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# Assessing microleakage of different class V restorations after Er:YAG laser and bur preparation

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**SUMMARY This study assessed *in vitro* marginal leakage of class V cavities prepared by turbine and Er:YAG laser and restored with different materials. Sixty cavities with enamel and dentine margins were prepared and assigned to six groups: I, II, III by turbine and IV, V, VI by Er:YAG laser. The following restorative systems were used: groups I and IV: Bond 1 + Alert; II and V: Fuji II LC; III and VI: SBMP + Dispersalloy. After finishing, specimens were thermocycled for 8 h and 45 min (500 cycles), isolated, immersed in a 0·2% Rhodamine B solution, sectioned oro-facially and analysed for leakage. The dye penetration means (%) were: occlusal I: 10·09 (±21·28), II: 3·25 (±10·27), III: 0, IV: 41·77 (±42·48), V: 23·37 (±33·79), VI: 12·66 (±24·06); cervical I: 16·49 (±26·67), II: 4·34 (±13·71), III: 0, IV: 37·71 (±30·47), V: 39·56 (±43·35) and VI: 72·53 (±37·79). The use of Er:YAG laser for cavity preparation yielded higher degree of marginal leakage, as compared with the use of conventional air-turbine. The enamel interface provided better marginal sealing, comparing with dentine/cementum margin. As to the cavity preparation device (i.e. laser or bur), the analysis of the results showed that bonded amalgam and Fuji II LC provided less infiltration, than Alert. On the other hand, for lased cavities, Alert provided the best results, similar to those of Fuji II LC and superior to those reached by bonded amalgam.**

**KEYWORDS: microleakage, cavity preparation, Er:YAG laser, bonded amalgam**

## Introduction

Most recently, alternative methods for preparing dental hard tissues, such as laser irradiation, have been studied increasingly. Indeed, efforts to apply lasers in dentistry date back to the introduction of this technology and its applicability for different procedures has become a subject of great interest since, for dental research.

Shortly after Maiman (1960) published his pioneering experiment, dental researchers began to investigate the possibility of preparing dental hard tissues with laser. Stern and Sognnaes (1965) examined the effects on tooth structure and were the first to report that dental enamel could be vaporized by the ruby laser. Further investigations, however, revealed that laser irradiation resulted in fusion and charring of dental and surrounding tissues and inevitably caused irreversible damage as a result of the considerable temperature rise (Stern, Renger & Howell, 1969). Therefore, at that initial stage, laser devices yielded no acceptable application to dental practice. However, as it seemed to be a promising and widely applicable technology, those negative results did not discourage dental laser investigation.

The goal of the first laser irradiation was to replace conventional high- and low-speed dental drills providing the same effectiveness with freedom from pain and discomfort by eliminating pressure, vibration, noise and, in most cases, the need for local anesthetic (Cozean *et al.*, 1997; Keller *et al.*, 1998). It would also allow the conservative removal of incipient lesions, without extending preparation into sound tooth structure.

Continuous research led to the development of other laser systems and opened the dimensions and possibilities in dental laser investigation. Nowadays, by varying some parameters (pulse mode, frequency, output energy, irradiation time), several types of laser, such as argon, GaAsAl, carbon dioxide and neodymium:YAG have been used for different purposes, including polymerization of light-activated materials, bacterial reduction, caries prevention, tooth bleaching and endodontic procedures (McCormack *et al.*, 1995; Berkiten, Berkiten & Okar, 2000; Matsumoto, 2000; Powell & Blankenau, 2000; Sun, 2000; Westerman, Hicks & Flaitz, 2000; Hossain *et al.*, 2001; Huang *et al.*, 2001).

The last years, an impressive number of studies (Moritz *et al.*, 1996; Visuri *et al.*, 1996; Cozean *et al.*, 1997; Niu *et al.*, 1998; Hossain *et al.*, 1999; Mehl *et al.*, 1999; Aoki *et al.*, 2000; Borsatto *et al.*, 2001; Ceballos *et al.*, 2001; Corona *et al.*, 2001; Roebuck, Whitters & Saunders, 2001) have been focused on investigating the efficiency of Er:YAG laser for potential dental applications, such as removal of carious tooth substance, cavity preparation, surface treatment, periodontal procedures and other. Laboratory research and clinical trials have demonstrated the ability of Er:YAG laser to effectively ablate hard dental tissue with minimum injury to pulp and surrounding structures. The 2·94-μm wavelength emission coincides with the main absorption peak of water and hydroxyapatite, thus resulting in good absorption of erbium laser in all biological tissues, including enamel and dentine (Cozean *et al.*, 1997; Pelagalli *et al.*, 1997; Roebuck, Saunders & Whitters, 2000).

