Argon Laser and Remineralizing Solution Treatment Effects on Root Surface Caries

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Purpose: The effects of argon laser (AL) irradiation exposure and remineralizing solution (RS) treatment were evaluated alone and in combination on caries-like lesion formation in permanent tooth root surfaces in an in vitro study.

Materials and Methods: Ten caries-free permanent tooth root surfaces were divided into 4 segments and each segment from each tooth was assigned to 1 of 4 treatment groups: no treatment control (n = 10), AL irradiation alone at 13.5 J/cm\textsuperscript{2} (0.270 W, 5-mm beam, 10 s, n = 10), RS treatment alone for 2 min (n = 10), and AL irradiation before RS treatment (n = 10). This allowed each tooth to serve as a matched internal control for each of the treatments. In vitro caries were created using a modified ten Cate solution. The longitudinal sections (3 per tooth segment, 30 per treatment group) were evaluated for mean lesion depth.

Results: After lesion formation, mean lesion depths (± standard deviation) were 288 ± 32 μm for the no treatment controls, 198 ± 23μm for AL irradiation alone, 188 ± 19 μm for RS treatment alone, and 109 ± 14 μm for AL irradiation before RS treatment. All treatment groups had mean lesion depths that were significantly less than those for the matched no treatment control group (ANOVA, Duncan multiple range [DMR] test, p < 0.05). AL irradiation before RS treatment significantly reduced lesion depth compared with AL irradiation alone or RS treatment alone (ANOVA, DMR test, p < 0.05).

Conclusion: Both AL and RS alone provided significant reductions in lesion depths for in vitro root surface caries compared with no treatment controls. However, the maximum reduction in caries-like lesion depth on permanent tooth root surfaces was achieved when the RS, containing calcium, phosphate, and fluoride in a carbopol base, was combined with AL irradiation.

Keywords: permanent teeth, root surface, caries, argon laser, calcifying solution, remineralization, demineralization, artificial caries.

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Prevalence with low socioeconomic status individuals, males, and individuals with a smoking history; also, the level of education was inversely correlated with prevalence of untreated root surface caries.

Prevention of dental caries, a complex multifactorial disease, requires risk assessment for future caries development and the institution of appropriate preventive modalities and oral hygiene education.²,³ Preventive modalities include use of systemic and topical fluoride, application of fluoride varnish, reduction of dietary cariogenic refined carbohydrates, use of improved plaque removal and oral hygiene techniques, placement of pit and fissure sealants, use of fluoride-releasing preventive and restorative materials, and the prescribing of antimicrobials.⁴⁻⁷

A relatively simple and noninvasive caries preventive regimen is treatment of permanent-tooth root surface with low-fluence argon laser (AL) irradiation, either alone or in combination with topical acidulated phosphate fluoride (APF) treatment. This has been shown to reduce root surface solubility, dissolution rates, and in vitro caries formation and progression.⁸⁻¹¹ Scanning electron microscopic evaluation shows that AL irradiation of root surfaces produces granular to globular calcium-phosphate mineral deposits¹² and fluoride-rich mineral deposits when combined with APF treatment.¹³

Two recent studies¹⁴,¹⁵ evaluated the influence of a commercially available remineralizing solution (RS) on in vitro caries formation in permanent and primary tooth enamel. This “broad spectrum” RS, which contains calcium, phosphate, and fluoride ions in a carboxyl base, enhanced enamel resistance to caries-like lesion formation in vitro. The ability of the enamel to resist in vitro caries formation was improved significantly over that of matched enamel surfaces exposed to APF treatment in permanent tooth enamel and AL irradiation in primary tooth enamel.

The RS effect on in vitro caries formation in permanent tooth root surfaces is not known. Therefore, we conducted this in vitro study to evaluate the effects of AL irradiation alone, RS treatment alone, and in combination with AL irradiation before RS treatment on artificial caries lesion formation in permanent tooth root surfaces using polarized light microscopic techniques.

**MATERIALS AND METHODS**

We selected 10 extracted permanent molar teeth with macroscopically caries-free buccal and lingual root surfaces, as determined with a stereo-zoom dissecting microscope (original magnification 16X), for this in vitro caries study. After performing soft-tissue debridement and fluoride-free prophylaxis, an acid-resistant varnish was applied to the teeth, leaving two buccal and two lingual windows of sound root surface exposed. The teeth were divided into sections (distobuccal, mesiobuccal, distolingual and mesiolingual) to provide 4 segments with sound root surface windows from each tooth, and assigned each segment from each tooth to 1 of 4 treatment groups. This allowed each tooth to serve as a matched internal control for each of the treatments. The 4 treatment groups were no treatment control \((n = 10\) tooth segments), AL irradiation alone \((n = 10)\), RS treatment alone \((n = 10)\), and AL irradiation before RS treatment \((n = 10)\).

AL irradiation was performed using an AL unit (ARAGO, LaserMed; West Jordan, UT, USA) with low-fluence irradiation at 13.5 J/cm² (0.270 W, 5-mm beam, 10 s). The RS (Remin+, Raintree Essix; Metairie, LA, USA) was applied to the root surface for 2 min as stipulated in the manufacturer’s recommendation, followed by copious air-water spray rinsing. The RS contained calcium, phosphate, and sodium fluoride in a carboxyl base (trimethylamine, calcium phosphate, calcium chloride, dibasic sodium phosphate, sodium fluoride, carboxyl).

