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Ultraconservative Ablation in Operative and Esthetic Dentistry

Rosane de Fátima Zanirato Lizarelli[a], Lílian Tan Moriyama[b], Vanderlei Salvador Bagnato[c]

[a] Professor, Faculty of Odontology, Araraquara University, São Carlos USP, São Carlos, SP, Brazil.
[b] Physicist, Instituto de Fisica de São Carlos USP, São Carlos, SP, Brazil.
[c] Professor, Instituto de Fisica de São Carlos USP, São Carlos, SP, Brazil.

Purpose: To investigate comparative ablation rate and morphological aspects of different composite resins and dental hard tissues after Er:YAG laser irradiation, with the aim of developing a new clinical technique for the selective removal of restorations and tooth substance.

Materials and Methods: We used 11 exfoliated primary anterior and posterior teeth and 6 extracted permanent molars. Three different types of composite resin were chosen (microfilled, hybrid, and condensable) in terms of chemical and structural composition. Composite disks and the teeth were irradiated with an Er:YAG laser under different conditions and energy levels per pulse (100, 200, 300, and 400 mJ). The resulted values were plotted and fitted to allow a comparative observation of the material removed as a function of energy level per pulse.

Results: While selective ablation seems to be applicable for the enamel of primary and permanent teeth, it does not apply well to primary or permanent dentin. For dentin, the composition and content of water makes the Er:YAG laser ablation rate equal or superior to that found for the three resins used.

Conclusion: The goal of this study, ie, to propose a new clinical technique, was met. It is clear from our results that differential ablation of composite resin restorations using Er:YAG is practicable where enamel surfaces are involved, because their more mineralized composition makes the tissue more resistant to this laser system. Clinically, this new technique presents the Er:YAG laser as an interesting and unique tool in esthetic procedures which also preserves healthy dental hard tissues.

Key words: differential enamel/dentin ablation, Er:YAG, composite resin.

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In operative dentistry, it is important to search for alternative tools more suitable to each kind of clinical situation. Decayed tissues and damaged restorations must be removed or modified to reestablish dental function and esthetics, with different clinical situations requiring different treatments. Currently, there are new tools and techniques under in vitro and in vivo investigation.

Research on many laser systems for the removal and preparation of dental hard tissues is being conducted all around the world.[1-7] The feasibility of replacing mechanical procedures with laser-based procedures in cavity preparation is still under debate and more research is necessary to provide answers.

A possible advantage of laser ablation would be a conservative cavity preparation technique to remove old resin restorations while preserving the original dental tissue, ie, dentin or enamel. In other words, laser would have an advantage over mechanical methods if it were possible to develop a laser technique which removed resin faster than it did dental hard tissue.[8-9]

In the present study, the aim was to compare Er:YAG laser ablation characteristics on dentin and enamel of permanent and primary teeth with three differ-