Several parameters, including power and energy densities focal length, beam mode and refrigeration during irradiation (Burkes *et al.*, 1992; Tanji, 1998), also play significant roles in the response of tissues to Er:YAG laser, pointing out the volume of ablation as well as the maintenance of surrounding dental tissues' integrity.

However, despite the recognized effectiveness of Er:YAG laser for enamel and dentine ablation, the literature has shown controversial results concerning the marginal infiltration on cavities prepared by erbium laser, depending on the restorative filling material (Liberman *et al.*, 1990; Keller & Hibst, 1993; Wright, McConnell & Keller, 1993; Khan *et al.*, 1998; Niu *et al.*, 1998; Ramos, 1998; Roebuck *et al.*, 2000, 2001; Corona *et al.*, 2001; Palma Dibb *et al.*, 2002; Quo *et al.*, 2001). Moreover, there are few reported researches evaluating the marginal sealing of amalgam and packable composite resin in cavities prepared with laser irradiation.

Despite the great diversity of dental materials, the restoration of abrasion, erosion or abfraction cervical lesions still consist of a major challenge for professionals and researchers. The margins of such restorations are generally located in dentine/cementum, thereby constituting an additional difficulty for the restorative materials that relies on chemical and/or mechanical union to provide retention on tooth structure. The direct restorative materials usually indicated for class V cavities include composite resin, glass–ionomer cement and amalgam (Corona *et al.*, 2001).

Therefore, the aim of this study was to assess *in vitro* microleakage on class V cavities restored with compactable composite resin, resin-modified glass–ionomer cement and bonded amalgam, comparing high-speed dental bur and Er:YAG laser for cavity preparation.

## Materials and methods

Thirty sound human third molars, extracted within a 6-month period and stored in saline solution at 4 °C, were selected and cleaned with water/pumice slurry in dental prophylactic cup. Sixty class V cavities, with the occlusal margin in enamel and cervical margin located 1 mm below the amelocemental junction, were prepared on buccal and lingual surfaces. Cavity dimensions were standardized utilizing a template to trace onto both surfaces an outline with a mesiodistal width and a occlusalgingival measure of 3 mm. The depth of cavity was 1·5 mm, calibrated by measuring it with a marked periodontal probe. The specimens were randomly assigned to six equal groups of 10 cavities. In each tooth, buccal and lingual preparations were restored with different materials.

For groups I, II and III, cavities were prepared using a round-nosed no. 245 carbide bur at high-speed with air/water spray. New burs were used after every five preparations.

For groups IV, V and VI, cavities were prepared by a short-pulsed Er:YAG laser (Kavo Key Laser 2)* with an output energy of 500 mJ at 5 Hz, emitted at a wavelength of 2·94 μm under water spray coolant. The diameter of the laser beam at tooth surfaces was 1·0 mm and a handpiece (2051) with a removable tip was used attached to flexible fibre delivery system. After cavity preparation, dental surface was treated by short-pulsed Er:YAG laser with lower dosimetries (120 mJ, 4 Hz).

*Kavo Co., Biberach, Germany.

**Table 1.** Tested materials

| Groups | Cavity preparation | Restorative system | Batch No. | Manufacturer |
|---|---|---|---|---|
| I | Air turbine | Bond 1 + Flow-It + Alert | 22853, 14822 | Jeneric-Pentron, Inc. |
| II | Air turbine | Fuji II LC | 0002091 | GC Corporation |
| III | Air turbine | SBMP (activator, adhesive, catalyst) + Dispersalloy | 6JD, 7RU, 4AK 000316 | 3M Dentsply Caulk, |
| IV | Er:YAG laser | Bond 1 + Flow-It + Alert | 22853, 14822 | Jeneric-Pentron, Inc. |
| V | Er:YAG laser | Fuji II LC | 0002091 | GC Corporation |
| VI | Er:YAG laser | SBMP (activator, adhesive catalyst) + Dispersalloy | 6JD, 7RU, 4AK 000316 | 3M Dentsply Caulk |

Cavities were filled with three different materials: a compactable composite resin (Alert)†; a resin-modified glass–ionomer cement (Fuji II LC)‡; and an admixed high copper amalgam alloy (Dispersalloy)§ (Table 1).

