

EVALUATION OF APICAL LEAKAGE OF ROOT CANALS OBTURATED WITH Nd:YAG LASER SOFTENED GUTTA-PERCHA, LATERAL AND WARM VERTICAL CONDENSATION TECHNIQUES USING TWO TYPES OF ENDODONTIC SEALERS : AN *IN VITRO* STUDY

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Abstract

An *in vitro* study was carried out to compare the apical leakage of root canals obturated with different techniques: Nd:YAG laser softened gutta-percha, cold lateral condensation and warm vertical condensation, and to evaluate the leakage of root fillings.

Sixty human premolars (with single patent canal) were submitted to instrumentation by means of the step-back technique. The teeth were randomly divided into three experimental groups according to the obturation technique. The first group (n=20) was obturated by Nd:YAG laser softened gutta-percha, the second group (n=20) by cold lateral condensation and the third group (n=20) was obturated using the warm vertical condensation. Each group was divided into two equal subgroups depending on the type of sealer (AH 26® or Dorifill). Afterwards teeth received an impermeable coating on the external surfaces of the crown and root (except for the area nearby the apical foramen). After obturation, the access cavities were sealed and the teeth were immersed in aqueous 1% methylene blue dye for 7 days at 37°C. After that, the teeth were longitudinally sectioned and the apical leakage was evaluated using a stereomicroscope.

The warm vertical condensation presented the best apical sealing ability, followed by Nd:YAG laser and the lateral condensation technique. The statistical analysis of the apical leakage values showed no statistically significant differences between AH 26® and Dorifill in leakage rate.

Keywords: Nd:YAG laser - warm vertical condensation – microleakage – AH 26® sealer - Dorifill sealer.

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ÉVALUATION DE LA PERCOLATION APICALE DES CANAUX OBTURÉS AVEC LE LASER ND: YAG, LA GUTTA-PERCHA CHAUFFÉE, LES TECHNIQUES DE CONDENSATION VERTICALE LATÉRALE: UNE ÉTUDE *IN VITRO*

Résumé

Une étude *in vitro* a été effectuée pour comparer la micro-infiltration au niveau des canaux radiculaires obturés avec différentes techniques: la gutta-percha ramollie au laser Nd:YAG, la condensation latérale et la condensation verticale, et d'évaluer l'infiltration des obturations canalaires.

Soixante prémolaires humaines (avec un seul canal) ont été instrumentées par la technique «step-back». Les dents ont été divisées au hasard en trois groupes expérimentaux selon la technique d'obturation. Le premier groupe (n = 20) a été obturé par de la gutta-percha ramollie au laser Nd:YAG, le second groupe (n = 20) par la technique de condensation latérale et le troisième groupe (n = 20) a été obturé par la technique de condensation verticale. Chaque groupe a été divisé en deux sous-groupes égaux en fonction du type du matériau de scellement (AH 26® ou Dorifill). Ensuite les surfaces externes des couronnes et des racines des dents (à l'exception de la zone à proximité du foramen apical) ont été recouvertes par un revêtement imperméable. Après obturation, les cavités d'accès ont été scellées et les dents ont été plongées dans une solution aqueuse à 1% du bleu de méthylène pendant 7 jours à 37 °C. Après, les dents ont été sectionnées longitudinalement et la fuite apicale a été évaluée à l'aide d'un stéréomicroscope. La technique de condensation verticale a présenté la meilleure étanchéité apicale. Aucune différence statistiquement significative dans le taux de micro-infiltration n'a été retrouvée entre AH 26® et le Dorifill.

Mots-clés: condensation verticale à chaud – condensation latérale - matériau d'obturation canalair – Dorifill - AH 26®.

