The healing of surgical defects in alveolar bone produced with ultrasonic instrumentation, chisel, and rotary bur


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A histologic comparison of the effects of an ultrasonic instrument, a low-speed rotary cutting bur, and a surgical chisel, all used with water coolant, on the rate of healing of dog alveolar bone was made. After reflection of a mucoperiosteal flap, each instrument was used to produce a 3 by 3 by 3 mm. defect in buccal alveolar bone, 3 mm. apical to the alveolar crest and directly overlying the root structure of the right premolar teeth. Dogs were killed immediately following flap replacement with sutures and 3, 7, 14, 28, 56, and 90 days later. Histologic examination of the surgical area revealed that the bur produced the smoothest surface. At day 3, specimens prepared with the chisel and the ultrasonic instrument exhibited areas of cellular organization along surfaces within the defect and the formation of osteoid in adjacent marrow spaces. At day 7, osteoblastic activity was most pronounced in specimens prepared with the chisel and least in those prepared with the bur. The subsequent rate of healing in later periods appeared histologically to be best with the use of the chisel, followed closely by the use of the ultrasonic instrument, and slowest with the bur, the order of which is consistent with the overall microscopic evaluation of the effect of the three instruments.

The use of high-frequency mechanical vibrations in tools to cut hard substances was initially developed for industrial use. The dental profession evaluated this method to cut dento-osseous structures and at present ultrasonic mechanical instruments are used to remove deposits on the crown and substructure of removable prosthesis.

We investigated the effect of instrumentation as a method of healing and compared this method with the chisel and a conventional histologic evaluation of the healing of dog alveolar bone.

MATERIALS AND METHODS

Ten essentially healthy adult beagle dogs were sedated with promazine (2.5 mg. per kilogram of body weight). Sterile operatory, exposed surgical burs and periodontal disease were performed. Adequate soft tissue wounds were rinsed with sterile saline.

A buccal mucoperiosteal groove around the teeth. The maxillary and mandibular premolar teeth, while the upper ones were used with the use of alveolar bone. Each defect was produced with water coolant to ensure adequate cooling. One defect was produced with a standard P-3 insert bur. The second defect was produced with a standard insert bur. Intermittent irrigation was applied by an assistant. The third defect was produced with a carbide bur in a Midwest stream of water directed to the dental unit.

Each defect measured 3 by 3 by 3 mm. over the root structure of the right premolar teeth, directly above the upper maxillary and mandibular muscle insertion points.

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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We investigated the effect of the chip-like action of ultrasonic mechanical instrumentation as a method for the surgical removal of bone. We have compared this method with those entailing the use of a standard sharp surgical blade and a conventional-speed rotary cutting bur. This study reports on the in vivo evaluation of the effect of such instrumentation on the removal of dog alveolar bone.

MATERIALS AND METHODS

Ten essentially healthy 2-year-old mongrel dogs of similar size and physical characteristics were sedated with atropine (0.02 mg. per kilogram) and thiopronazine (2.5 mg. per kilogram). They were then anesthetized with a 4 percent solution of thiopental sodium administered intravenously (17.5 mg. per kilogram). Sterile operating procedures were maintained by draping the head, neck, and exposed cephalic areas of each jaw. The oral mucous membranes and dentition were rinsed voluminously with sterile isotonic saline solution and wiped clean with sterile gauze sponges.

A buccal mucoperiosteal flap was reflected from an incision in the free gingival groove around the teeth. The maxillary flap included the first, second, and third premolar teeth, while the mandibular flap included the second, third, and fourth premolars. With the use of a template, three defects were produced in the buccal alveolar bone. Each defect was produced with a different instrument in conjunction with water coolant to simulate the instrument's actual use in clinical procedures. One defect was produced by means of an ultrasonic dental unit* with the standard P-3 insert and the normal water spray, which generated from the unit. The second defect was produced with a Stent No. 1 chisel with light blows from a standard mallet. Intermittent sprays of water from the dental unit attachment were applied by an assistant to the surgical site during this procedure. The third defect was produced with a No. 637 rotary cross-cut fissure, tungsten-carbide bur in a Midwest handpiece at a speed of 12,500 r.p.m. A continuous stream of water was directed to the bur tip by means of the water attachment on the dental unit.

