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HIGH-SPEED OR CONVENTIONAL DENTAL EQUIPMENT FOR THE REMOVAL OF BONE IN ORAL SURGERY

III. A HISTOLOGIC AND MICRORADIOGRAPHIC STUDY ON BONE REPAIR IN THE RABBIT

by

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INTRODUCTION

Several experimental studies have been carried out in order to evaluate the clinical healing and the postoperative reactions (*Kilpatrick*, 1958; *Thompson*, 1958; *Hall*, 1959; *Szmyd et al.*, 1960; *Hoffman*, 1965) and the histologic response of bone (*Mazorov*, 1960; *Moss*, 1964; *Calderwood et al.*, 1964; *Costich et al.*, 1964; *Boyne*, 1966) in connection with high-speed instrumentation in oral surgery.

Ågren (1963, 1964) has previously studied bone repair and other reactions in relation to the velocity of dental engines. The object of the first investigation was to test whether high-speed burs were more suitable for bone surgery in man than slow-speed instruments. This study was performed by recording the magnitude and duration of measurable local and systemic reactions. No differences could be demonstrated between the two methods in this respect. However, the gain in time and the lighter pressure required with the high-speed instrument were considered factors of value in surgical work.

Changes in circulation as a result of trauma can interfere with the healing of bone. The second investigation was thus performed in order to study disturbances in the regional circulation around experimental defects in the tibia of white rabbits. Disappearance measurement of Na^{22} in bone defects produced with round surgical carbide burs No. 8 at slow speed (about

8,000 r.p.m.) and at high speed (about 48,000 r.p.m.), respectively, showed no difference between the methods during the 3 to 9 days' observation-period. The operation produced, however, a considerable disturbance of the regional circulation, which lasted during the entire observation period.

Recent histologic investigations (*Calderwood et al.*, 1964; *Costich et al.*, 1964; *Boyne*, 1966) have mainly been in consistency concerning the final results of bone repair. The interpretation of the initial osseous reactions, however, have been less uniform.

The present study was carried out in order (1) to perform a histologic and microradiographic evaluation on the healing of experimentally produced cavities, and (2) to elucidate the role of the periosteum and the endosteum during the period of bone repair.

MATERIAL AND METHODS

Nine healthy, adult white rabbits, male and female were used for the experiments. The animals weighed between 2,500 and 4,240 g. Anesthesia and surgery were performed according to a previously described method (*Ågren*, 1964). The defect was produced in one hind leg by means of a high-speed dental machine with a turbine powered handpiece having a loaded speed of about 48,000 r.p.m.,[1]) and in the other hind leg by means of a conventional dental machine with a loaded speed of about 8,000 r.p.m.[2]) The defects were produced with No. 8 round carbide burs, a new one for each animal. One centimetre below the tuberosity of the tibia in one hind leg a one centimetre long cavity was drilled at the anterior border of the bone, until the marrow was faintly visible at the bottom of the cavity. Clinical healing was uncomplicated in all rabbits. The animals were sacrificed after 0 to 40 days (see Table I).

The treated area was dissected and the cavity localized by macroscopic measurements and X-rays. The bone with the defect and adjacent tissue was divided in two equal parts. The upper part facing the tuberosity of the tibia was used for histologic examination. The specimens were fixed in 10 per cent neutral formalin, demineralized in 7,5 per cent nitric acid, embedded in paraffin wax, the sectioned surface oriented horizontally. Sectioning was made horizontally in 6 μm serial sections. They were stained with hematoxylin and eosin, Azan's stain, Hansen's trioxyhematein, and Gomori's stain for reticulin.

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[1]) Atlas Copco Dental Air Rotor, Atlas Copco, Stockholm, Sweden.
[2]) Svedia Technomotor No. 8186, Stockholm, Sweden.

The lower part of the cavity was in a similar way embedded in methylmethacrylate and sectioned at five different levels for microradiography. The sections were ground to a thickness of about 75 μm and polished. A Philips diffraction unit, PW 1009 with copper anode and nickel filter, was used and operated at 20 kV and 10 mA. Kodak MR photographic plates were used.

