the staining solution was not observed. Probably, the alterations suffered by the dentine irradiated by Nd: YAG laser made it smoother, reducing the sealing potential of the retrofilling material. Stabholz et al. (1992) reported that the application of laser causes fusion of apical dentine, new solidification and recrystallization of melted areas in an incomplete and discontinuous way. This incomplete and discontinuous recrystallization may favor marginal leakage and may be improved by the method of laser application inside the root-end cavity, moving in a spiral course, aiming that the optical fiber, and consequently the laser light, touches as perpendicular as possible the cavity walls. The factors described may have contributed to the greater microleakage observed in the groups with Nd: YAG laser application in relation to those with dentinal primer.

Pozza et al., 2009 found opposite results concluding that the best technical sequence was: 90° apicoectomy performed with bur and application of Nd: YAG laser at apical surface, showing low rate (less than 20%) of dye penetration. And assigned this to fact that the smear layer produced during the resection with a bur served as substrate for melting when treated with Nd: YAG laser and, thus, providing occlusion of dentinal tubules.

In a study conducted by Girish et al., 2013 polymethylmethacrylate bone cement was considered a better material as root end filling to prevent apical microleakage. Beside this, authors concluded that MTA presents minimum microleakage and is considered the gold standard root end filling material. And that Er:YAG laser when compared with
Associations used as retrograde root filling. Yui, et al.

Ultrasonics is a better choice for root end preparations maybe due to better preservation of the integrity of root-end cavities from the standpoint of dentinal chipping.

The use of laser presents some clinical limitations, particularly in endodontics, relative to the high cost of the device and the restrictive use in a few procedures, besides the laser has a poor access inside of root canal, especially in the apical region. In current study, results obtained by laser application were comparable to those obtained without its use.

Conclusion

It was concluded that groups that used self-etching primer presented significantly lower degrees of marginal microleakage. Teeth treated with Nd: YAG laser presented same results as a control group. The area of application did not reduce marginal leakage (for both laser and self-etching primer). Only MTA as a retro filing material was not sufficient to prevent marginal microleakage.

References