Electron Microscopic Study of the Effect of Water Jet Lavage Devices on Dental Plaque

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The maxillary posterior teeth of nine rhesus monkeys were treated with a pulsating water lavage instrument at 70 psi (high setting). Electron microscopic studies of pre- and post-lavage plaque samples showed that water jet devices as used in this experiment either removed the plaque completely or caused irreversible damage to the microbial forms in the plaque matrix.

Water jet devices have been shown to be effective in the debridement and decontamination of wounds.[1–3] Their ability to remove bacteria, loose tissue fragments, and foreign material from wound and tooth surfaces has been demonstrated. Jann[3] has reviewed water irrigation devices. The purpose of the present study was to examine the effect of the pulsating water jet on the ultrastructure of the dental plaque that had not been removed with this treatment. Results indicated that retained plaque organisms are irreversibly altered after exposure to the water jet device.

Materials and Methods

Nine female rhesus monkeys 8 to 11 years old, were housed in the animal facility from one to two years and fed a standard diet of monkey chow, supplemented daily with fresh fruits and vegetables. No previous experiments had been performed on these monkeys. Plaque samples were curetted from a region just above the gingival crest of the labial surface of the maxillary left premolars and first molar. The specimens were fixed immediately in 0.05 *M* cacodylate buffer (pH, 7.4), which contained 2% glutaraldehyde at 4 C. The labial surfaces of the maxillary right posterior teeth then were lavaged for 30 seconds with the water jet device at 70 psi (high setting), curetted immediately thereafter, and fixed as described. After all samples were fixed for 24 hours, they were washed in cacodylate buffer that contained 7.8% sucrose, postfixed in 1% osmium tetroxide, dehydrated in graded solutions of ethyl alcohol, and embedded in epoxy resin. Sections were cut with an ultramicrotome,[a] stained with lead citrate and uranylacetate, and examined on an electron microscope.[b]

Results

Plaque samples from the untreated tooth surfaces consisted of an intercellular matrix and a varied assortment of microorganisms. The majority of the samples were rich in coccal forms, with several clusters of filamentous and rod-shaped bacteria (Fig 1). Most of the microorganisms had a "viable" appearance; that is, the cell contents were dense, with granular deposits especially prominent beneath the cell membrane. The cell walls were intact and curved smoothly. Intercellular material was finely granular, with occasional microvesicles. In some regions shrunken bacterial forms were present with clumps of microvesicles and filaments. Regions of fully calcified plaque contained bacteria in various stages of calcification in "lacunas" of the crystallized plaque matrix. Most of the bacterial cytoplasm was calcified fully with the cell wall region apparently uncalcified. Calcification appeared as large plates and

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Resources, National Academy of Sciences, National Research Council.

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[a] LKB 8801A, LKB-Producter AB, Stockholm, Sw.
[b] Hitachi HU-11B, Hitachi Ltd., Tokyo, Jap.

FIG 1.—Monkey plaque before water lavage. Coccal (*a*) and rod (*b*) microorganisms predominate, with occasional empty cell body (*c*) (orig mag ×12,000, reproduced at 82%).

coarse needles in the microorganism, but as finely granular in the matrix (Fig 2).

After lavage, no plaque could be recovered in two of the nine monkeys. In the other seven there was a significant change in plaque ultrastructure. Most notably, there was an evacuation of bacterial cell content, and the cell wall remained intact (Fig 3). Evacuation of contents varied between total and slight, with the central portion of the cell content the last to disappear. Several microorganisms suffered rupture of the cell-limiting membrane, usually accompanied by total loss of cell content. The large filamentous organisms assumed highly irregular shapes with loss of smooth surface contour, and many indentations appeared in the cell wall. The cell content retained the structure as found in the untreated plaque. The intercellular space contained large clumps of dense material, presumably cell contents. In regions of calcified plaque (Fig 4), no gross changes were noted, although some less calcified forms exhibited shrinkage away from the inner surface of the calcified extracellular space.