RESULTS

The microradiographs which revealed the rate of bone formation in the injured tissue were compared with the histologic sections in order to establish the relationship between the state of the soft tissue and the formation of new bone. The observations are listed in Table I.

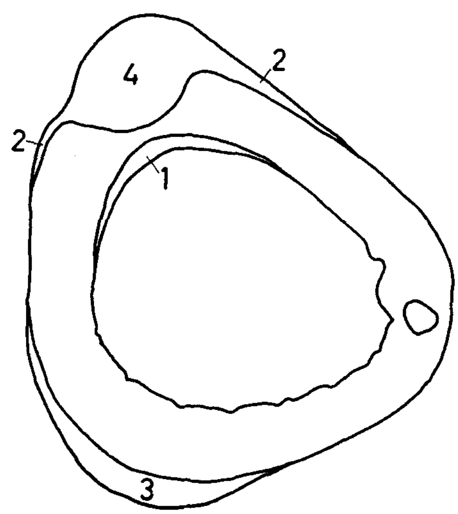

Fig. 1. Sketch of a rabbit tibia indicating the sites of new bone formation. The numbers refer to the symbols (1), (2), (3), (4) in Table I.

From Table I it appears that the inflammatory response to the injury was vigorous in the first period, it diminished gradually and vanished almost after about 30 days. Initially a hemorrhagic debris, containing polymorphonuclear leucocytes filled the defect. The polymorphonuclear cells contained an eosinophilic cytoplasm. They should, however, not be confused with eosinophiles and the reaction judged to be an eosinophilic one. In spite of

Table I

Soft tissue reactions and bone repair in the rabbit tibia

Microradiographs	Observation period, days	Histologic sections
Smooth surface of the cavity.	0	Cavity almost empty. Walls partly lined with accumulations of erythrocytes, leucocytes (eosinophilic), and bone splinters.
No visible reactions.	3	*Soft tissue:* Hemorrhages, leucocytes (eosinophilic), degeneration of muscle fibres. Focal round cell infiltration in the muscles, necrotic tissue remnants. *Bone:* (1) Endosteal reactive osteoid formation (Fig. 2 B). Osteocytes pycnotic but still present in most lacunae (Fig. 2 A). Congested capillaries in the bone marrow. Local interstitial fibrin clots. (Fig. 2 C).
Endosteal bone spiculae. No resorption. (Fig. 3 A and B).	5	*Soft tissue:* Inflammatory reactions outside the cavity. Some muscle fibres necrotic (Fig. 4 A). *Bone:* Osteocytes pycnotic but still present in most part of the lacunae (Fig. 4 B). (1) Endosteal spiculae under formation. (2) Hyalinization of the connective tissue outside the cavity at the sides of the tibia 1—3 mm from the cavity edge.
The endosteal bone formation more pronounced than at five days.	7	*Soft tissue:* Inflammatory reaction, degeneration of muscle fibres. Inflammatory exsudate between periost and bone. *Bone:* Still pycnotic osteocytes in some lacunae. (1) Endosteal bone formation. (2) Distant periosteal reaction at the sites of muscular attachment (Figs. 5 A, B). (3) Osteoid tissue apposition diagonally to the cavity at the outher surface of the tibia.

Microradiographs	Observation period, days	Histologic sections
Bone formation in progress (1) endosteal beneath the cavity, (2) outside the tibia at some distance from the margin of the cavity, (3) diagonally to the cavity, (4) at the margin of the cavity with extensions into the defect.	10	*Soft tissue:* Inflammatory reaction still pronounced *Bone:* Bone formation as described in the microradiographs. (Figs. 6 A and B).
Pronounced bone formation at sites (1), (2), (3) and (4). The cavity almost filled with coarse trabecular bone (Figs. 7 A and B).	15	No sections.
Bone formation at sites (1), (2), (3) and (4). Filling the cavity and, at *48,000 r.p.m.* exophytic bone formation at sites (2) forming an exostosis. (Fig. 8 A).	20	*Soft tissue:* The inflammatory cells well demarcated and *accumulated at some distance from the cavity* (Fig. 8 B). The cavity filled with partly mineralized osteoid tissue (Figs. 8 B and C). *Bone:* Continued bone formation at sites (1), (2) and (3). Connective tissue transformed to bone with trabeculae extending from the fundus and the walls of the defect (4). (Fig. 8 B).
Situation about the same as after 20 days.	30	*Soft tissue:* Inflammatory reaction subsided. *Bone:* In the cavity, bone trabeculae growing coarser and the enclosed connective tissue transformed to loose fibrillar bone marrow (Fig. 9).
The defect refilled with an almost normal bone tissue. Degree of mineralization of new bone lower than of old one. Bone at sites (2) and (3) consolidated, forming a reinforcement of the weakened tibia. (Figs. 10 A, B and C).	40	*Soft tissue:* As above. *Bone:* Cavity filled with new bone with coarse trabeculae and big marrow spaces. Outer surface smooth and encapsulated with a connective tissue sheath. Endosteal surface rough with spiculae extending into the marrow space (Fig. 11).