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Introduction

The concept of three-dimensional cleaning, disinfecting, and shaping of the root canal system has become the major aim of modern root canal treatment [1]. Not only are cleaning and shaping important but also sealing the root canal three dimensionally without any leakage from the apical foramen up to the coronal aspect of treated teeth. Sealing a root canal completely may increase the clinical success to a rate as high as 96.5% [2]. Periradicular tissue fluids, microorganisms and their associated toxins will leak into the root canal along the interface of the dentinal walls if the obturation is incomplete. Disseminated microorganisms in incompletely obturated root canals will reproduce and can migrate to the periradicular tissues and may cause irritation or inflammation. In endodontic practice, 60% of all the failures in root canal treatment are due to incomplete and unsuitable root canal obturations [2, 3].

Over the last several years, there has been much controversy over the use of lasers in dentistry in both the hard and soft tissue areas [4]. Recent developments in laser dentistry have led to an increasing acceptance of this technology by both professionals and general public. The potential hard tissue applications are: operative dentistry, endodontics, fixed prosthodontics, oral and maxillofacial surgery, periodontics and other branches of dentistry. In endodontics, the laser can be used as a source of heat, thereby, making possible to thermoplasticize gutta-percha in order to obturate the root canal system and to achieve a complete three-dimensional obturation of the root canal system without any potential leakage [5].

Many obturation techniques have been introduced specifically to increase the quality of the apical seal.

Lateral condensation of gutta-percha has been proven to be a very common and clinically effective filling technique. Schilder reported that vertical condensation of thermoplasticized

gutta-percha could achieve a complete three-dimensional obturation of the root canal system without any potential leakage [6].

The most commonly used core filling material is gutta-percha, but this material does not seal the canal when used alone because it adapts but does not adhere to the dentine walls. A sealer must be used concomitantly to fill the irregularities and minor discrepancies between the core filling material and the canal walls thereby providing a seal. Sealers can be classified as epoxy resin-based, zinc oxide and eugenol-based, glass ionomer sealers, non-eugenol sealers and calcium hydroxide sealers.

Among other physico-chemical properties, the sealing ability of sealers is important. For many years, an inadequate apical seal has been considered responsible for the failure of endodontic treatment [7].

The purposes of this study were:

1- To compare the effect of three types of obturation techniques (laser obturation technique, lateral condensation technique and warm vertical condensation technique) on the apical leakage.

2- To compare the effect of two types of endodontic sealers (zinc oxide eugenol and epoxy resin sealers) on the apical leakage.

Materials and methods

Sample selection

Sixty extracted human lower premolars with single canal, free of caries, restorations, cracks or obvious defects were cleaned and stored in 50% ethanol at 8°C for a maximum of 1 month following extraction in order to avoid microbial contamination. This storage medium was chosen because it produces little change in dentin permeability [5]. Prior to the experiments, the teeth were placed in water for 24 hours at 20°C [5].

Sample preparation

External soft tissue and debris were removed from the tooth using

ultrasonic scaler. The coronal portion of each tooth was removed to the level of the cervical line using a diamond disk with a straight hand piece (Fig. 1). Patency of each canal was established by passing a #10 k-file through the apical foramen; the pulpal tissue was removed by using barbed broaches, then the working length was determined by subtracting 1mm from the length at which the tip of #10 k-file just appeared at the apical foramen. The canals were instrumented using conventional hand instrumentation with circumferential filing action to master apical k-file #60. Each canal was irrigated after each instrument with 2.5% solution of sodium hypochlorite throughout the canal preparation, and then the canals were dried with paper points.

Sample grouping

The specimens were randomly divided into three groups:

*Group 1 (n=20): Nd:YAG laser softened gutta-percha technique.