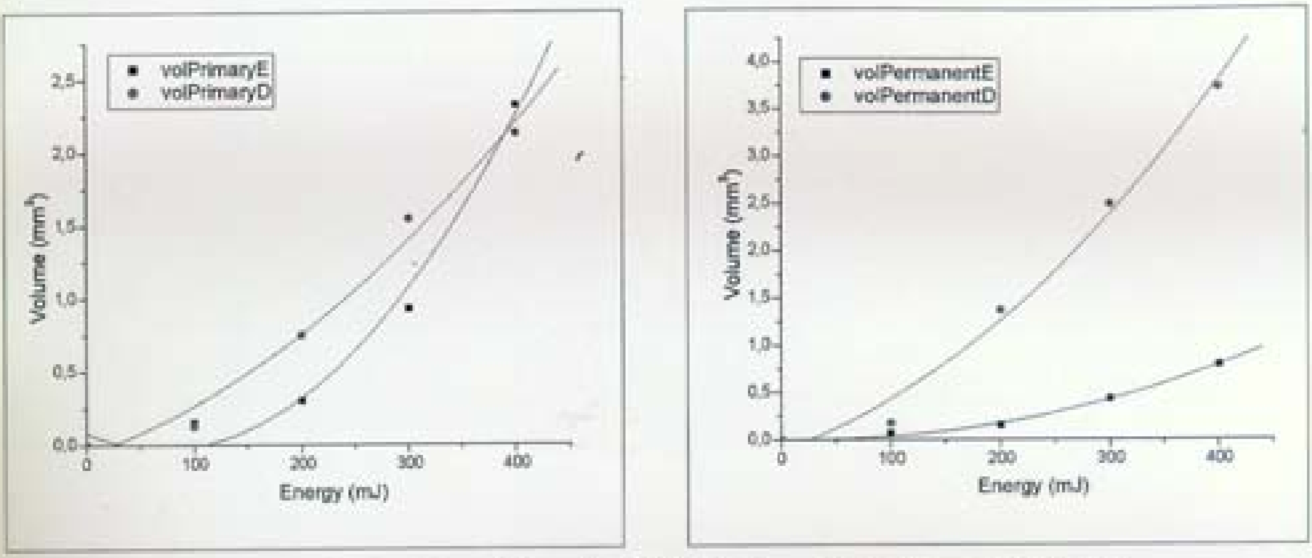


Fig 1 Comparison between the total ablated volume of enamel and dentin for primary (left) and permanent (right) teeth.

ent types of resin composites: microfilled, hybrid, and condensable. First, the main features of each substrate are described; second, the possibilities of conservative cavity preparation are examined in which resin can be removed with a minimal effect on dental tissue; third, a clinical case is presented.

MATERIALS AND METHODS

Eleven extracted or exfoliated primary anterior and posterior teeth and six extracted permanent molars were used. The teeth were cut in quadrants and embedded in polyester resin to allow polishing of the surface before laser exposition. The samples were polished with abrasive paper down to 600 grit.

Using a metallic mold, we prepared 60 disks of composite resin 2.0 mm thick and 8.0 mm in diameter. Three different materials were chosen: a microfilled resin (Durafil VS, Heraeus Kulzer, Germany), A20 (lot A30122); a hybrid resin (Z100, 3M, St Paul, MN, USA), A2 (lot OWN 2003-05); and a condensable resin (Alert, Jeneric Pentron, Wallingford, CT, USA) A2 (lot 39722 2002-12). The microfilled and hybrid resins have a bis-GMA and TEG-DMA matrix, but the fillers are different: Durafil VS has prepolymerized grains of silicon dioxide (0.02 to 0.07 µm in diameter) and Z100 has silicon and zircon particles (0.01 to 3.5 µm in diameter). The condensable resin has a dimethacrylate polycarbonate matrix with microfillers of silicon oxide (0.01 to 0.07 µm in diameter), aluminoborosilicate (0.7 mm in diameter), and glass fibers of magnesium and aluminum oxide 6 to 10 µm in diameter and 40 to 80 µm in length.

Composite disks and the teeth were irradiated with an Er:YAG laser (operating at 2940 nm, peak energy up to 500 mJ, frequency up to 15 Hz, and a pulse duration of 200 to 450 µs. After passing through the instrument optics, the spot size of the surface interaction is measured to be ca 0.5 mm², which corresponds to a spot diameter of about 0.8 mm.

We operated the laser at 10 Hz, focused on the target 12.0 mm from the laser window, for an exposition time of 10 s and pulse energy levels of 100, 200, 300, and 400 mJ. All the ablation procedures took place using the water supply system of the laser itself, which corresponds to a water flux of 0.14 ml/s in the form of a spray.