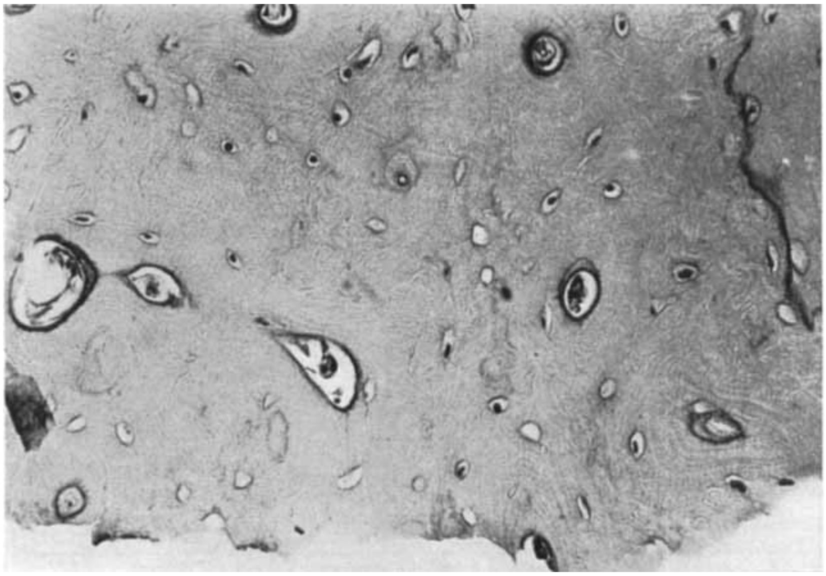

Fig. 2 A. Mild bone reaction beneath the cavity. Some osteocyte lacunae empty, a few osteocytes pycnotic. 3 days, 48,000 r.p.m. The picture is representative also for 8,000 r.p.m. × 320. B. Endosteal reactive osteoid formation with fringe-like osteoblasts (upper arrow). In the bone marrow a megakaryocyte (lower arrow). 3 days, 48,000r.p.m. × 500. C. Fibrin clot and congested capillaries in the bone marrow indicating a slight damage. 3 days, 48,000 r.p.m. × 500. D. Necrotizing muscle bundles at the edge of the soft tissue injury. 3 days, 48,000 r.p.m. × 500.

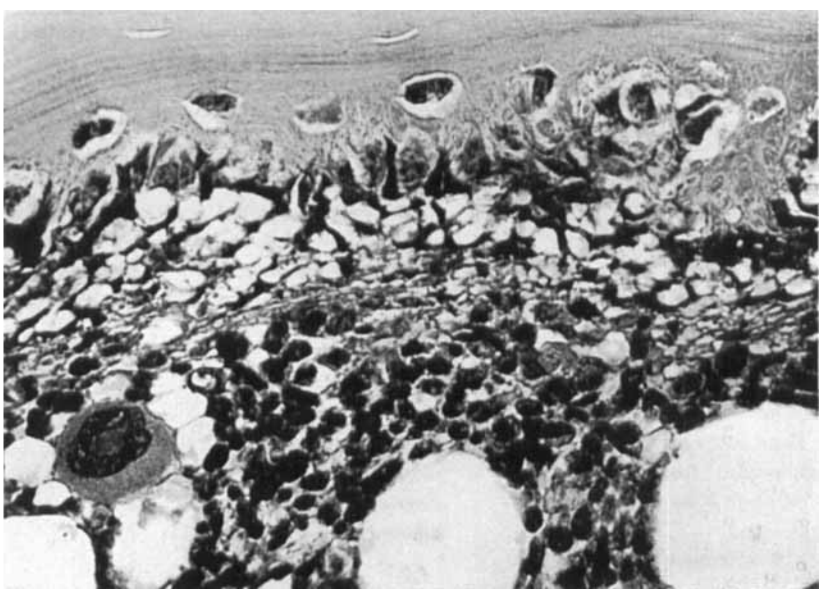

Fig. 2 B.

