Removing subgingival plaque and calculus is a major goal of periodontal treatment. Few attempts have been made to evaluate the use of lasers for root surface debridement in periodontal therapy. The aim of the present study was to compare, histologically, the effects of hand instrumentation, ultrasonic instrumentation, and CO₂ lasers on the root surfaces of teeth treated in situ.

Methods: A total of 33 teeth scheduled for extraction due to severe periodontal disease were divided into three groups. In the first group, teeth were treated by ultrasonic bactericidal curettage (UBC) with an ultrasonic scaler; in the second group, teeth were treated by hand instrumentation; and in the third group, after hand instrumentation, roots were lasered by a CO₂ laser. The samples were then processed for histological examination.

Results: In the first and second groups, plaque and calculus were present in interradicular septa, lacunae, and surface concavities. In the third group, surfaces of specimens treated by a low-power defocused CO₂ laser showed areas devoid of cementum, with completely sealed dentinal tubules, and no bacterial cell remnants.

Conclusions: The CO₂ laser treatment, used at low power and in the defocused mode, combined with traditional mechanical instrumentation, could improve root surface debridement of periodontally involved teeth. More extensive, long-term studies are needed to confirm this hypothesis. J Periodontol 2005;76:476-481.

KEY WORDS
Dental calculus/prevention and control; dental plaque/prevention and control; dental prophylaxis; lasers/therapeutic use; periodontal diseases/therapy; tooth root.
with the Er:YAG laser using air/water surface cooling and the CO₂ and Nd:YAG lasers, both with and without a surface coolant. They observed that the Er:YAG laser, when used at low-energy densities, showed sufficient potential for root surface modification, thus warranting further research. Similar results were observed by Barone et al. using a CO₂ laser at low energy in pulsed mode. The aim of the present study was to compare the effects of hand instrumentation, ultrasonic instrumentation, and CO₂ laser treatment on root surface debridement and the integrity of periodontally involved teeth.

MATERIALS AND METHODS
A total of 33 teeth scheduled for extraction, 15 incisors, 9 premolars, and 9 molars affected by severe periodontal disease, were included in this study. Each tooth type (i.e., molar, premolar, incisor) was randomly assigned to the experimental and test groups so that each treatment group received an equal number of each tooth type. All teeth included in the study were affected by severe periodontal disease, showing probing depths (PD) >6 mm and clinical attachment levels (CAL) >8 mm, and were scheduled for extraction. They had not received periodontal treatment in the last 6 months.

Clinical trial
Pretreatment periapical x-rays and six point measurements of probing depths (mesio-buccal, mesio-lingual, buccal, disto-buccal, disto-lingual, palatal) were obtained. Gingival full-thickness flaps were resected around each tooth to gain access to root surfaces. The 33 teeth were divided into three groups as follows:

- Teeth in the first group were treated by ultrasonic bactericidal curettage (UBC) with an ultrasonic scaler,† using constant irrigation in a sterile saline solution at a concentration of 1:10. The solution was prepared fresh for each use by combining directly into a reservoir container 150 cc of iodine solution with 1,000 cc of sterile saline. Ultrasonic root debridement was carried out until it was clinically determined that calculus had been removed.

- Teeth in the second group were treated by hand instrumentation.‡ Root surfaces were instrumented until a smooth surface was achieved.

- In the third group, after hand instrumentation, roots were lasered by a CO₂ laser§ in defocused pulsed mode. The laser beam was emitted with a 2.5 mm diameter spot size in pulse mode with a frequency of 1 Hz, a power of 2 W, and a duty cycle of 6%. The duty cycle is defined as the ratio of laser pulse duration to the length of one repetition period, and varies between 2% and 40%. The energy density was 2.45 J/cm². All teeth were extracted immediately after the experimental treatment procedures.

