Restoration-enamel interface with argon laser and visible light polymerization of compomer and composite resin restorations: a polarized light and scanning electron microscopic *in vitro* study

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This polarized light (PL) and scanning electron microscopic (SEM) in vitro *study investigated the effect of argon laser (AL) and visible light (VL) polymerization on the interfaces between compomer and composite resin restorations and the enamel cavosurfaces. Surface topography by SEM revealed a smooth transition between the restorative materials and adjacent enamel surfaces with no microspaces between the restorations and enamel surfaces. The enamel surfaces showed relatively smooth surface coatings with AL curing, compared with exposure of etched prism endings with VL curing. The restoration-enamel interface by PL showed an intimate relationship between the restorative materials and the cavosurface enamel. No differences were found between AL and VL polymerization. With the restoration-enamel interface by SEM, compomers and composite resins were adapted closely to the cavosurface enamel and tags of restorative material protruded into the adjacent cavosurface enamel. Both VL and AL polymerization of compomers and composite resin restorations* in vitro *produced closely adapted restorations with intimate restoration-enamel interfaces. Such restoration-enamel interfaces may provide a certain degree of resistance against secondary caries formation, and this may be enhanced by the caries protective effect of argon laser irradiation.*

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INTRODUCTION

The interface between enamel and a restorative material provides an important function in avoiding secondary caries formation.[1-3] The ability to eliminate voids and microspaces along this interface are paramount in decreasing the likelihood of secondary caries development. It is well known that voids and microspaces at the surface and along the restoration-enamel interface allow access of acidic ions produced by cariogenic bacteria into this interface, and may lead to the initial demineralization phase of caries. Over time, the demineralized interface will become increased in width and provide a protective niche for acidogenic bacteria. Ultimately, these voids and microspaces will result in failure of the restoration due to development of clinically detectable secondary caries.

In several clinical surveys and reviews,[1,4-10] secondary caries is implicated as the primary reason for replacement of existing restorations. With the results from these surveys, it has been shown that approximately 50% of restoration replacement is due to secondary caries. During a single month period in one survey,[9] almost 3,200 restorations were placed. Of these, two-thirds were replacement restorations. Secondary caries was responsible for 45% of restoration replacement; while bulk and margin fractures accounted for about 25% of failures, non-carious defects occurred in 9% of failed restorations, tooth fractures occurred in 7% and other reasons (sensitivity/pain, poor anatomic form and discoloration) accounted for the remainder. Of interest is the fact that amalgams had the highest secondary caries prevalence (51%) and this rate of secondary caries was significantly higher than those (20 to 39%) for composite resins, glass ionomers and compomers.

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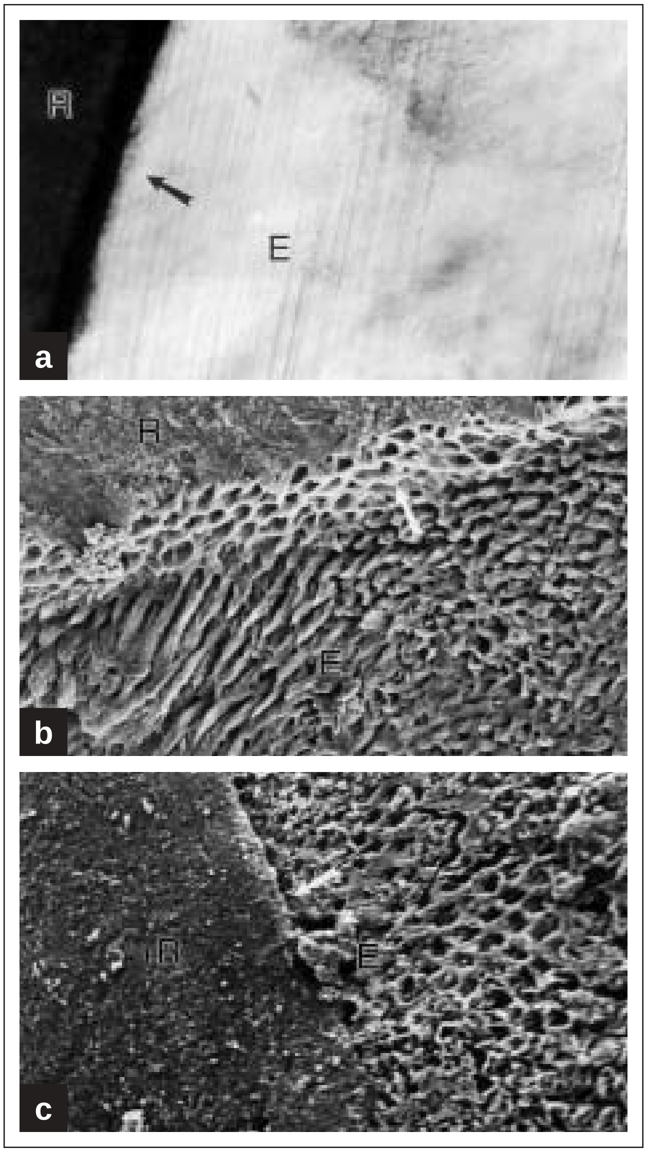