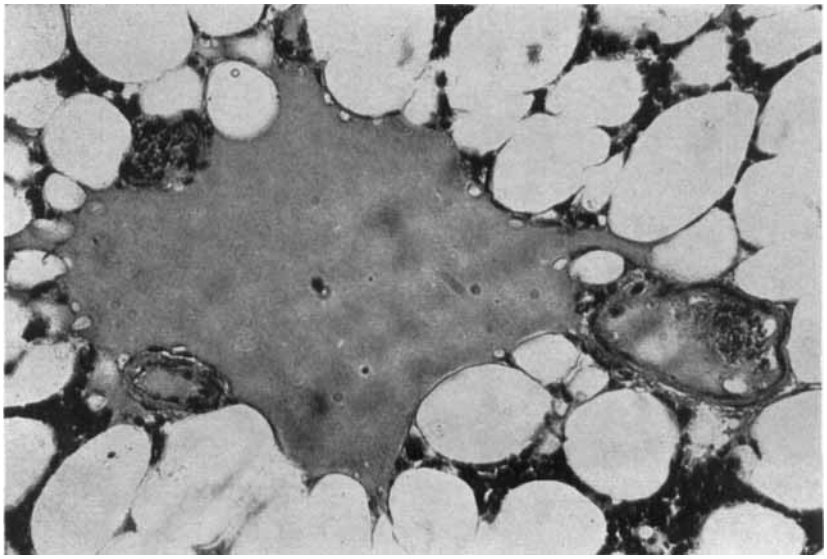

Fig. 2 C.

Fig. 2 D.

the strong initial reaction and the considerable disturbance of the regional circulation stated in the disappearance study a formation of reinforcing bone tissue in the weakened tibia started almost immediately.

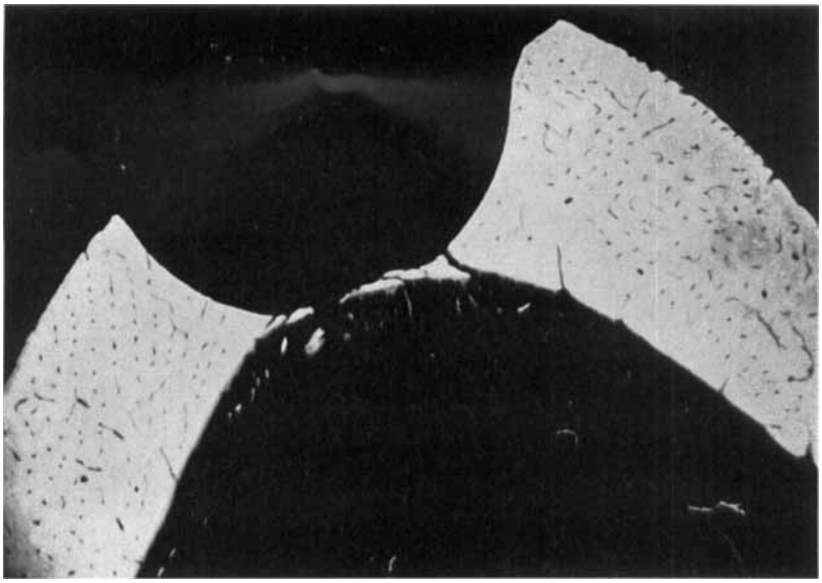

Fig. 3 A. Endosteal tiny bone spicules beneath the cavity. 5 days, 8,000 r.p.m., microradiograph. × 25. B. The same as Fig. 3 A with 48,000 r.p.m. No apparent difference in bone reaction between the two speeds. Microradiograph × 25.