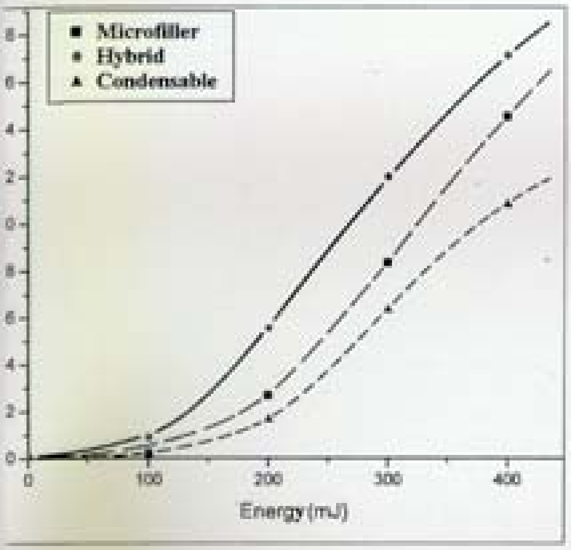
The diameter and depth of each resulting microcavity were measured and the volume of material removed calculated.

RESULTS

Ablation Rates

The resulting values were plotted and fitted to allow comparison of the material removed as a function of energy level per pulse, as shown in Figs 1 to 6.

The overall ablation rate is a combined effect of



Volume of resin ablated as a function of pulse energy for ee composite resins tested.

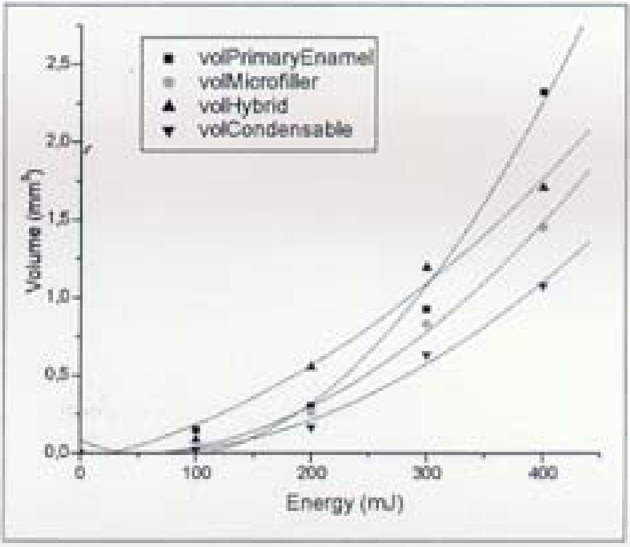
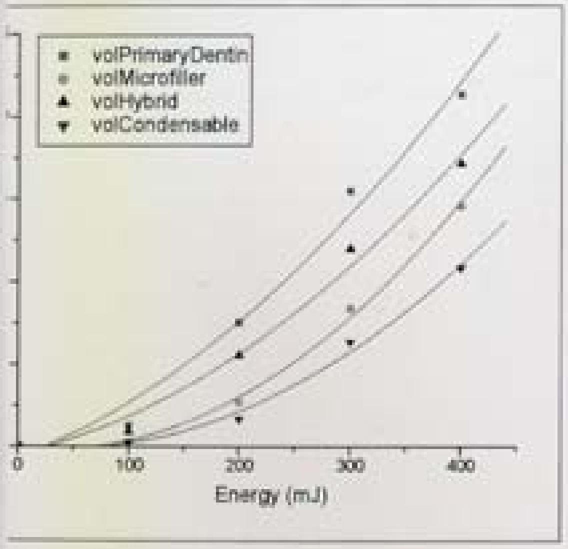


Fig 3 Ablated volume of primary enamel compared to the three resins tested.



Ablated volume of primary dentin compared to the three ested.