The tooth specimens were rinsed in distilled/deionized water and then exposed to synthetic saliva (20 millimolar sodium carbonate, 3 mmol/L phosphate, 1 mmol/L calcium, pH 7.0) for 24 h. An in vitro artificial root surface carious lesion was created using a modified ten Cate solution (2.2 mM calcium, 2.2 mM phosphate, 5.0 mM fluoride, pH 3.90). After exposing the specimens to the artificial caries solution for five days, three longitudinal sections (100 μm thick) were made from each tooth segment, resulting in 30 caries-risk sites per treatment group. The longitudinal sections were imbedded with water and examined with polarized light microscopy in a blinded fashion. Evaluated images of the lesions were captured and examined using a computer-interfaced image software program (UTH-SCSA ImageTool, Version 3.0 Final; University of Texas Health Science Center at San Antonio, TX, USA, http://ddsdx.uthscsa.edu/dig/download.html) for mean lesion depth determination. The four treatment groups were compared (no treatment control \([n = 30]\) lesions), AL irradiation alone \([n = 30]\), RS treatment alone \([n = 30]\), and AL irradiation before RS treatment \([n = 30]\) using analysis of variance (ANOVA) and Duncan multiple range test analysis for paired samples (alpha level of \(p < 0.05\)).
RESULTS

Table 1 shows mean lesion depths for the four treatment groups. When compared with the matched no-treatment control group (288 ± 32 μm), mean lesion depths were significantly less (p < 0.05) for AL irradiation alone group (198 ± 23 μm), RS treatment alone group (188 ± 19 μm), and AL irradiation before RS treatment group (109 ± 14 μm). Mean lesion depths decreased by 31% for the AL irradiation alone treatment group compared with the matched no treatment control group (p < 0.05). A comparison of mean lesion depths between the no treatment control and the RS treatment alone group revealed a 35% reduction in mean lesion depth (p < 0.05). The mean lesion depth for the AL irradiation before RS treatment group was 62% less than that for the no treatment control group (p < 0.05). When compared with the AL irradiation alone group, the RS treatment alone group had an additional 5% reduction in mean lesion depth (p > 0.05). AL irradiation before RS treatment group significantly reduced mean lesion depth compared with either AL irradiation alone group (45%, p < 0.05) or RS treatment alone group (42%, p < 0.05).

The histopathologic appearances of the representative in vitro root surface carious lesions from each group (Figs 1 to 4) can be correlated readily with the mean lesion depth findings among the four treatment groups. The representative lesions from the AL, RS, and AL before RS treatment groups (Figs 2 to 4) demonstrated dramatic decreases in body of the lesion depths compared with the representative lesion from the no treatment control group (Fig 1). Not only were lesion depths affected, but certain qualitative differences in the lesions were also noticed. The body of the lesion in the AL irradiation before RS treatment group (Fig 4) showed a qualitatively decreased degree of positive birefringence and a negatively birefringent surface. This indicates a lessened degree of demineralization. In contrast, the no treatment control lesion (Fig 1) showed a relatively high degree of positive birefringence qualitatively, with loss of the typical dentin matrix morphology within the body of the lesion.

While the surface cementum overlying the in vitro root surface carious lesions for all four groups was intact, a degree of irregularity was observed in the surface cementum in the no treatment control (Fig 1) and AL irradiation alone (Fig 2) groups, indicating commencement of surface erosion of the cementum. The lesions in these groups had positively birefringent surface layers that merged with their underlying positively birefringent bodies of the lesions. In contrast, with lesions in the RS treatment alone group (Fig 3), the surfaces were composed of interspersed areas of pseu-

<table>
<thead>
<tr>
<th>Treatment group (No. of lesions)</th>
<th>Mean lesion depth (± SD)</th>
<th>Reduction in lesion depth (%) vs control</th>
<th>Reduction in lesion depth (%) vs AL* alone</th>
<th>Reduction in lesion depth (%) vs RS† treatment alone</th>
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<tbody>
<tr>
<td>No treatment control (30)</td>
<td>288 ± 32 μm</td>
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<tr>
<td>AL irradiation alone (30)</td>
<td>198 ± 23 μm</td>
<td>31‡</td>
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<tr>
<td>RS treatment alone (30)</td>
<td>188 ± 19 μm</td>
<td>35‡</td>
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<tr>
<td>AL irradiation before RS treatment (30)</td>
<td>109 ± 14 μm</td>
<td>62‡</td>
<td>45§</td>
<td>42¶</td>
</tr>
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* AL: argon laser
† RS: remineralizing solution
‡ Analysis of variance and Duncan multiple range test: p < 0.05 compared with the no treatment control group
§ p < 0.05 compared with the AL irradiation alone group
¶ p < 0.05 compared with the RS alone group
doisotropy and negative birefringence, which are indicative of a lessened mineral loss, compared with the lesions in the no treatment control (Fig 1) and AL irradiation alone treatment (Fig 2) groups. In the lesions in the AL irradiation before RS treatment group (Fig 4), the surfaces were uniformly negatively birefringent and comprised a considerable proportion of the entire lesion depth (at least 50%).