Histologic procedure
Following extraction, the teeth were immediately placed in Karnovsky’s fixative; left overnight; and then embedded in resin. The crowns were removed and samples sectioned in a plane perpendicular to the long axis of the teeth using a microtome. Ten root sections of 1 mm each were taken from the cemento-enamel junction toward the apex perpendicular to the long axis of each tooth, for a total of 330 histological samples. The sections were ground down to a thickness of 10 to 15 um using a grinding and polishing machine. The unstained specimens were examined by phase-contrast and Nomarski differential interference contrast (DIC) using a microscope.

RESULTS
Root surfaces treated with the ultrasonic instrument showed a scaly and rough topography with some gouges in several areas (Fig. 1). The cementum layer presented variable thickness along the root surfaces (Fig. 2) and, in some areas, it had been completely removed, leaving a superficial layer of dentin. In some histological sections, cracks were observed in the dentinal structure, possibly due to the prolonged time of instrument tip contact on the root surface. Residual bacterial aggregates were observed along root surfaces in two teeth, and in the interradicular septa of premolars and molars (Fig. 3).

Teeth treated by curettes presented smooth root surfaces, especially on convex surfaces (Fig. 4). Cementum

† Odontoson M, Goof, Denmark.
‡ Gracey curet, Hu-Friedy, Chicago, IL.
§ DEKA, Florence, Italy.
¶ Epon, Fluka, Chemie AG, Buchs, Switzerland.
†† Isomet, Buehler, Lake Bluff, IL.
‡‡ Buehler.
** Fomi III, Carl Zeiss, Oberkochen, Germany.
was completely absent and the dentin layer exhibited open tubules. Defects on the dentin layer were also present along root surfaces. In two teeth, one molar and one premolar, plaque and calculus were present in interradicular septa, in lacunae, and in concavities.

Specimens treated with a low-power defocused CO\textsubscript{2} laser exhibited areas devoid of cementum with completely sealed dentinal tubules (Fig. 5). The dentin surface appeared as a melted layer (Fig. 6), showing a flat and smooth surface with an apparent fusion of the smear layer. The dentin layer had the appearance of a glazed surface (Fig. 7). Further, no residual bacteria were observed on any of the examined roots following CO\textsubscript{2} laser irradiation.

**DISCUSSION**

The effectiveness of lasers in dentistry has been the subject of recent reviews,\textsuperscript{21} including specific analyses referring to periodontal practice.\textsuperscript{22} At present, the question is which parameters can the clinician use in order to achieve the desired goals in root conditioning without initiating damage to the root surface. Misra\textsuperscript{23} studied histologically the effect of the CO\textsubscript{2} laser compared to citric acid, EDTA, and hydrogen peroxide in the
removal of the root surface smear layer after root planing on periodontally involved root surfaces. A smear layer was present on root surfaces of teeth that had been root planed. In contrast, with the use of the CO2 laser, plaque was completely eliminated and, at some power density levels, glazed root surfaces were obtained without cracks or damage to the dentinal layer; the most effective energy level and time of exposure was 3.0 W at 1.0 second. With these values, a complete removal of the smear layer was attained. The power density in the Misra study was similar to that of other investigations.19,24 EDTA and citric acid were also effective in removing the smear layer, but they exposed tunnel-shape dentinal tubules. A low-power beam and a short exposure time has been suggested also by Simeone25 for hard tissue conditioning because these conditions limit temperature increases on the surface, where it is necessary to obtain detoxification, and in depth, where damage to vital tissues might be caused. In the Simeone study, various power and application time combinations were tried in order to observe cooling rate on the surface structure.