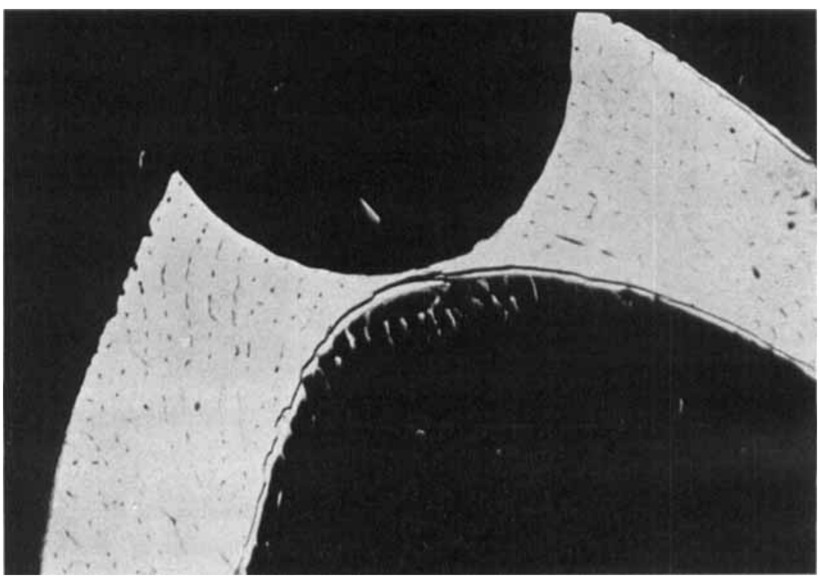

Fig. 3 B.

After *three days* the osteoblasts were arranged in a fringe-like array at the endosteal surface beneath the cavity (Fig. 2 B). Other places for reinforcing bone formation were determined by the attachments of the muscle fibres (Figs. 1, 5 and 7).

Bone spicules were found in the defect after the *10th day*. The trabeculae extended from the fundus, margins, and walls of the cavity.

After *15 days* the tibial defect was filled with coarse trabecular bone (Figs. 7 A and B).

At *20 days* an exostosis was observed in one rabbit (Fig. 8 A).

After *30 days* the inflammatory reaction had subsided, and the cavity was to some excess filled with new bone.

At *40 days* the defect was evenly filled with new bone and the tibia remodelled (Figs. 10 A, B and C, 11).

The time for full mineralization which is beyond 40 days could not be established in these experiments.

The observations did not indicate any difference in the mode of tissue reaction between the two experimental series.

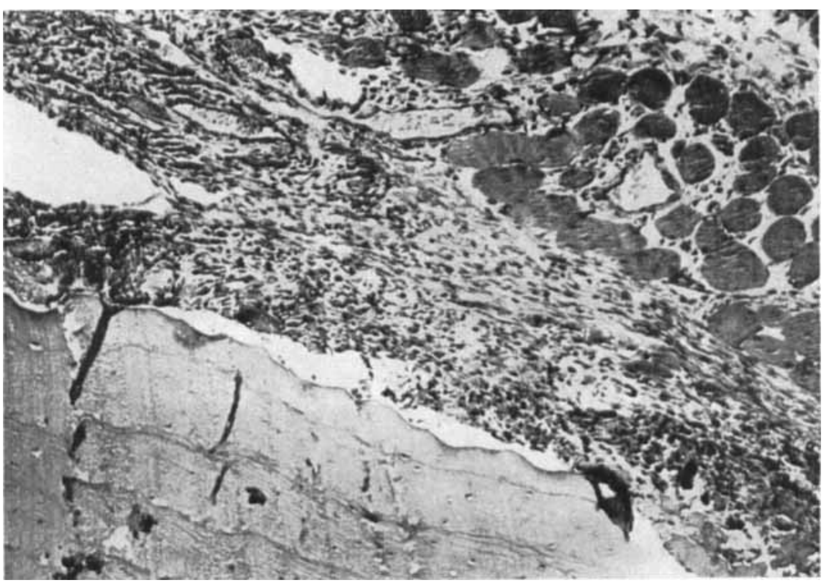

Fig. 4 A. Inflammatory reaction outside the cavity. Some muscle fibres necrotic. 5 days, 48,000 r.p.m. × 125. B. Osteocytes partly pycnotic but rather few lacunae empty. 5 days, 48,000 r.p.m. × 125.

