Root Surface Morphological Changes After Focused Versus Defocused CO₂ Laser Irradiation: A Scanning Electron Microscopy Analysis

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Background: Many studies have observed damages to root surfaces treated by CO₂ laser in continuous mode with a focused beam. The morphologic changes observed were always associated with temperature increase induced by high energy release.

Methods: The purpose of this study was to analyze by scanning electron microscopy (SEM) the effects of CO₂ laser in 2 different modes on root surfaces. Study samples consisted of 30 extracted single-rooted periodontally compromised human teeth. Root specimens were randomly assigned to 3 groups: group A (12) treated with CO₂ laser in continuous mode with a focused beam of 0.8 mm; group B (12) treated with CO₂ laser in pulsed mode with defocused beam of 4 mm; and group C (6), untreated controls.

Results: Group A (continuous mode) showed severe damages to dentin surfaces such as craters and fissures. Group B (defocused mode) did not result in any damages to the root surfaces, showing flat and smooth surfaces with apparent fusion of the smear layer and dentinal tubules almost completely sealed. The untreated control group was characterized by irregular and amorphous surfaces with several shallow depressions.

Conclusions: Although both laser modes resulted in changes to the treated root surface specimens, the changes resulting in a smooth surface from use of defocused pulsed beam may present an advantage in periodontal treatment. J Periodontol 2002; 73:370-373.

KEY WORDS
Comparison studies; lasers/adverse effects; tooth root.

Bacterial colonization of root surfaces is recognized as the primary cause of periodontal disease. Cementum from root surfaces exposed to bacterial colonization could act as a reservoir for bacterial endotoxins, causing further loss of attachment apparatus.1-3

Traditional treatment to detoxify periodontally diseased root surfaces is performed with scaling and root planing using hand instruments and/or ultrasonics.

Some authors reported that the CO₂ laser has a bactericidal activity4 and could be useful in detoxification of dentin and alveolar bone.5,6

Several studies have shown dramatic changes on the lased root surface including cracks, charring,7,9 and crater formation with melting of the root surfaces.10,11

Anic et al.12 observed craters with a fungoid-like and lace-like formation on the cementum on root surfaces following use of a CO₂ laser. Other authors evaluated the effects of Nd:YAG laser on root surfaces in vitro.13 The results from this study showed a significantly lower number of fibroblast attachment in the endotoxin-treated samples exposed to laser compared to control and non-lased endotoxin-treated groups. The authors concluded that laser treatment could modify the biocompatibility of cementum to fibroblastic attachment. The same group14 examined chemical changes at the root surfaces after Nd:YAG laser treatment using photoacoustic spectroscopy. They concluded that laser treatment could induce a reduction of the protein/mineral ratio and a
contamination of root surfaces with protein by-products which may inhibit fibroblast adhesion. The changes in the root surface after Nd:YAG laser irradiation may be extensive and dependent on the power setting.15

Laser treatment might cause thermal side effects with morphologic and chemical modifications of dental hard tissues. Shariati et al.16 have studied the effects of CO2 laser on root surfaces in continuous mode with a beam size of 1 mm. This laser treatment, using different power energies and exposure times, induced charred craters and an apparent melting of dentin. The increase in power setting and exposure time resulted in an increase in the width and depth of damages to dental hard tissues.

Most of the studies reporting extensive changes to tooth structure used the CO2 laser in continuous focused mode. The use of pulsed laser may induce less thermal damages to root surfaces, because the tissue cools down between the pulses. The spot size seems to influence the power density. The larger the spot, the greater the power required to maintain the same power density.

The purpose of the present study was to observe and compare in vitro 2 types of laser treatment, continuous focused mode and pulsed defocused mode, on dental hard tissues using scanning electron microscopy (SEM).

MATERIALS AND METHODS
Sample Collection and Preparation
Thirty freshly-extracted single-rooted human teeth without crown or root fractures were used in this study. The teeth were periodontally compromised and selected based on the following criteria: 1) sites with probing depth (PD) >6 mm and attachment level (AL) >5 mm; 2) no visible root fractures or anatomical abnormalities of the root; 3) root surfaces carious free and not endodontically involved; and 4) absence of restorative materials.

Immediately after extraction, teeth were scaled with ultrasonic scaler‡ to remove soft tissues and plaque. Thirty root specimens (5 x 5.0 mm and 3.0 mm thick) were cut longitudinally with a water cooled-low speed handpiece using a diamond bur. Each specimen was prepared from each root surface of one extracted tooth.

Treatment Groups
Specimens were randomly assigned to 1 of the 3 groups: group A (12) treated with a CO2 laser§ in a focused (0.8 mm spot size) continuous mode with 8.0 W power setting; group B (12) treated with the same laser in non-focused (4.0 mm spot size) pulsed mode with a frequency of 4.0 Hz and 2.0 W of power setting; and group C (6) untreated controls.