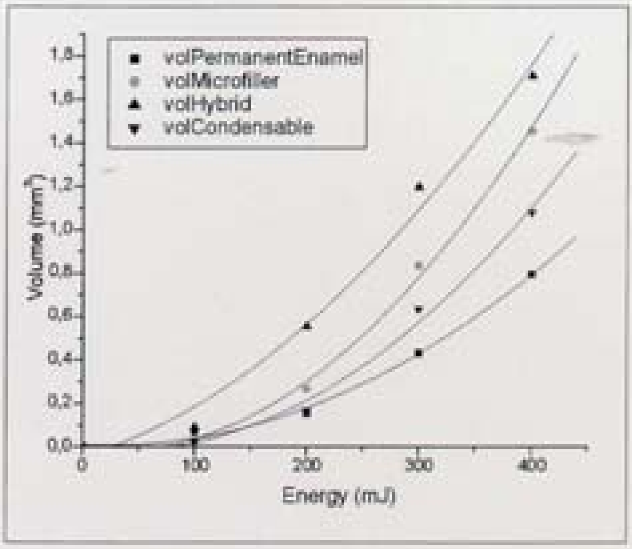


Fig 5 Ablated volume of permanent enamel compared to the three resins tested.

and diameter of ablation, as depicted in Fig 1. ermanent teeth, the volume of ablation and conntly the rate of material removal can be five to times higher in dentin than in enamel. This fact is or less independent of the energy used. Howblation seems to be somewhat accelerated as the y increases. Primary teeth show technically no ence between penetration depth in dentin and l, while permanent teeth exhibit a considerable difference. The fact that the dentin of permanent teeth is a more structurally varied tissue than enamel is responsible for the great difference, which does not seems to be the case for primary teeth.

Figure 2 shows the volume of removed resin as a function of energy level per pulse. The graph reflects similar curves of penetration depth for all three composites tested. An energy level E_{th} per pulse is necessary to start material removal. From zero energy up.

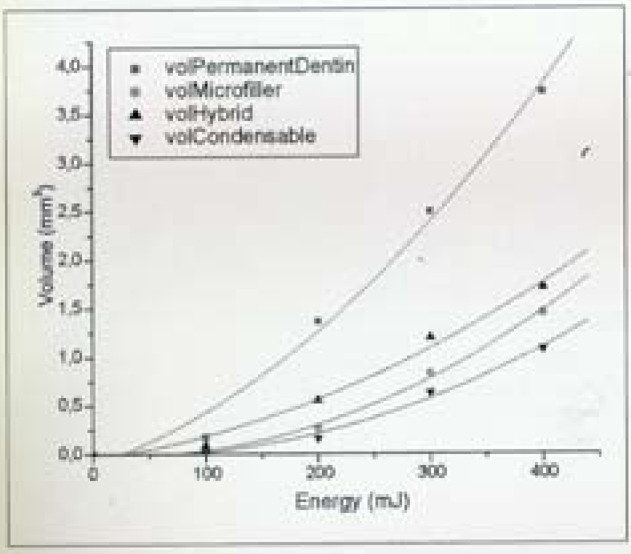


Fig 6 Ablated volume of permanent dentin compared to the three resins tested.

the volume seems to be quite low until a threshold energy value is attained, upon which volume rapidly increases. Just after this rapid rise, the volume removed increases more slowly with increasing of energy with a possible saturation point, similar to the case of penetration depth. The existence of E_{th} shows that there is a minimum energy able to overcome the shielding effects, allowing more molecules to interact with laser energy. This causes a rapid increase in the volume of removed material.

Figure 3 shows that the ablation rate of the hybrid composite is much higher than of primary enamel, which would seem to make it a better candidate for using a selective laser ablation technique than the condensable resin, because its rate of ablation is only slight higher than that of the primary enamel. Figure 4 demonstrates that in terms of primary dentin, the situation is not as favorable as for primary enamel. The rate of material removal (represented by the ablated volume) is favorable for a differential removal technique only for the hybrid resin, restricted to the energy interval ranging from zero to 300 mJ. Beyond this range, and for the microfilled and condensable resins, the ablation rate of dentin is comparable to the resins or even higher.

The differences between ablation rates of permanent enamel and that of the composites is depicted in Fig 5. The consequences of these considerable differences are also reflected in the overall ablated volume. For permanent enamel, a conservative procedure in which the resin is removed while simultaneously conserving the original tooth tissue seems feasible. For all three types of resin tested, their overall ablation rate ranges from 5 to 10 times that of enamel, allowing safe removal of those materials with little effect on the enamel.