Teeth were obturated using the Nd:YAG laser obturation technique (Fig. 2). The Nd:YAG laser was used as an intracanal heat source for the sectional warm gutta-percha condensation technique. The gutta-percha cone was cut into 2 mm long small particles using a surgical blade. The intracanal dentin walls were coated with a thin layer of sealer using a spiral lentulo [1]. The apical portion of the master cone was introduced into the canal and inserted to the apical stop using a hand plugger (Dentsply). The optical fiber was placed into the canal 1 mm from the gutta-percha fragment. Then the gutta-percha fragment was lased twice with the Nd:YAG laser (TwinLight™, Italia) at a pulsed wave (60mJ, 10Hz, 0.6 W). Immediately after withdrawing the optical fiber, gutta-percha was condensed vertically using a hand plugger (size 2) that was pre-sized to fit 1 mm from the working length. The condensed gutta-percha was lased once more and an additional gutta-percha fragment was inserted into the canal. Insertion of gutta-per-

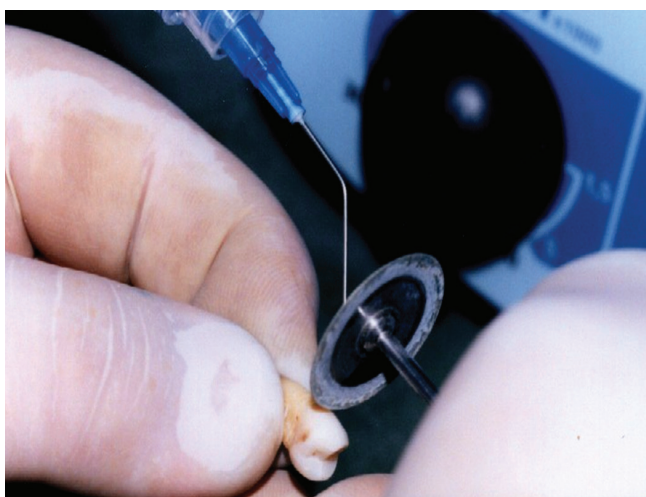


Fig. 1: Crown sectioning.



Fig. 2: Nd:YAG laser.



Fig. 3: Materials and equipment used in the study.

cha fragments, lasing, and condensation steps were repeated in the same manner and the larger size plugger (size 3) was used until the desired level was achieved [1].

*Group 2 (n=20): cold lateral condensation technique.

*Group 3 (n=20): warm vertical condensation technique.

Each group was divided in two subgroups depending on the sealer applied:

-In subgroups 1a, 2a and 3a, the sealer used was zinc-oxide-eugenol-based (Dorifill, Dorident) (Fig. 3).

-In subgroups 1b, 2b and 3b, the sealer used was an epoxy resin sealer (AH 26® sealer, Dentsply) (Fig. 3).

The coronal access preparations were obturated with zinc phosphate cement after removing the excess of gutta-percha from the coronal pulp chamber. All the teeth were stored in 100% humidity at 37°C for 48 hours to give sufficient time for the setting of sealers.

Further processing of the samples

After checking the obturation of all samples with radiographs (Figs. 4, 5), the samples were dried and cov-

ered with two layers of nail varnish to prevent leakage from the root surface, leaving the 2 apical millimeters uncovered. Samples were suspended by dental floss in a closed test tube containing a 1% aqueous solution of methylene blue dye (pH= 7) for 7 days at 37 °C. After 7 days, the teeth were removed from the dye and rinsed with tap water for 5 minutes (Fig. 6). After that, nail varnish was ablated with a curette (Fig. 7). Teeth were bi-sectioned longitudinally. Sections were observed under a stereomicroscope (Olympus SZ 4045, Tokyo, Japan), and the linear extent of maximum dye penetration



Fig. 4: The intraoral camera used.