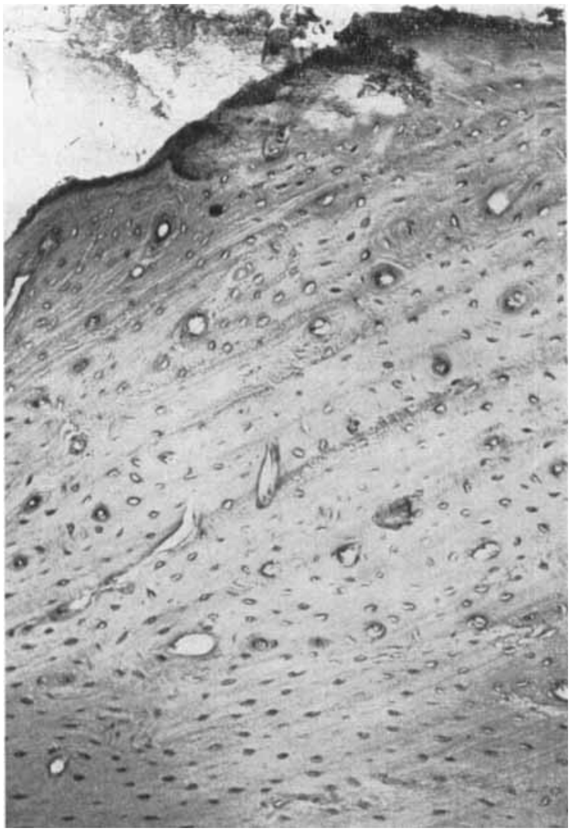

Fig. 4 B.

DISCUSSION

The knowledge of wound healing and bone repair is to a great extent founded on observations on laboratory animals. It is a complicated problem, however, to relate the results of such experiments to the healing of surgical defects in human oral cavity. As the presence of saliva, microflora, and food debris might interfere with the results, the tibia of the rabbit was selected in accordance with previous work (*Ågren*, 1964). This permitted a standardization of the trauma and concomitantly a control of the use of the bur in a manner similar to that in oral surgery.

A comparison between findings in *Calderwood's* (1964), *Costich's* (1964), and *Boyne's* (1966) investigations and the observations in the present study indicated that no substantial differences existed between the healing and

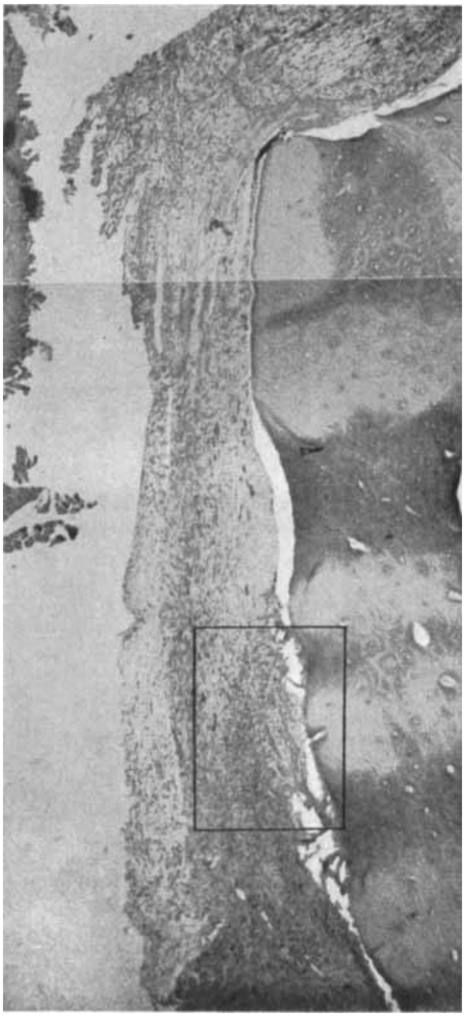

Fig. 5 A.