Again, the situation is not as favorable when permanent dentin is considered (Fig 6). In this case, ablated cavity depth, diameter, and shape are not very different in dentin vs resins, and as consequence, the overall removed volume is basically equal to or higher than that of the resins, depending on the energy range applied. Below 150 mJ, small differences are noted. Above 150 mJ, it is clear that permanent dentin is removed at a higher rate than the three composite resins tested here. Thus, it is equally obvious that for permanent dentin, the differential laser ablation technique would not work properly.

CLINICAL CASE

A 13-yr-old female patient presented stained, mesial Class IV composite resin restorations on the two central maxillary incisors. Figure 7 illustrates the clinical sequence of the procedure applying the new differential ablation technique: the initial aspect showed a stained composite restoration; Er:YAG laser focused on the resin surface for 120 s/tooth at 300 mJ and 10 Hz; cavity preparation done; only the composite resin was removed or ablated; note the aspect of the anterior bevel. Finally, Fig 8 shows the final clinical aspect immediately after placement of the new composite resin restoration (a) and at follow-up 6 months later (b).

Usually, in a case such as this, the entire resin core would be removed; however, using these parameters, it was possible to differentially ablate unsatisfactory pre-existing composite resin restorations, preserving the healthy enamel tissue.

CONCLUSION

While the idea of selectively ablating composite resins more quickly than adjacent/underlying enamel seems feasible, at the present stage of laser development it does not apply well to primary or permanent dentin. The composition and water content of dentin makes Er:YAG laser ablation rate equal or superior to that of the three resin composites tested.

This study examined the possible selective ablation

Fig 7a

Fig 7b

Fig 7c

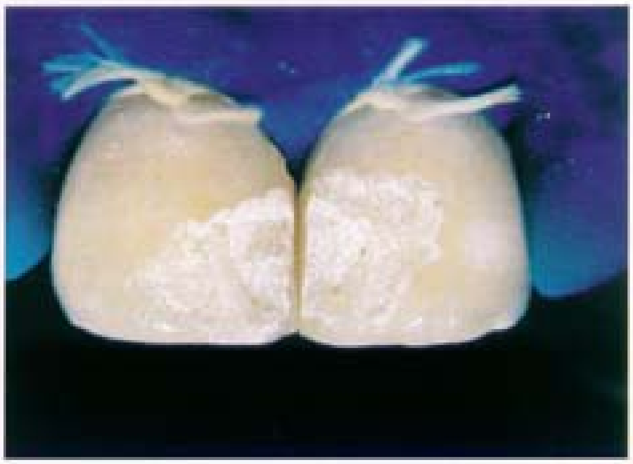


Fig 7d

Fig 7 Clinical sequence using Er:YAG laser to preferentially remove composite resin restoration. (a) initial aspect, (b) laser in action; (c) clinical aspect immediately after laser irradiation of tooth #8, and (d) teeth #8 and #9, dried.

Fig 8a

Fig 8b

Fig 8 (a) Final aspect just after completion of new composite resin restoration, (b) follow-up after six months.

of pre-existing composite resin restorations and dental hard tissues using an Er:YAG laser, with the goal of proposing a new clinical technique: differential ablation for composite resin restorations using Er:YAG laser. It is clear from our results that the technique can be applied where enamel surfaces are involved, because their more mineralized composition makes the tissue more resistant to this laser system. Clinically, this new technique represents a real possibility to use Er:YAG laser as an interesting and unique tool in esthetic procedures, preserving healthy dental hard tissues.

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Contact address: Dr. Lizarelli, Instituto de Física de São Carlos USP, Av. Trabalhador Sancarlense, 400. São Carlos, SP, Brazil. Tel: +55-16-271-2012, Fax: +55-16-273-9811. e-mail: lizarelli@if.sc.usp.br