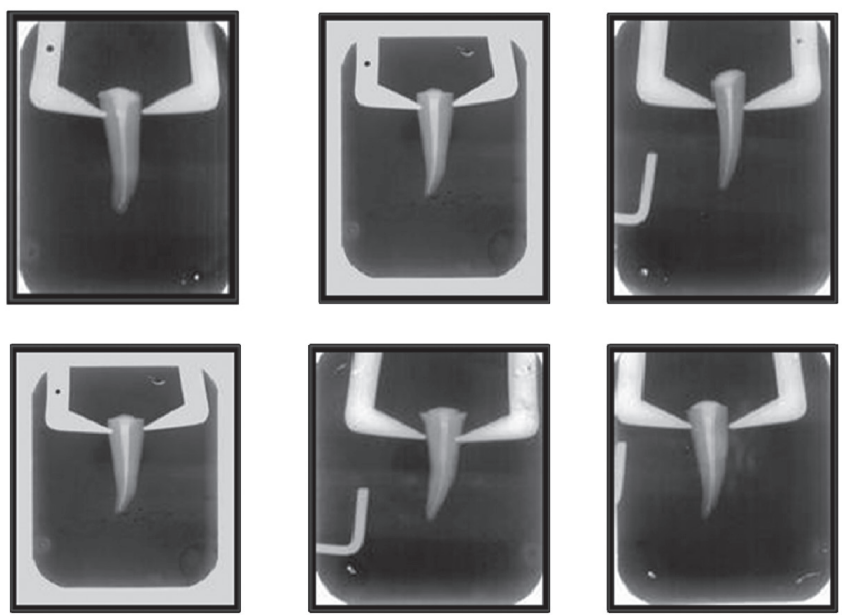


Fig. 5: Radiographs of obturated specimens.



Fig. 6: The samples after removing from the dye.



Fig. 7: Specimens after nail varnish ablation.

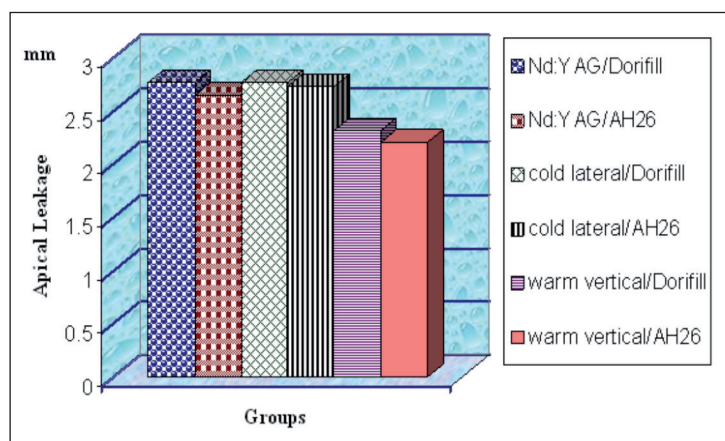


Fig. 8: Mean dye penetration values (mm).

Groups	N	Mean value of dye penetration
Group 1a: Nd:YAG +Dorifill	10	2.767 ± 0.290
Group 1b: Nd:YAG +AH 26®	10	2.652 ± 0.298
Group 2a: Cold lateral condensation + Dorifill	10	2.769 ± 0.312
Group 2b: Cold lateral condensation + AH 26®	10	2.725 ± 0.291
Group 3a: Warm vertical condensation + Dorifill	10	2.316 ± 0.373
Group 3b: Warm vertical condensation + AH 26®	10	2.206 ± 0.478

Table 1: Mean dye penetration values (mm).

from the terminus of the gutta-percha was recorded with a digital caliper.

Statistical analysis

Statistical analyses were performed using a software program (SPSS for Windows, Version 13.0, Chicago, IL). The level of significance was set at $\alpha = 0.05$. Two-way analysis of variance followed by multiple comparison tests was conducted to compare the mean values of microleakage among groups.

Results

Under the conditions of the present study, all experimental groups demonstrated different degrees of dye penetration alongside the canal space and in the dentinal tubules (Fig. 8).

The mean values of linear microleakage for the different groups and sub-groups are presented in table 1.

The results of the study did not show significant differences between Dorifill and AH 26® for the Nd:YAG group ($p > 0.05$), the cold lateral condensation group ($p > 0.05$) and the warm vertical condensation group ($p > 0.05$). On the other hand, the obturation with the warm vertical condensation technique (AH 26® and Dorifill) showed the lowest apical dye penetration ($p < 0.05$); however, no significant difference was found between Nd:YAG and cold lateral condensation technique ($p > 0.05$).