Discussion

The untreated rhesus plaque in this study showed the same features that are seen in human material. Regions of uncalcified plaque contained predominantly coccal forms; dense islands of filamentous organisms, short rods, and occasional spirochetal forms were pres-

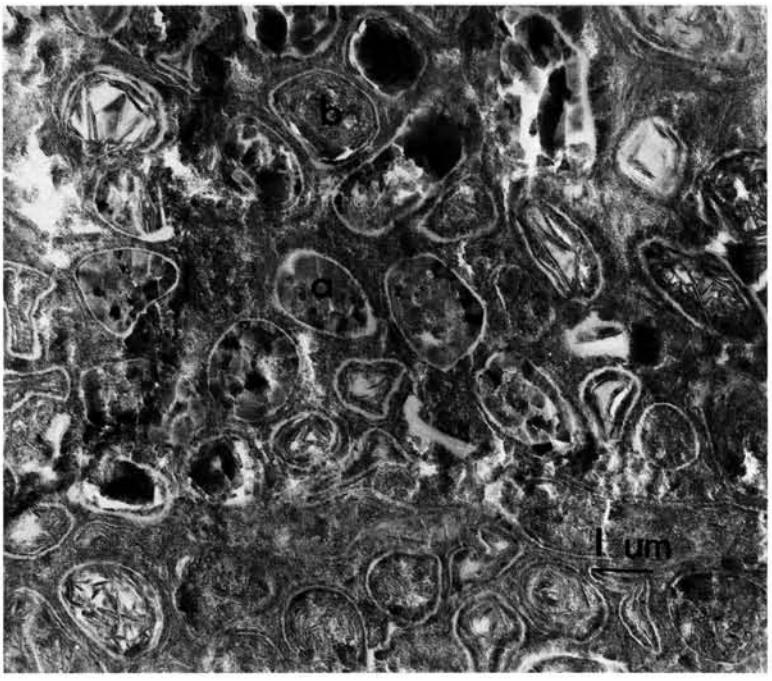

FIG 2.—Calcified monkey plaque before water lavage. Most organisms contain plate (*a*) or needle (*b*) shaped crystals. Entire interbacterial matrix is calcified except for thin zone around each microorganism (orig mag ×11,000, reproduced at 72%).

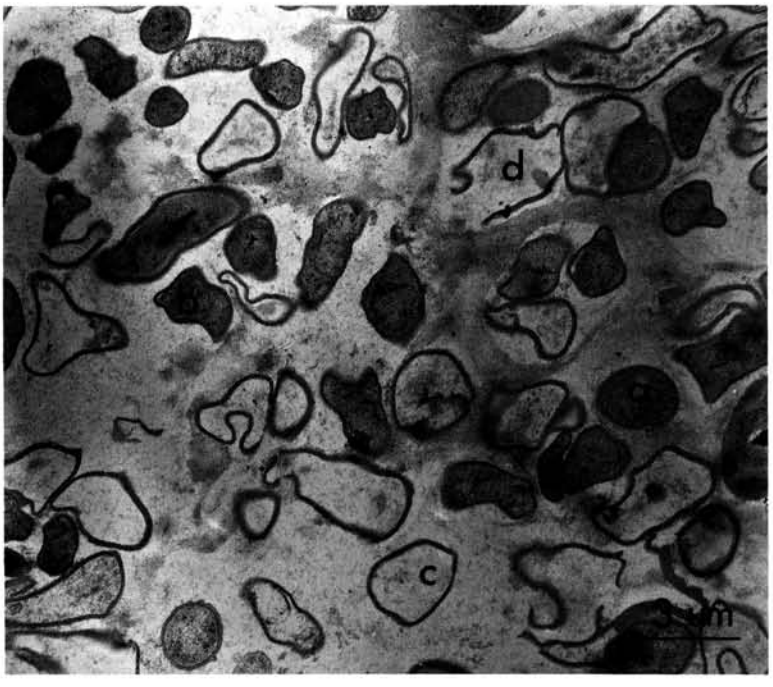

FIG 3.—Monkey plaque immediately after water lavage. Some organisms are normal in appearance (*a*). Majority exhibit either irregular cell shapes with normal cell content (*b*), or evacuated forms with intact (*c*) or broken (*d*) cell walls (orig mag ×7,000, reproduced at 72%).