In the groups restored with the compactable composite resin (Alert), enamel and dentine surfaces were etched with a 37% phosphoric acid gel (Gel Etchant)¶ for 20 s, rinsed for 20 s and gently dried with absorbing paper to remove water excess and keep tooth surface moist. Two coats of a single-component bonding system (Bond-1)† were applied, air-thinned and light-cured for 10 s using a visible light-curing unit with an output of 450 mW $cm^{-2}$ (XL3000)**. According to the technique proposed by Hansen (1986), a uniform layer of a flowable composite resin (Flow-It!)† was initially applied at both axio-occlusal and axio-gingival angles and light-cured for 40 s and then the compactable composite resin was incrementally inserted with appropriate instruments. Each increment, of about 1 mm thick was light-cured for 40 s. The finishing was accomplished by removing the roughest excesses with a scalpel blade.

The cavities restored with resin-modified glass–ionomer cement (RMGIC) were treated with a 40% polyacrylic acid (Durelon)††, applied over enamel and dentine surfaces with light scrubbing motion for 10 s. Afterwards, Fuji II LC standard powder/liquid ratio (3·2 g/1·0 g), was dispensed and mixed within 20 s, as specified by the manufacturer. The resultant mixture was injected into the cavities in a single increment using a Centrix injector‡‡ to prevent void and bubble formation and light cured for 30 s. Restorations were finished with a scalpel blade and a thin layer of fluid resin (Single bond)** was applied over the restoration to prevent water loss and uptake.

For the cavities restored with bonded amalgam, tooth surface was etched with a 35% phosphoric acid gel** for 15 s, washed for 15 s and gently dried with absorbing paper to remove water excess and keep tooth surface moist. Scotchbond Multi Purpose Plus adhesive system** was placed according to manufacturer's instructions: activator was applied to enamel and dentine and air-thinned for 5 s. Straight away, amalgam was mechanically triturated, manually condensed and carved.

After a 7-day storage in distilled water at 37 °C, Alert and Fuji II LC restorations were polished with aluminium oxide discs (Super Snap)§§ and amalgam restorations were polished with bladed finishing burs and abrasive polishing pastes.

Specimens were subjected to a thermocycling regimen of 500 cycles (lasting for 8 h and 45 min) between 5 and 55 °C waterbaths. Dwell time was 1 min with a 3-s transfer time between baths.

In preparation for the dye penetration test, the specimens were dried superficially, wholly sealed (including apical region) with epoxy resin and two coats of nail varnish, leaving a 2-mm window around the cavity margins and immersed in a 0·2% Rhodamine B solution for 24 h. Then, the surface-adhered dye was carefully rinsed in tap water and after the epoxy resin and nail varnish were removed with a sharp instrument. The teeth were embedded in chemically activated acrylic resin (JET)¶¶ and bisected longitudinally in a mesiodistal direction with a water-cooled diamond saw in a Minitom*** sectioning. Then, the separated buccal and lingual halves were embedded again in blocks of

†Jeneric-Pentron, Inc., Wallingford, CT, USA.
‡GC Co., Tokyo, Japan.
§Dentsply Caulk, Milford, DE, USA.
¶Kerr Corporation, Orange, CA, USA.
**3M Dental Products, St Paul, MN, USA.
††ESPE Dental Medizin, Seefeld, Germany.
‡‡Centrix, Shelton, CT, USA.
§§Shofu Inc., Kyoto, Japan.
¶¶Clássico, São Paulo, Brazil.
***Struers A/S, Copenhagen, Denmark.