Discussion

A three dimensional obturation and a complete coronal and apical seal

is one of the important aims of root canal treatment. Since microorganisms may remain in the root canal system after instrumentation, a tight apical seal is desired to prevent bacteria and their by-products from invading the apex [8]. Allison et al. [9] explained that the quality of apical seal was related directly to the method of canal preparation.

In the present study, single-rooted teeth with single patent root canals were selected to minimize anatomical variation and allow standardization. The teeth were chosen based on strict criteria to promote comparison between experimental groups and eliminate many clinical variables. The roots were without great curvature; the determination of working length, canal access and instrumentation were uncomplicated.

For the examination of the leakage behavior of different sealers and root canal filling techniques, numerous methods are described. The differences among the obturation techniques were not independent of the measuring technique. Miletib et al. [10], in their study concluded that there was no statistically significant correlation between leakage measured by the fluid transport and dye penetration.

Assessment of linear dye penetration is a common method to explore apical leakage of root fillings. This measurement involves either splitting the root longitudinally or decalcifying the tooth and measuring how far the dye traveled up the central canal. Veis et al. [11] reported in 1996 that these two methods resulted in differences of length so close and were considered insignificant. As the dye entered accessory canals and the dentinal tubules, volumetric measurements offered a better look at the actual leakage patterns. Al-Hashimi & Zakaria [12] reported that dye penetration is one of the oldest and most frequently used methods for the evaluation of microleakage due to its simplicity and relatively good results determination.

The methylene blue was used in the present study because it was

reported that normal dentine would permit the penetration of the dye into the dentinal tubules of human teeth [13]. Methylene blue dye was found to be useful as a tracer of microleakage, because it is detectable in dilute concentrations, easy to photograph, non-toxic and permits more reproducible results. In fact, the high contrast between the methylene blue dye and the pink gutta-percha material makes the leakage pattern quite visible and linear penetration easy to measure with micrometer device.

The possible routes of dye penetration through filled root canals are [14]:

- (a) Between the sealer and dentine.
- (b) Between the core material (gutta-percha) and sealer.
- (c) Through the core material.
- (d) Through the sealer.

Stereomicroscope examination of the sectioned specimens showed that AH 26® specimens leaked between the sealer and the dentine, which suggests that the sealer appeared to bond more effectively to gutta-percha than to dentine. Tagger et al. [15] support our results when measuring the bond of endodontic sealers to gutta-percha as shearing strength; they found that the epoxy-resin sealers had significantly higher bond strengths than the other five sealers used [15]. This finding is in agreement also with another study [14].

In the present study, the decalcification and clearing method wasn't adopted because it has been shown that the particles of the methylene blue dissolve during decalcification and clearing, thus affecting the end result [16].

However, evaluating the leakage under stereomicroscope after root sectioning presents a major disadvantage represented by the inability to measure leakage without destroying the root specimens. Repeated observation of the same specimen overtime to reveal changes in sealing ability is therefore impossible [17].

Root-canal obturations were performed using three different methods: the classic cold lateral condensation

technique, the warm vertical condensation technique and a sectional gutta-percha vertical condensation technique using a laser device (Nd:YAG) as an intracanal heat source. The results showed that the warm vertical condensation technique presented the lowest mean of apical infiltration, followed by the Nd:YAG laser thermoplasticized gutta-percha, with no significant difference between the two groups.

The literature shows wide diversification with respect to the apical leakage caused by the lateral condensation technique [18]. In the present study, cold lateral condensation technique presented a higher mean of apical leakage compared to the remaining techniques. Lateral condensation produces a less homogeneous obturation with poorer adaptation to the canal walls; maximum gaps are observed because gutta-percha cones are merely laminated together compared to the techniques that use thermoplasticized gutta-percha [19]. This may possibly explain the fact that the root canals obturated with this technique numerically presented the highest mean of apical leakage.