Figure 1. Compomer restoration with visible light polymerization (**a:** polarized light microscopy, water imbibition; **b:** restoration-enamel interface, SEM; **c:** surface morphology of restoration and adjacent enamel surface; e=enamel, r=restoration, arrow = restoration-enamel interface).

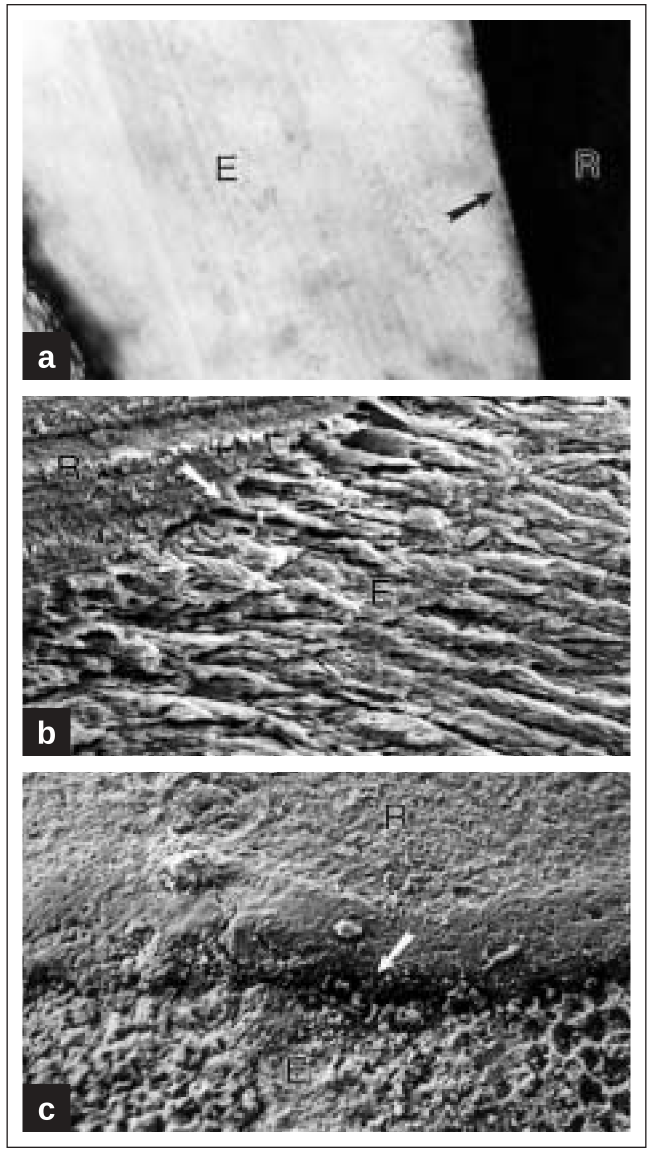

Figure 2. Compomer restoration with argon laser polymerization (**a:** polarized light microscopy, water imbibition; **b:** restoration-enamel interface, SEM; **c:** surface morphology of restoration and adjacent enamel surface; e=enamel, r=restoration, arrow = restoration-enamel interface).

It is interesting to note that compomers and glass ionomers tend to be used in a higher proportion of patients with poor oral hygiene (23 to 29%), and in those considered to be at high risk for future caries development (30 to 35%). It is quite obvious that restorative materials that contain and release fluoride may be beneficial in decreasing the prevalence of secondary caries in both the pediatric and adult populations.[10] The introduction of resin-modified glass ionomers and polyacid-modified resin-based polymers (compomers) has provided dental materials that have improved strength characteristics compared with conventional glass ionomers, while releasing fluoride to adjacent tooth structure and into the local oral environment.[10] There is evidence, particularly in the pediatric population, for a shift from placement of traditional amalgam and composite resin restorations to placement of resin-modified glass ionomer and compomer restorations.[4]