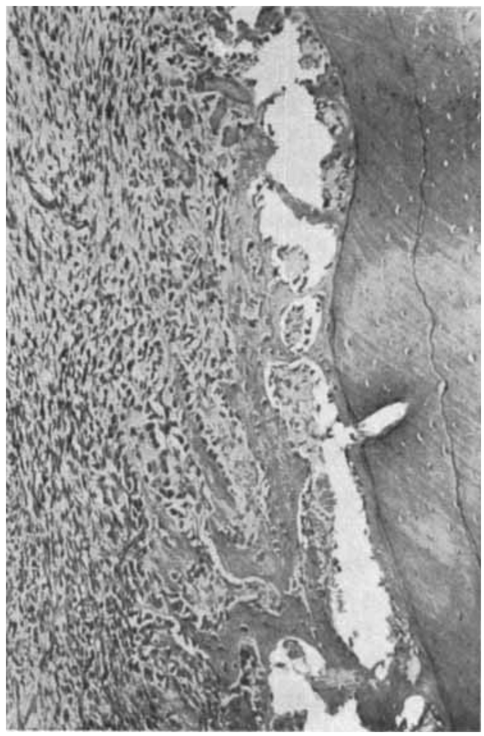

Fig. 5 B.

Fig. 5 A. Reactive bone formation at the sides of the tibia outside the cavity. 7 days, 48,000 r.p.m. × 32. B. Magnification of Fig. 5A showing the formation of new bone. 7 days, 48,000 r.p.m. × 125.

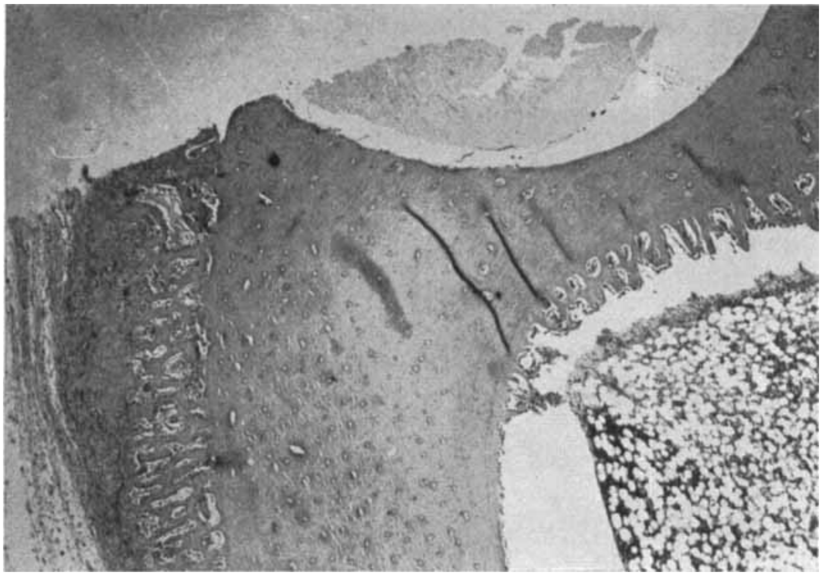

Fig. 6 A. Bone formation endosteal (1), and periosteal (2) outside the cavity margin. 10 days, 8.000 r.p.m. × 32. B. Magnification of Fig. 6 A, showing the endosteal bone spicules. 10 days, 8,000 r.p.m. × 125.

bone repair in defects produced with different speed of rotation in the mandible of the dog and in the tibia of the rabbit, provided the burs were sharp and sufficiently water cooled. Differences in anatomic characteristics of the surgical test site might exist but biologically the healing proceeded in about the same manner.

In the rabbit, a direct apposition of bone tissue without previous resorption appeared to take place. No osteoclastic activity was observed at any stage of the healing process. This indicates that the damage of the hard tissues was negligible. It follows that resorption is predicated by bone necrosis produced by rough handling.

The number of empty osteocyte lacunae adjacent to the cavity was in fact very small. Consequently, there was no resorption and the apposition could start immediately.