Each defect was measured by 3 by 3 mm. and was located 3 mm. apical to the alveolar crest, directly overlying the root structure of each tooth in the right maxillary and mandibular arch (Fig. 1). The crown of each tooth was marked for orientation with a diamond wheel, so that the line of cut would bisect the midpoint of the experimental defect. Sham operations of equivalent duration were performed on the left sides at the same time to serve as controls. Mucoperiosteal flaps were approximated with interrupted 4-0 silk sutures, which were removed on the fifth postoperative day. The dogs were maintained for 7 days on

commercial canned dog food of soft consistency, and their diet was then changed to a standard commercial dry dog food.

Dogs were killed with an overdose of pentobarbital sodium immediately following the surgical procedure and 3, 7, 14, 28, 56, and 90 days later. The jaws were removed and immediately placed in 10 per cent buffered formalin. Individual experimental areas with eponymous defects and corresponding control areas were dissected into smaller nontumoral blocks of tissue containing the complete tooth root and adherent nonvitalized tissue. These individual biopsy specimens were dehydrated in ETOH, cleared by clearing the defect area along the apical axis into two pieces marked A and B, and embedded in paraffin. Sections 6 microns thick were cut from the middle of each bisected surface toward and beyond the mesial and distal extensions of the eponymous defect.

Tissue sections were stained with hematoxylin and eosin, Masson trichrome, periodic acid-Schiff, and phosphotungstic acid-hematoxylin and submitted for microscopic evaluation. Each biopsy specimen was coded by an assistant at the time of surgery, and the code was not revealed until all histologic interpretations of the sections were completed.

RESULTS

Each instrument was found to remove bone without difficulty. Equal time was required with the use of the chisel and the ultrasonic instrument. Clinically, healing of the surgical site proceeded uneventfully. Histologic observations were recorded for each postoperative period.

Immediately following surgery

The cut surface of bone produced with the chisel was irregular. The appearance of this surface suggested a slight separation along lamellar planes. The separation was more pronounced at the bone surface. The osteoclasts were more numerous at the edges of the bone margin. The osteon surfaces within the bone were smooth and regular. The osteons in the bone from each instrument were more homogeneous. The bone surface gave good attachment.
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Fig. 2. Representative histologic photomicrographs of alveolar bone of dog immediately following surgical procedures, characterizing the appearance of the cut edge of alveolar defects following the use of a surgical chisel (A), an ultrasonic instrument (B), and a low-speed rotary bur (C). (Hematoxylin and eosin stain. Magnification x280.)

separation was more prominent in areas adjacent to narrow spaces (Fig. 2, A). The ultrasonic tip produced a more irregular cut bone surface than the sharp-edged chisel. In addition, the separations along lamellar planes were more accentuated, providing obvious communication of the defect area with Haversian canals and immediate subjacent narrow spaces. No evidence of a burring effect to the bone could be seen (Fig. 2, B).

The conventional-speed bur produced a cut bony surface which appeared extremely smooth with no separation of the bone lamellae (Fig. 2, C).

All other parameters on the day of surgery were approximately equal.

Three days following surgery

Chiseled and ultrasonically produced defects were filled with a loose, fibrovascular type of granulation tissue with almost total replacement of the clot. Osteoclasts were more numerous in defects produced by the chisel, especially along bone margins and spicules where lamellae were devoid of osteocytes. Specimens from both methods also exhibited areas of cellular organization along osseous surfaces within the defect. Narrow spaces immediately subjacent to the surface of bone gave good evidence of osteoid formation (Fig. 3, A and B).
The 3-day-old defect was initially noted in the initial clot and an inflammatory reaction involving the fibrous vascular stroma was evident. Osteoclastic activity was observed (Fig. 3, C).

On the basis of the initial observation, the depth of the cut by the conventional method was determined to be adequate to a depth of 300 micrometers.

Seven days following surgery, the osteoclastic activity was markedly reduced.
The 3-day-old defect area produced by the bar was still primarily filled with the initial clot and an infiltration of polymorphonuclear leukocytes. A minimal fibrous connective tissue matrix was present where resolution of the clot was more advanced. Osteoclastic activity was minimal, and no osteoid formation was noted (Fig. 3, C).

On the basis of the presence or absence of stained osteocytes in lacunae from the surface of the defect, osteocytic death was more pronounced in bone cut by the conventional speed bur and the ultrasonic instrument than in that cut by the surgical chisel. This distance by measurement varied from no empty lacunae to a depth of 300 microns from the cut surface.