Almost a decade ago, the Federal Drug Administration approved the argon laser for polymerization of visible-light cured dental materials.[11] Argon laser curing of these materials resulted in less unpolymerized material and a shortened polymerization time, while maintaining the physical properties of the material.[11] Of considerable importance is the fact that both clinical pilot studies and laboratory investigations[3,12-25] have identified enhanced resistance to caries development with argon laser

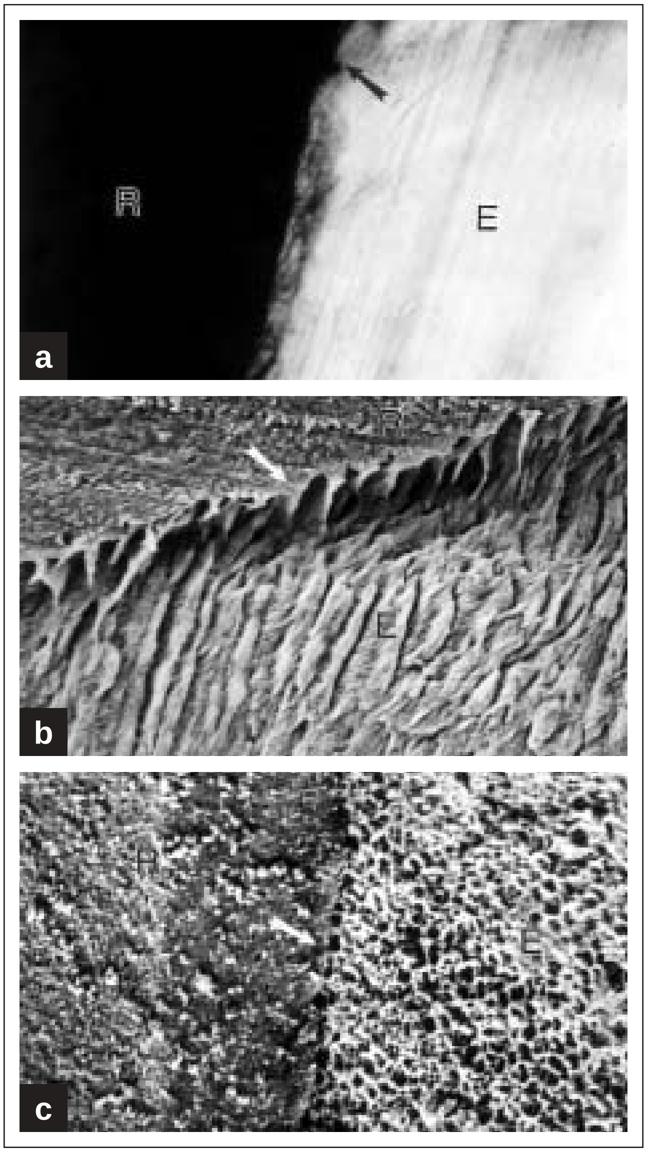

Figure 3. Composite resin restoration with visible light polymerization (**a:** polarized light microscopy, water imbibition; **b:** restoration-enamel interface, SEM; **c:** surface morphology of restoration and adjacent enamel surface; e=enamel, r=restoration, arrow = restoration-enamel interface).