Further confirmation of the lower power choice was obtained by Barone, while comparing the effect of a continuous focused beam with a pulsed, defocused mode.19 In the first case, using a continuous focused beam, outcomes confirmed other negative results previously published.18 In the latter in vitro study, a comparison between Er:YAG, Nd:YAG, and CO2 lasers, the authors used high-energy densities, between 100 and 400 J/cm2, obtaining results that included melting and surface charring. They used a focused beam from a 0.8 mm diameter ceramic delivery tip 1 to 2 mm from the target surface. The CO2 power density can be calculated as 100 J/cm2, and the authors concluded that increased energy densities were directly related to changes in the target surface. This is in agreement with Barone’s in vitro experimental results of severe damage to root surfaces with a focused beam at a power density of 1,600 W/cm2 in continuous mode. An alternative to such high-power densities with the CO2 laser is the defocused mode of application. Beyond the focal point, typically less than 1 mm in diameter, the beam cone diverges and therefore its power density decreases. In this mode Barone et al.19 used the low-power CO2 laser without damaging hard tissue, confirming other positive results.26,27 Ben Hatit28 compared the effects of scaling and Nd:YAG laser treatments with that of scaling alone on cementum and levels of Actinobacillus actinomycetemcomitans (Aa), Tannerella forsythensis (Tf), Porphyromonas gingivalis (Pg), and Treponema denticola (Td). After treatment, scanning electron microscopic examination of the specimens irradiated with the Nd:YAG laser at increasing power levels showed different levels of root surface alterations. These results revealed the usefulness of scaling and root planing; however, when scaling was followed by low-power Nd:YAG laser treatment and appropriate oral hygiene instruction, the suppression and eradication of the three types of subgingival microorganisms (Tf, Td, and Pg) were more evident than with scaling alone. The specimens treated by Nd:YAG laser revealed root surface changes, e.g., melt-down and resolidified areas with a flat and smooth appearance. When used at energy densities between 11 and 41 J/cm2, the CO2 laser may destroy microbial colonies without inflicting damage to root surfaces.29 In a histological study, Frentzen30 compared the effects of Er:YAG laser instrumentation of diseased root surfaces to mechanical removal of plaque and calculus with ultrasonic instruments and scalers. Areas of subgingival calculus were identified on 40 freshly extracted human teeth. Each of these areas was randomly divided into two equal parts. The control site was treated either with scaling and root planing or with an ultrasonic instrument. Histologically, scaling resulted in complete debridement in all samples, producing a smooth root surface. At the test sites, laser scaling was accompanied by an increased loss of cementum and dentinal tissue, and roughened surfaces. In addition to physical radiation parameters, the parameters of clinical handling, in particular the angulation of the application tip, have a strong influence on the amount of root substance removal obtained with Er:YAG laser radiation.31

Subgingival plaque and calculus removal appears to be equivalent when using either ultrasonic devices or hand instruments,32-40 although in the present study both ultrasonic devices and hand instrumentation were not able to remove all residual plaque and calculus deposits present on root surfaces, in septa
of furcations, or in lacunae defects, zones where instruments cannot thoroughly clean. Both ultrasonic devices and hand instrumentation left residual plaque and calculus along root surfaces of premolars and molars. However, ultrasonic root debridement left fewer bacteria along treated surfaces than hand instrumentation alone, so there may be additional advantages to using ultrasonic devices in conjunction with hand scalers for removing bacterial plaque. Specifically, the lavage effect produced by the water coolant used with power-driven scalers provides a constant flushing activity during instrumentation, which appears to have some therapeutic effects.41-44 The antimicrobial effect may be due to effective disruption of the bacterial cell wall. Breininger et al.15 obtained similar results when they observed bacterial aggregates after hand instrumentation in 11 of 14 instances and after ultrasonic scaling in 8 of 22 samples. Curettes appeared to be somewhat more prone to leaving calculus-associated plaque than ultrasonic devices. The authors concluded that both hand and ultrasonic instrumentation left very little adherent plaque, and ultrasonic devices appeared to maintain effectiveness in plaque removal.

In conclusion, CO2 laser treatment, used at low power and in the defocused mode, combined with traditional mechanical instrumentation, could be considered an adjunctive tool for root treatment of periodontally involved teeth.45 However, further studies are needed to better understand the usefulness of the CO2 laser in root conditioning.

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