**Table 2.** Mean (%) and standard deviation of dye penetration at enamel and dentine/cementum margins

| | Groups | | | | | |
|---|---|---|---|---|---|---|
| Margin | I | II | III | IV | V | VI |
| Enamel | 10·09 b (±21·28) | 3·25 a (±10·27) | 0 a | 41·77 e (±42·48) | 23·37 d (±33·79) | 12·66 bc (±24·06) |
| Dentine/cementum | 16·49 bcd (±26·67) | 4·34 ab (±13·71) | 0 a | 37·71 e (±30·47) | 39·56 e (±43·35) | 72·53 f (±37·79) |

Same letters indicate statistical similarity.

acrylic resin and sectioned in a buccolingual direction, providing two to three cuts of 1·0 mm thickness for each tooth. This was chosen, as the third molar's accentuated convexity does not enable the buccal and lingual preparations to be centralized, and therefore would not allow both restorations to be appropriately sectioned in the same slice. After sectioning, the cuts were initially thinned in a polishing machine (Politriz)*** using nos 180–600 machine sandpaper and then manually smoothed with nos 1000 and 1200 watery sandpaper to obtain a flattened, smooth surface and a final thickness of approximately 0·25 mm.

The sections were identified, fixed on microscopic slides and separately analysed for dye penetration, by viewing them under a ×2·5 magnification optical microscope (Axioskope)[†††] connected to a colour video camera with ×10 magnification lens (TK-1270)[‡‡‡]. The images obtained were transmitted to a personal computer and, after digitization, were analysed using the KS300-v2·0 software[§§§] that provides standardized assessment of microleakage in millimetres. The depth of the cavity and dye penetration along occlusal and cervical margins towards the axial wall was measured and the percentage of infiltration was calculated. The data were submitted to statistical analysis using the ANOVA and Tukey tests ($P < 0{\cdot}05$).

## Results

The mean and standard deviations of the dye penetration are shown on Table 2.

Statistical analysis of data showed that the use of the Er:YAG laser for cavity preparation yielded higher degree of marginal leakage, as compared with the use of conventional air-turbine ($P < 0{\cdot}01$).

[†††]Zeiss, Jena, Germany.
[‡‡‡]JVC, Tokyo, Japan.
[§§§]Kontron Elektronik, GmbH, München, Germany.

The enamel interface provided improved marginal sealing, as compared with dentine/cementum margin, this difference being statistically significant ($P < 0{\cdot}01$).

With regard to the cavity preparation device (i.e. laser or bur), the individual analysis of the results showed that bonded amalgam and Fuji II LC provided less infiltration, presenting statistically significant difference to Alert ($P < 0{\cdot}05$) and its was more evidence in bur-prepared cavities. On the other hand, for lased cavities, Alert provided the best results, which were statistically similar to those of Fuji II LC and superior to those reached by bonded amalgam ($P < 0{\cdot}05$).

## Discussion

The findings of the present study disclosed that the use of the Er:YAG laser for cavity preparation may interfere decisively with the marginal sealing, as lased cavities showed a higher degree of leakage than those of conventionally bur-prepared teeth, at both enamel and dentine/cementum margins. The probable explanation for this result is that the cavosurface margins produced by Er:YAG laser irradiation presents a quite rough appearance as compared with the margins produced by high-speed cutting. Therefore, this marginal contouring could result in increased microspacing and greater leakage (Wright *et al.*, 1993). Similar results were reported by Ramos (1998), Corona *et al.* (2001) and Setien *et al.* (2001).

Considering the tested materials, it was found that amalgam restorations were greatly influenced by cavity preparation device, as the cavities prepared by laser presented a high degree of infiltration, even using the bonded amalgam technique. On the other hand, optimal marginal sealing was observed for bur-prepared cavities filled with amalgam. These results may be due to the difficulty of controlling laser irradiation onto the desired area and to the appropriate depth. Cavities cut by laser could not provide precise, clearly identifiable outlines and therefore the irregular walls, angles and margins might have interfered with the adaptation of amalgam to cavity and resulted in deficient marginal sealing of restorations (Tanji, 1998). Otherwise, the high-speed bur provided the well-defined walls and angles required for amalgam restorations.

Keller and Hibst (1993) have investigated microleakage after filling class V cavities prepared by Er:YAG laser and air-turbine with amalgam and found no difference between both techniques. These findings diverge from those of the present study in which bur-prepared cavities showed improved results, and the association of air-turbine and bonded amalgam resulted in complete marginal sealing.