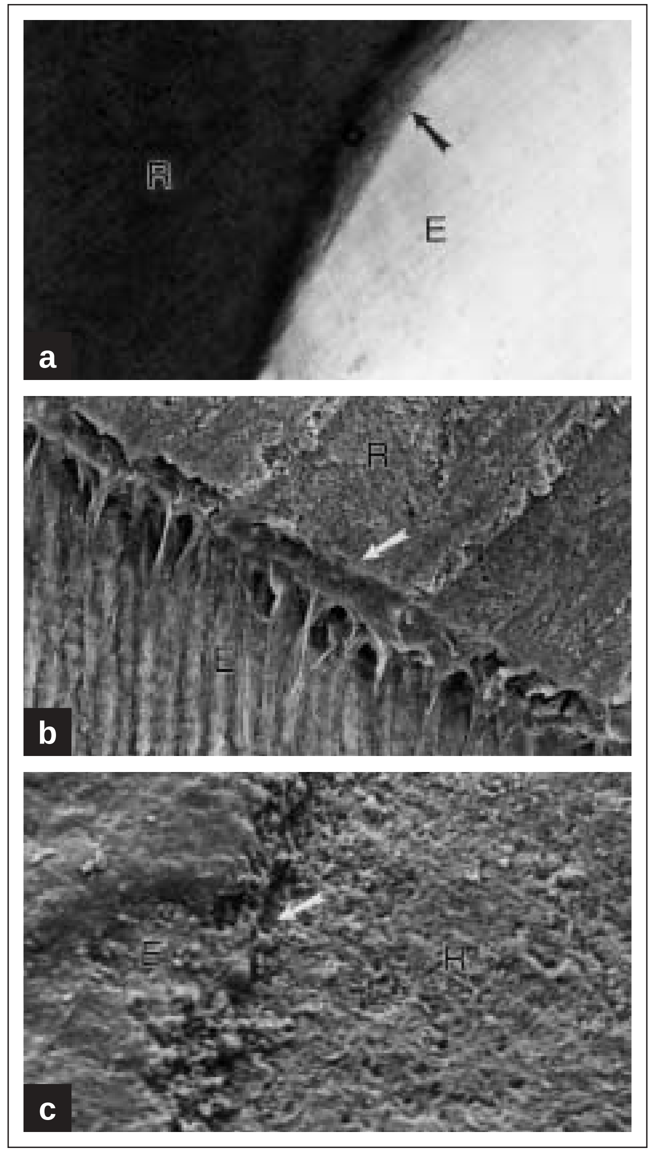

Figure 4. Composite resin restoration with argon laser polymerization (**a:** polarized light microscopy, water imbibition; **b:** restoration-enamel interface, SEM; **c:** surface morphology of restoration and adjacent enamel surface; e=enamel, r=restoration, arrow = restoration-enamel interface).

exposures at low energy levels (250mW, 12 Joule/cm^2) for short time periods (10 seconds). A synergistic effect between topical fluoride and argon laser irradiation has also been established with dramatic reductions in enamel and root surface caries formation.[15,19-23,26]

The purpose of this polarized light (PL) and scanning electron microscopic (SEM) *in vitro* study was to investigate the effect of argon laser (AL) and visible light (VL) polymerization of compomer and composite resin materials on the restoration-enamel interface.

MATERIALS AND METHODS

Cavity preparations without bevels or featheredging were prepared with straight fissure burs using a high-speed handpiece in the buccal and lingual coronal enamel surfaces of 20 extracted caries-free permanent molars. The teeth were assigned to either the compomer group (n=10, Hytac with ESB adhesive, 3M-ESPE, Minneapolis MN) or composite resin group (n=10, Filtek Z250 with Scotchbond multipurpose adhesive, 3M-ESPE, Minneapolis MN). With each tooth, one restoration was polymerized with visible light (40 seconds); while the other restoration was argon laser polymerized (231 mW, 12 Joules/cm^2, 10 seconds, Model 8, HGM, Salt Lake City UT). Otherwise, the restorations were placed according to the recommendations of the manufacturer. Following restoration, the teeth underwent thermocycling in deionized-distilled water (500 cycles, 5˚-50˚C). The restoration surfaces and adjacent intact enamel were evaluated by scanning electron microscopy (SEM, 5kV, uncoated, JEOL 610, Peabody MA). Following SEM examination, longitudinal sections were taken to evaluate the restoration-enamel interface using polarized light (water imbibition) and scanning electron microscopy (5kV, uncoated). For SEM evaluation of the restoration-enamel interface, the cut surface was exposed to phosphoric acid (37% for 10 seconds) and then rinsed with deionized-distilled water (30 seconds).

RESULTS

The restoration-enamel interface, as evaluated by polarized light microscopy, showed an intimate relationship between the restorative materials (Figure 1a-4a) and their enamel cavosurfaces. Both compomer (Figures 1a, 2a) and composite resin (Figures 3a, 4a) restorations were closely adapted to the prepared cavity walls without voids or microspaces, despite extensive thermocycling of the specimens. There was no difference in the adaptation of compomer or composite resin materials, regardless of whether the dental materials had been polymerized with visible light or the argon laser. SEM examination of the restoration-enamel interfaces following acid-etching demonstrated a similar morphologic appearance among the treatment groups (Figures 1b-4b). Both compomer (Figure 1b, 2b) and composite resin (Figure 3b, 4b) restorations showed interdigitation of the restorative material with the enamel prisms forming the cavosurface. Tags of restorative material were seen protruding into the enamel prisms. No voids or microspaces were identified.