**Seven days following surgery**

The osteoclastic activity in chiseled and ultrasonically produced defect areas was markedly reduced. In addition to bone deposition adjacent to narrow
spaces, new bone formation was now obvious within the defect area. This new bone formed directly on cut surfaces of vital and nonvital bone as well as within the defect proper (Fig. 3, A and B). The formation of new bone in chisel specimens was generally more advanced, as evidenced by amount and maturity of organization.

The bone formation within the 7-day-old defect produced by the bur was delayed. Outside the defect, osteoid formation was noted within surrounding narrow spaces. The bone defect was now filled with fibrovascular granulation tissue. Some degree of cellular organization was observed along the cut bone walls (Fig. 4, C).

Fourteen days following surgery

The defects that were created by the surgical chisel and the ultrasonic instrument exhibited an increase in osteoblasts and bone formation (Fig. 5). In general, the amount and maturation of the bone in defects produced by the surgical chisel appeared more advanced.

Sections from areas produced by the rotary bur now manifested bone formation within the defect proper. However, a noticeable lag in the over-all formation of bone still appeared to exist in the bur-produced defect when compared to that produced by the ultrasonic instrument.

Later periods following surgery

All specimens evaluated at 28 and 56 days showed progressive amounts of bone formation. Difficulty ensued in identifying major differences among the three methods. Minimal from each section. By different methods could not be distin such modeling had occurred. The periodontal tissue examined. The inflammatory cell types in the tissues compons of polarized light micrographs. The minimum differences were found in the microscopic method. Except for areas of bone formation in maxillary bone, the bone defect has been presented by the bur.

DISCUSSION

The term ultrasonic refers only to the oscillation. The action of the bur is not dependent solely on the edge of the tip. Hard structures during instrumentation consists of a series of points which approximately 0.2 mm distant, which are close physical and mechanical relationships which are as extraneous to the two instruments. Osteosynthesis defects produce useful reference techniques are acceptable mechanisms in experimental work. Documentation exists with or without bone formation. The periosteal problems include no bone deposition of bone. His specimen was composed of bone which seemed to be extraneous to the periodontal process.
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other methods. Minimal attempts at remodeling were noticed in isolated areas of each section. By day 30, the original defects produced by the three instruments could not be distinguished from each other. Considerable amounts of bone remodeling had occurred.

The periodontium underlying each surgical site at each time period was also examined. The inflammatory infiltrate was minimal and unremarkable for each procedure. Also, no disruption of the orientation of fiber bundles was observed. The collagenous components of the periodontal membrane were examined by means of polarized light and were considered to be normal.

Minimal differences were observed between maxillary and mandibular specimens. The inflammatory and fibrovascular infiltrates of maxillary defects appeared more pronounced than in the mandible. In addition, the amount of bone formation in maxillary specimens appeared to be more advanced with each method. Except for anatomic differences, no distinction between maxillary and mandibular specimens was found.

DISCUSSION

The term ultrasonic as applied to contemporary dental prophylaxis units refers only to the oscillation of the vibratory tip and not to the power of operation. The action of the tip is neither radiant nor electrical, but mechanical. Clark has presented an excellent review of the historical development and mechanics of ultrasonic instruments. Bone removal is generally accomplished by a chip of some other instrument with multiple cutting edges. The standard ultrasonic P-3 insert is chip shaped, but the edge of the tip is purposely blunted to preclude inadvertent cutting of hard structures during dental prophylactic procedures. The action of this instrument consists of a series of repetitive blows in a slightly elliptical motion in which approximately 0.21 foot-pounds per second of power is expressed at the point of contact, which is along the major axis of the ellipse. With such a close physical and mechanical similarity between the ultrasonic instrument and the chisel, as well as extensive use of the chisel in clinical therapy, a direct comparison of the two instruments appeared feasible.