For packable composite resin restorations, a significant increase in microleakage was observed in cavities prepared by laser irradiation. These observations are supported by an earlier investigation with the same methodology (Corona *et al.* 2001). Furthermore, other studies (Latta, Blankenau & Ellis, 1999; Palma Dibb *et al.*, 2002) demonstrated that the use of Er:YAG laser for cavity preparation may influence the degree of penetration of bonding agents.

Conversely, earlier investigations (Wright *et al.*, 1993; Niu *et al.*, 1998), did not find a significant difference between the high-speed dental bur and the Er:YAG laser preparations, for composite resin.

Scanning electron microscopic (SEM) observations have revealed that cavity surface treated by erbium laser shows various patterns of microirregularities, often accompanied by microfissure propagation, only few fusion or recrystallization areas and absence of smear layer. Additionally, open dentinal tubules have been widely reported, although laser is not able to increase tubules' openings (Visuri *et al.*, 1996; Pelagalli *et al.*, 1997; Tanji, 1998; Tokonabe *et al.*, 1999; Martinez-Insua *et al.*, 2000; Corona *et al.*, 2001; Palma Dibb *et al.*, 2002). Denaturation of collagen fibres has also been observed, as the action of erbium laser system relies directly upon water molecules (Cozean *et al.*, 1997).

All those morphological changes on tooth structure resulting from laser irradiation may affect to some degree, the performance of restorative materials, especially the adhesive systems. Additionally, it has been demonstrated that an increase in pulse energy results in a deeper crater pattern in tooth surface, which may influence the adaptation of the restorative material to cavity walls (Roebuck *et al.*, 2000).

When the resin-modified glass–ionomer cement (RMGIC) was employed, it was observed better results for bur groups in comparison with laser-prepared samples, which showed higher degree of marginal leakage. This increase in microleakage for RMGIC restorations may be ascribed to the dentinal tubules (in the absence of the smear layer) and to the resulting increase in permeability and surface humidity. Moreover, apart from micromechanical retention, the adhesive mechanism of glass–ionomer cements relies upon a chemical interaction between the carboxylic groups from the material and calcium ions from dental substrate, which means that for an optimal performance, the ionomeric cement requires an intimate contact with tooth structure. Cavity pre-treatment should preserve the available calcium content and it is mandatory to use only weak acids (polyacrylic acid) to remove solely the smear on and let the mineral components and the smear in obliterating the dentinal tubules' openings. As laser irradiation produces a disorganized, indiscriminate destruction of organic and inorganic components and provides irregular surfaces, the adhesion of glass–ionomer cements would be compromised.

The results of the present study, using Fuji II LC, were similar to those of Liberman *et al.* (1990), who reported that glass–ionomer cements are more sensitive to changes in hard tissue composition than composite resins, whose adhesion is based exclusively on mechanical features. However, Quo *et al.* (2001) found no significant difference in marginal leakage on lased or bur-prepared cavities filled with Fuji II LC.

The ability of Er:YAG for caries removal and cavity preparation has been widely described and many investigations (Cozean *et al.*, 1997; Pelagalli *et al.*, 1997; Reyto, 2001) have reported equal or better results than the use of high-speed dental bur. However, further investigations focusing on the long-term effect of ultrastructural changes observed in enamel and dentine substrates prepared by Er:YAG laser are required to assess the performance of different restorative systems available when applied to lased cavities.

These observations are extremely important for laser users to acknowledge that wavelength, peak energy, pulse duration, delivery system and a number of other variables are all unique to each laser type as well as to a specific manufacturer's system. In other words, it means, for example, that the sensible, modern restorative materials may have some of their properties and characteristics (particularly adhesion or marginal sealing/integrity) affected by the use of laser irradiation. Constant research will certainly lead to restorations with increased bonding and marginal sealing and therefore lead to improved microleakage prevention as well as to an even more widespread applicability of Er:YAG laser in clinical practice.

## Conclusions

On the basis of these results, and within the limitations of this *in vitro* study, it may be concluded that, within the tested parameters, the cavities prepared by Er:YAG laser showed higher degree of marginal leakage than those conventionally prepared by air-turbine, regardless of the restorative material.

However, it is relevant to notice that among the lased cavities, those restored with adhesive materials yielded better marginal sealing than did those restored with bonded amalgam.

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