DISCUSSION

Caries formation in root surfaces is a dynamic process with periods of remineralization interspersed with episodes of demineralization.16-21 Whether a root surface develops clinically detectable caries is dependent on a number of factors. These include presence of plaque, cariogenic bacteria with plaque, carbohydrate substrate, composition of tooth (lack or decreased amounts of fluoridated hydroxyapatite), and salivary factors (such as calcium, phosphate, and fluoride content, immunoglobulin levels, and flow rate). It is well known that the cementum and dentin composing root surfaces are considerably more vulnerable than enamel to caries development. This is reflected as a relatively higher critical pH (6.2) and lower solubility product (pI = 105), at which the mineral substances of the root surface undergo acid dissolution in comparison with either enamel or hydroxyapatite.16,18,22-25 Using the results from our study, it is evident that AL irradiation of
the root surfaces alone provided a significant level of in vitro caries resistance compared with untreated root surfaces from matched no treatment controls (p < 0.05). This implies that the critical pH and solubility product for the AL irradiation treated root surfaces would be increased, and there would be lessened dissolution of the root surface following treatment.

Recently, the effects of the combination of AL irradiation and RS treatment, as well as RS treatment and traditional topical APF treatment, have been evaluated as to caries resistance of sound enamel. Promising results, with respect to enhancing the caries resistance of sound primary tooth enamel, have emerged from an in vitro caries study combining AL irradiation and RS treatment. Similar results with respect to enhancing the caries resistance of sound permanent tooth enamel have emerged from an in vitro caries study comparing the RS with traditional topical APF treatment. RS (Remin+) contains a proprietary formulation of calcium, phosphate, and sodium fluoride in a carbopol base (trisodium phosphate, calcium phosphate, calcium chloride, dibasic sodium phosphate, sodium fluoride, and carbopol) and has been marketed primarily to orthodontists for the prevention of white-spot lesions adjacent to orthodontic brackets and appliances.

In our in vitro study of root surface caries, the RS treatment alone group had a 35% reduction in lesion depth compared with the matched no treatment control group, and a 31% reduction when compared with the AL irradiation alone group. The RS provides an exogenous source of calcium, phosphate, and fluoride for remineralization of hypomineralized or clinically undetectable demineralized sound root surface, and enhancing the resistance of sound enamel to a cariogenic attack. The minerals contained in the RS may result in precipitation of fluoride-rich calcium and phosphate mineral phases that probably form stable, less soluble mineral phases within the superficial root surface, and result in fluoride-rich mineral deposits on and in the root surface that become mobilized during cariogenic challenges. These fluoride-rich mineral phases may markedly reduce the dissolution rate of root surfaces.

A synergistic effect was observed on in vitro caries formation in root surface when AL irradiation took place before RS treatment in our study. This combined treatment of sound root surfaces resulted in the greatest reduction in mean lesion depth. With the AL irradiation before RS treatment, in vitro root surface lesion depths were reduced by 62% when compared with matched no treatment controls, by 45% when compared with AL irradiation alone, and by 42% when compared with RS treatment alone (p < 0.05). A similar synergistic effect has been reported when combining AL irradiation with topical APF application in an in vitro root surface studies.

The mechanisms for increasing the resistance of tooth mineral substance to cariogenic challenges, previously described for lasers and RS, no doubt play a role in root surface lesion depth reductions found in our study. Caries resistance imparted by low-fluence argon laser irradiation may be related to the creation of a microsieve network within tooth mineral substance. This microsieve network promotes rapid redeposition of calcium and phosphate mineral phases mobilized curing a cariogenic attack. In addition, the crystalline structure of tooth mineral may be altered and become more resistant to demineralization by removal of organic material and carbonate, and reduction in internal crystalline strain. Caries resistance may be improved by increased fluoride uptake that occurs with laser treatment. Increased fluoride with tooth mineral may lead to formation of less acid-soluble fluoridated hydroxyapatite (FHAP) from more soluble tooth mineral phases, such as octacalcium phosphate (OCP), dicalcium phosphate dihydrate (DCPD), and tricalcium phosphate (TCP). Organic matrix swelling within tooth mineral occurs and this may make the pore structure of tooth mineral less accessible to organic acids produced during the caries process. The ability of laser irradiation to affect enamel solubility is reflected by the change in critical pH at which enamel dissolution occurs. It would appear that dentists should combine AL irradiation with a remineralizing agent for optimal root surface caries resistance.

**CONCLUSION**

AL irradiation alone or RS treatment alone provided significant in vitro caries reduction in permanent root surfaces when compared with matched no treatment controls (p < 0.05). The susceptibility of permanent root surfaces to a continuous cariogenic challenge decreased significantly with RS treatment alone when compared with AL irradiation alone. The maximum reduction in lesion depth in permanent root surfaces was obtained when AL irradiation occurred in combination with RS treatment (p < 0.05).
REFERENCES


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