The surface topography of the specimens prior to longitudinal sectioning for evaluation of the restoration-enamel interfaces revealed certain differences (Figures 1c-4c). The research design was such that beveling and featheredging of the restorative materials was not performed. The junctions between the restoration surfaces and the adjacent surface enamel were relatively well-defined. The restorative materials were without surface voids with either visible light (Figure 1c, 3c) or argon laser (Figure 2c, 4c) polymerization. Infrequent small saucer-shaped indentations were noted in the surfaces of the argon laser-cured restorations (Figure 2c). There was a relatively smooth transition between the restorative material and adjacent surface enamel. No voids or microspaces were seen with the junction of the surface enamel and restorative material. Argon laser polymerization (Figure 2c, 4c) did reveal a less irregular enamel surface contour and a smoother surface than that for visible light curing (Figure 1c, 3c). The effects of acid-etching and treatment with the recommended of the manufacturer adhesive agents left etched enamel prisms exposed with visible light polymerization (Figure 1c, 3c). There was no evidence of etched enamel prism exposure with argon laser polymerization (Figure 2c, 4c). In fact with argon laser curing, the enamel surfaces appeared to have confluent surface coatings.

DISCUSSION

Argon laser and visible light polymerization of both compomers and composite resin restorations placed *in vitro* allowed for close adaptation of the restorative materials to the cavosurface enamel. The lack of detection of voids and microspaces would indicate an adequate seal for protection against microleakage along the restoration-enamel interface, even with extensive thermocycling of the restorations. The major difference between argon laser and visible light polymerization was noted by the topographic changes in the surface enamel adjacent to the restorations. It was quite apparent that the argon laser resulted in surface coatings that masked the underlying enamel surfaces.

Imbrication lines, prism endings and etched prism structures were obliterated by argon laser polymerization. The changes in surface morphology with the argon laser are well recognized.[18,19,25] It is believed that the surface coatings created with the argon laser may result from alterations in the mineral structure and organic component, and produce a reactive surface that is less susceptible to caries formation.[12,18,19,25] In initial laboratory studies[3] over a decade ago, it was noted that argon laser polymerization of pit and fissure sealant material significantly reduced the susceptibility of the adjacent surface enamel and the cavosurface to caries-like lesion formation. Since that time, both laboratory and clinical studies[12-25] have demonstrated the remarkable ability of a single argon laser exposure period of 10 seconds at a low fluence (250mW) to significantly affect caries initiation and progression, and surface morphology. The employment of argon laser polymerization for visible light-cured preventive and restorative materials[12-25] appears to provide additional protection against secondary caries formation along the surface enamel adjacent to the restoration, as well as along the cavosurface.

Compomers are polyacid-modified resin-based composites, and as such release a relatively low continuous amount of fluoride into the oral environment.[1,2,10,27-32] These materials contain a higher content of composite resin with a lower amount of glass ionomer material and polymerizable acidified monomer than resin-modified glass ionomers. With the increased composite resin composition, there is a concomitant improvement in the physical properties when compared with resin-modified glass ionomers. At the same time, there is a lessened amount of fluoride available for release compared with glass ionomers. Fluoride in adequate ranges[33-35] to affect the demineralization process are released from compomers into deionized distilled water, artificial saliva and demineralizing-remineralizing fluids.[1] In fact, compomers respond very much like glass ionomers when exposed to demineralization, with a dramatic increase in fluoride release.[1] A 5 to 7-fold increase in the amount of fluoride released occurs with *in vitro* cariogenic challenges.[1] This release of fluoride is known to limit the demineralization process, lower the critical pH in order to make enamel more caries resistant, and facilitate redeposition of mineral phases into tooth structure when the demineralizing challenge is removed and oral fluids are available for remineralization.[1,33-35] In addition, compomers have the ability to recharge the fluoride content[1,10] when exposed to exogenous fluoride sources, such as fluoridated dentifrices, fluoride rinses and topical fluoride applications.

The penetration of an adhesive resin-based material into the enamel forming the cavity wall reduces the susceptibility of enamel to acid demineralization and dissolution.[1-3,10,29] Resin-based materials tend to penetrate enamel for a considerable distance and coat the mineral crystals of enamel prisms and dentinal tubules, as noted in the present study with both compomer and composite resin restorations. This resin coating protects the crystals from demineralization and provides an additional defense against a cariogenic attack. With compomers, the material possesses the caries resistance property afforded by the acid-resistant resin, while still retaining the fluoride-releasing ability ascribed to glass ionomers.[1,10,27,29] Argon laser polymerization creates an additional level of protection against secondary caries formation in surface enamel adjacent to a restoration and along the restoration-enamel interface.

CONCLUSIONS

Argon laser polymerization of compomers and composite resin restorations *in vitro* produced closely adapted restorations with intimate restoration-enamel interfaces, identical to those for visible light polymerized compomers and composite resins. Such restoration-enamel interfaces may provide a certain degree of resistance against secondary caries formation. The creation of surface coatings overlying the enamel adjacent to the argon laser cured restorations may facilitate increased resistance against a cariogenic challenge.

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