RESULTS
All root specimens treated in the continuous focused mode (group A) exhibited zones of heat cracking, fissuring, and pronounced roughness under SEM examination. The central area of the lased surfaces was characterized by melted mineral surface (Fig. 1) alternating with fissures and craters. This mode of treatment induced severe changes of the dentin layer and no remnants of bacterial cells were observed by SEM.

The surfaces of specimens treated by laser in pulsed non-focused mode (group B) showed areas without cementum with completely sealed dentinal tubules (Fig. 2). The dentin appeared as a melted layer (Fig. 3), showing a flat and smooth surface with an apparent fusion of the surface of the smear layer. This characteristic feature of the dentin layer gave the appearance of a “glazed dentin,” the dentinal tubule orifices appeared almost completely plugged (Fig. 4). No remnants of bacterial cells were observed after the laser irradiation. In contrast, the untreated specimens (group C) were substantially different compared with lased specimens, exhibiting a relatively irregular and amor-
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Phosphous surfaces characterized by several shallow depressions. Such areas showed isolated islands of microbial plaque deposits composed of cocci and rods as well as a small number of collagen fibrils.

**DISCUSSION**

Several authors have reported observing severe damages to dentin surfaces after Nd:YAG and CO₂ laser exposure. Tseng and Liew¹⁷ in an in vitro study noted heat penetration and damage on cementum and dentin surfaces after laser treatment. Morlock et al.¹⁶ used a Nd:YAG laser on root surfaces followed by root planing and observed characteristic morphologic changes such as charring, carbonization, fissures, and craters.

These morphologic changes to the root surface after the Nd:YAG laser irradiation may be dependent on the power setting used and not on the laser application.¹⁵ Furthermore, Nd:YAG laser irradiation may have a negative effect on fibroblast attachment on the root surface.¹⁰,¹³,¹⁸

Shariati et al.¹⁶ studied the effects of a CO₂ laser at 2 power levels and 6 exposure times on root dentin. The observations showed surface cratering and fissures followed, at a deeper layer, by melting of the dentin and partial sealing of the tubules. The authors noted that with the increase of the exposure time the craters quickly expand causing severe changes of the tooth structures.

As with the results of the above studies, SEM analysis from our study revealed that the continuous laser mode with a focused beam caused severe changes to the dentin surfaces such as cracks, fissures, and pronounced roughness. In contrast, the pulsed laser mode with a defocused beam did not induce any extensive modifications to root surfaces. The surface of experimental specimens which received CO₂ laser irradiation in defocused pulsed mode showed an almost completely melted dentin layer. The scattering of the root surface in the pulsed mode is more homogeneous without deep craters or melting due to thermal damage, which has been observed after use of the continuous mode with the focused beam. SEM observations revealed an absence of residual bacterial cells on all laser irradiated specimens; specimens that did not receive laser treatment showed some residual bacterial cells probably because of insufficient initial mechanical instrumentation with the ultrasonic scaler. These findings were in agreement with results from other studies.¹⁹,²⁰ Misra et al.²¹ observed that CO₂ laser irradiation at low power

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**Figure 2.**
Root surface exposed to CO₂ laser in pulsed defocused mode showing melted root surface (original magnification, 120x).

**Figure 3.**
Root surface treated by laser in pulsed defocused mode. Melt-down smooth surface is observed (original magnification, 400x).

**Figure 4.**
Root surface treated by laser in pulsed defocused mode showing sealed dentinal tubules (original magnification, 4000x).
setting (3 watts) for 1 second was able to expose dentinal tubule orifices removing the smear layer without extensive damage to the root surfaces. The smear layer, normally obtained after root planing, always contains residual dental calculus as well as microbial plaque bacterial endotoxins which negatively affect new connective tissue attachment. Conditioning of the root surfaces by different methods has been recommended as an adjunctive tool in periodontal therapy to enhance regeneration of periodontal tissues.

Adriansen et al. showed bacterial invasion in the root cementum and dentinal tubules of periodontally diseased caries-free human teeth. Since this bacterial invasion cannot be eradicated by mechanical debridement alone and may be, in part, responsible for a rapid recolonization of periodontal treated sites, it would appear necessary to combine mechanical therapy with the use of adjunctive techniques.

The use of CO₂ laser has been suggested for detoxification of titanium surface in vivo. Mouhyi et al. examined different power settings of the CO₂ laser for optimal detoxification: the laser was used in pulsed mode at 8.0 W with pulse duration of 10 ms and repetition rate of 20 Hz to detoxify the titanium surface keeping the temperature below the critical levels of bone damage.

In conclusion, the findings presented from this study show that laser irradiation in the pulsed mode with a defocused beam induced some morphologic changes without causing extensive changes in the root surface. The role of CO₂ laser as an adjunctive tool in periodontal therapy should be investigated with more extensive and well-controlled studies. Further research must be conducted to test attachment of fibroblasts to the root surfaces after CO₂ laser irradiation.

REFERENCES