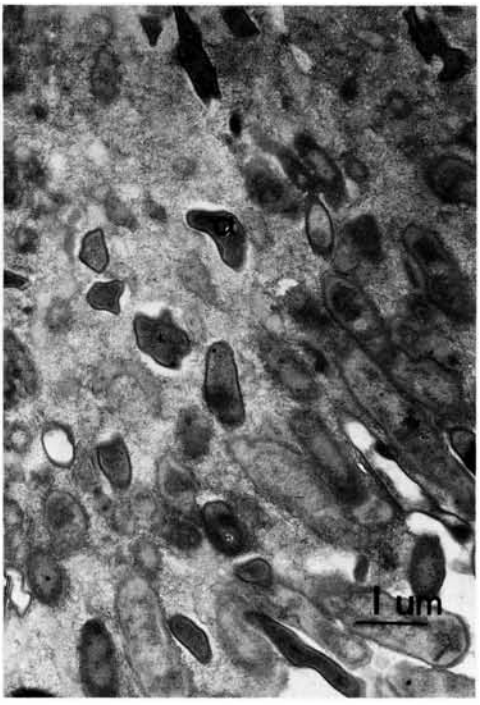

FIG 4.—Calcified monkey plaque immediately after water lavage. Only borders of calcified regions show changes. Not yet calcified cell forms appear irregular and withdrawn from plaque lacunas (*a*) (orig mag ×13,200, reproduced at 71%).

ent. In regions of calcification, crystallites appeared first in the outer surface of the bacterial cell wall and intercellular space. Crystallization seemed to be foccal, with old hard regions sharply demarcated from uncalcified material. Older calcified plaque contained densely calcified microorganisms with a clear unmineralized zone between the cell and the calcified intercellular space.

This study demonstrated significant changes in plaque ultrastructure after water lavage. Many of the fine-structural changes can be ascribed to the use of hypotonic tap water as the irrigant, alone or in combination with high pressure. Although some plaque may remain after lavage treatment,[4] the changes in the cell ultrastructure shown here probably are irreversible in light of the widespread rupture of bacteria and evacuation of cell content. Most severe damage is to rods and coccal forms, with a less, seemingly reversible, effect on the filamentous organisms. Lavage appears to irreversibly damage residual dental plaque. The advantage of water lavage in treating dental plaque is manifest, therefore, not only in its ability to remove the uncalcified plaque material, but also to alter the number and the nature of the bacteria. Because bacteria and their toxic products are a major portion of plaque material, it is obvious from these results that lavage affects the most deleterious part of the plaque. Although other methods of plaque control, such as flossing, cannot remove the entire plaque,[5] they are recommended as ancillary treatments together with water lavage.

Conclusions

The maxillary posterior teeth of nine rhesus monkeys were treated with a pulsating water lavage instrument at 70 psi (high setting). Electron microscopic studies on pre- and post-lavage plaque samples show that water jet devices as used in this experiment either remove the plaque completely or cause irreversible damage to the microbial forms in the plaque matrix. Cocci and rods are most severely affected; cell rupture and evacuation of contents are predominant. Filamentous organisms show severe changes in surface contour, although cell contents appear structurally intact. From these results we conclude that residual plaque is altered, which helps to explain the clinical improvement in gingival tissue after the use of the pulsating water jet device.

References

1. GROSS, A.; BHASKAR, S.N.; CUTRIGHT, D.E.; BEASLEY, J.D.; and PEREZ, B.: The effect of Pulsating Water Jet Lavage on Experimental Contaminated Wounds, *J Oral Surg* 29: 187, 1971.
2. GROSS, A.; BHASKAR, S.N.; and CUTRIGHT, D.E.: A Study of Bacteremia Following Wound Lavage, *Oral Surg* 31: 720, 1971.
3. JANN, R.: Water Irrigating Devices, *Period Abstr* 18: 6, 1970.
4. LOBENE, R.R.: The Effect of a Pulsed Water Pressure Cleansing Device on Oral Health, *J Periodontol* 40: 667, 1969.
5. DEWITT, K., and BRADY, J.M.: Evaluation of Plaque Debridement by Scanning Electron Microscopy, abstracted, IADR *Program and Abstracts of Papers,* No. 696, 1970.