Ossous defects produced by rotary burs have been studied extensively and provide useful reference. Histologic evaluation of the rate of healing provides an accepted method for studying the effects of different cutting instruments in experimentally produced bone defects. Documentatoy exists to indicate that ultrasonic instruments are able to remove mineralized tissue. Few studies have investigated the cutting of bone with ultrasonic instruments. Mazuren investigated bone removal in dogs by means of a scalpel-like blade on an ultrasonic unit. In contrast to our study, he found no bone deposition on the cut surface 2 weeks following the surgical procedures. His specimen revealed a darkly stained bony dense zone on the cut bone surfaces which failed to absorb and lacked bone apposition as late as the fiftieth postoperative day. Bone repair occurred from the periodontal surface lateral to the margins of the defects, and not from endosteal locations as presented here.
There are substantial differences between Mazaro’s study and ours to explain the differences in healing of the defects. One of these differences is the type of instrument used. His ultrasonic instrument was a thin scalpel blade; ours was thicker and chisel shaped. Each may produce different effects upon the surface of bone. Another difference may be the anatomie location of the defects. In this study they were in the alveolar process and extended through the cortical plate into narrow spaces. In Mazaro’s study the defects were located inferiorly in the buccal aspect of the body of the mandible, where the cortical plate is thicker. Boyne et al. has reported that healing in alveolar regions is more dependent upon the tissue response in underlying vascular spaces, while subperiosteal bone repair is the more noticeable component in mandibular interalveolar surfaces.

Mazaro et al. suggested that the amount of basophilic staining within the cut surfaces of bone specimens may be indicative of the rate of healing. The basophilic zone in bone defects has been discussed by Spatz and by Costich and associates. Youngblood interpreted this zone to be the result of a heat effect. In our study, increased staining of defect margins was minimal. While such a zone may, indeed, be related to the effect on bone by heat generated during cutting procedures, it does not seem to be related to the character of the cut surface as further suggested by Mazaro et al.

McFall and colleagues compared healing effects in tibias of adult rats with an ultrasonic scalpel and a low-speed rotary bur. They noted a slightly enhancement of repair in bur-produced defects. Defects produced with the ultrasonic scalpel also healed within normal limits. Direct comparisons with our study cannot be made because of differences in the ultrasonic tip, location of the defect and histologic material, which was observed only at the forty-second postoperative day.

In our study we found the healing response following the use of the chisel and the ultrasonic tip to be similar. Major differences were observed between these two instruments and the conventional-speed bur. The use of the bur produced a wider margin of osteocytic death. Also, within the defect proper, the fibrovascular component persists longer with this instrument and there is a delay in osteoclast and osteoblastic responses. Our histologic observations using the low-speed bur with water coolant are in agreement with other studies under comparable conditions. These reports indicated that new bone formation within defects was not seen 1 week postoperatively. Osteoclastic activity, however, must have been initiated immediately thereafter, for its presence was consistently observed in 2-week specimens. Rapid bone fill then ensued, and 8-week defects generally were seen to be filled with new bone.

The histologic changes of osteons repair observed in this study are in agreement with other reports evaluating the use of surgical instruments as well as healing in extraction sockets. Initial defects are filled with a blood clot which is subsequently infiltrated with granulomatous tissue. Organization of the clot occurs with loose, fibrovascular granulation tissue. New bone formation is initially found in narrow spaces adjacent to, but outside, the defect as early as 3 to 4 days postoperatively. Also, at this time, osteoclasts are present along disrupted bony margins with organization and within the defect there formation of osteoblasts a bone and lateral osteons as well as new bone in fashion, the lateral osseous surface, that is.

SUMMARY

A mechanical instrument investigated as a mean, where operative bone repair using a standard surgical chisel was used with water cooling by 2 mm. defects in dog specimens obtained from procedures at 3, 7, 14, and 28 days. The surface of bone was rougher than that seen in areas outside of the osteoid instrument. New bone formation produced by rate of healing in def ect postoperative day. This effect on all defects.

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REFERENCES

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A mechanical instrument vibrating in the ultrasonic frequency range was investigated as a means of surgically removing osseous tissue. The rate of postoperative bone repair was used to compare the effect of this instrument with a standard surgical chisel and a conventional-speed rotary burr. Each instrument was used with water coolant, as in an actual clinical procedure, to create 3 by 3 mm defects in dog alveolar bone. Healing was assessed histologically from specimens obtained from dogs killed immediately following the surgical procedure and at 3, 7, 14, 28, 56, and 90 days, respectively.

The surface of bone removed by the ultrasonic instrument and the chisel was rougher than that produced by the burr. The earliest bone formation was seen in areas outside defects which were produced by the chisel and the ultrasonic instrument. Bone repair within defects was also observed initially in preparations produced by these same two instruments. Definite differences in the rate of healing in defects produced by the burr were noted up to the fourteenth postoperative day. The subsequent rate of healing in later periods was similar in all defects.

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