In the third group, the warm vertical condensation method was used. According to Schilder, when using the warm vertical technique, the heat allows the plasticized gutta-percha to flow apically and into the root canal irregularities. Similar results were obtained in our study: the warm vertical technique gave the best results. This could be attributed to the fact that the use of pluggers in the vertical compaction of the plasticized gutta-percha additionally reduced the voids, filled the accessory canals and increased the homogeneity and adaptation [20].

Success in the clinical use of Nd:YAG lasers largely depends on the wavelength, output power, pulse duration, exposure time, spot size, type, and color of the irradiated tissue [21, 22]. In the present *in vitro* study, various findings were revealed, such as the Nd:YAG laser vertical thermoplasticized gutta-percha appeared to be also homogenous, but at fragment junc-

tions, there were carbonization areas at the impact points. The Nd:YAG laser beam caused burning of the gutta-percha and root canal sealer, which were blackened at the impact points between the gutta-percha fragments. Similar observations were reported in another study [1, 23]. The carbonization-like effect may change the physical and chemical properties of the root-canal sealer and gutta-percha, which may prevent fusion of the gutta-percha fragments [1, 24]. Argon and partial CO₂ lasers could be more suitable for softening the gutta-percha fragments in the apical third of the root canal [25]. However, all three laser devices were not acceptable for accomplishing complete root canal obturation [25].

Ideally, the root canal filling should be a complete, homogenous mass that fills the prepared root canal completely. To achieve this goal, sealers are evidently necessary. This is supported by many studies, which also showed that teeth obturated solely with gutta-percha exhibited extensive leakage [26-28].

A wide variety of root-canal sealers are commercially available; they are divided into groups according to their chemical composition. There is no consensus on which materials seal more effectively. Major advantage of sealer is elimination of any space that allows percolation, and resists dislodgment of the filling during subsequent manipulation (as when preparing for a post). Bonding or adhesion is not listed as one of the required properties of a sealer [29], however it should be tacky when mixed to provide good adhesion to the canal wall when set.

Endodontic sealers based on zinc oxyde eugenol (ZnOE) have been used clinically for several decades because they have satisfactory physicochemical properties [30]. In the present study, greater measured leakage for sealers based on ZnOE compared with epoxy resin-based sealers was found even though the difference wasn't statistically significant.

One possible explanation for this observed difference may be that AH

26® had been transported or mechanically forced into the dentinal tubules and thus it occluded the dentinal tubules. This resulted in a decrease in dentinal permeability, and consequently in dye penetration.

Brooke et al. [31] in their study explained the relationship of intra-canal pressure with the viscosity of endodontic sealer during warm gutta-percha vertical compaction; differences in intra-canal pressure were detected between sealer viscosity groups, the most viscous group had the largest intra-canal pressure. Also, throughout the phases of obturation, intra-canal pressure didn't remain constant; values at the time of heat application were lower than at the cone insertion and force application.

De Gee et al. [32] indicated that AH 26® showed diminished leakage by the time; they explained this as a result of the slow setting properties of the material. They reported that this property may allow sufficient time for the development of adhesion to dentin but the shrinkage stress may fracture the still weak unset sealer cohesively.

Conclusion

This study emphasizes the fact that no obturation technique is completely successful in eliminating all apical leakage.

The cold lateral obturation technique resulted in definite voids and gaps between gutta-percha and canal interface at all levels of the root canal. The warm lateral technique resulted in a uniform smooth surface and least observable space between gutta-percha and canal wall.

Within the limitations of this *in vitro* study, we conclude that:

Lateral condensation, warm vertical condensation, and Nd:YAG laser-softened gutta-percha techniques were effective in restricting apical dye penetration.

Obturation with the warm vertical condensation technique when the AH 26® was used as a sealer showed the lowest apical dye penetration, whereas

the cold lateral condensation technique with Dorifill used as a sealer showed the greatest dye penetration.

AH 26® root canal sealer (epoxy resin sealer), expressed the least degree of leakage in comparison with the Dorifill sealer (zinc oxide based), especially when it was used in conjunction with warm gutta-percha technique, but the difference was not statistically significant.

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