The regeneration of bone started from the endosteum (Figs. 2 B, 3 A and B). The transformation of the granulation tissue in the cavity to trabecular bone was slower. An exostosis observed in one rabbit was regarded

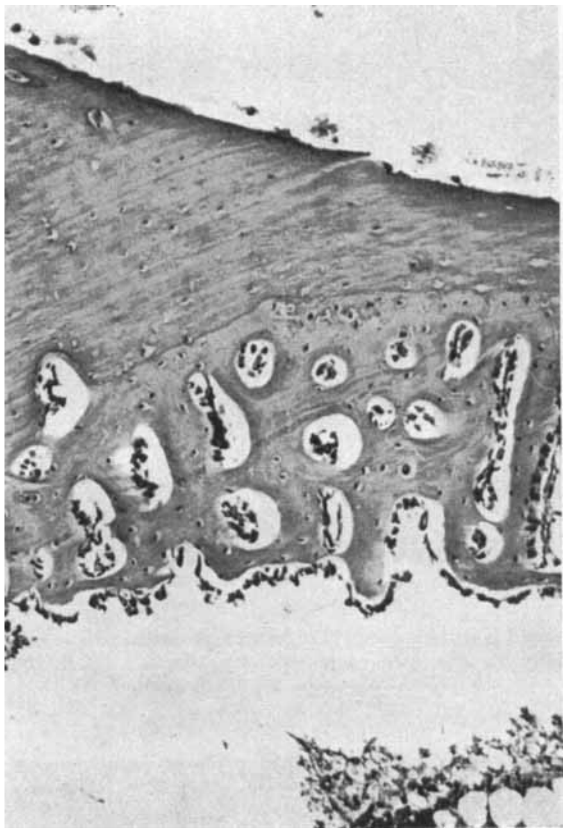

Fig. 6 B.

to represent a functional outgrowth corresponding to the cnemial crest where the terminal tendon of the main extensor muscle of the thigh is attached (*Romer*, 1962).

A certain similarity seems to exist between the healing of fractures, post-extraction sockets, and defects in the cortical bone. *Böhler* (1932), *Hertz* (1936), as well as more recent investigators (*Boyne & Kruger*, 1962; *Boyne*, 1963, 1966) have established that not only the periosteal, but also the endosteal cells in the bone marrow and the Haversian canals are bone forming, and thus play a part in the regeneration of bone in fractures and post-extraction sockets. According to *Hertz* (1936), bone regeneration occurred chiefly from the periosteum. The endosteum and the marrow also took part in the callus formation, though to a lesser extent. In the early stages of fracture

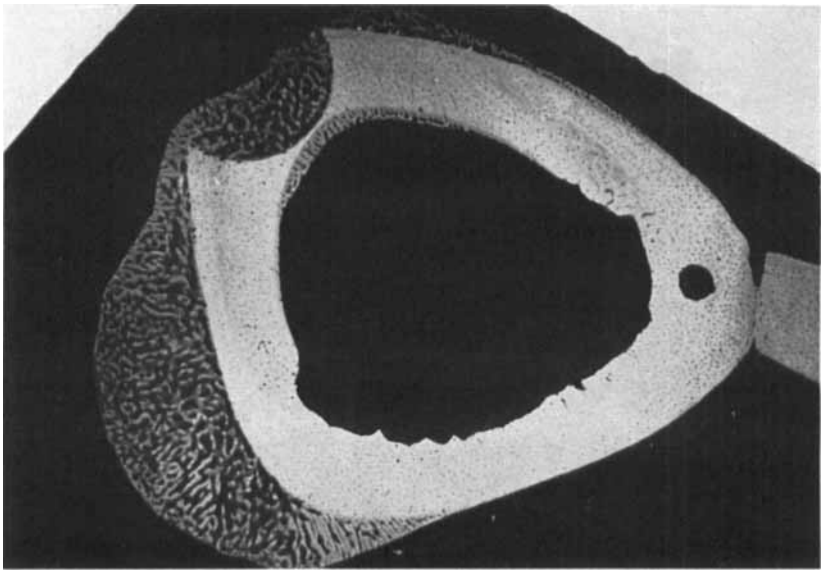

Fig. 7 A. Pronounced bone formation (1) endosteal, (2) distant periosteal, and (3) periosteal diagonal to the cavity. 15 days, 8,000 r.p.m., microradiograph. × 10. B. The same as Fig. 7A. 15 days, 48.000 r.p.m. microradiograph × 10.

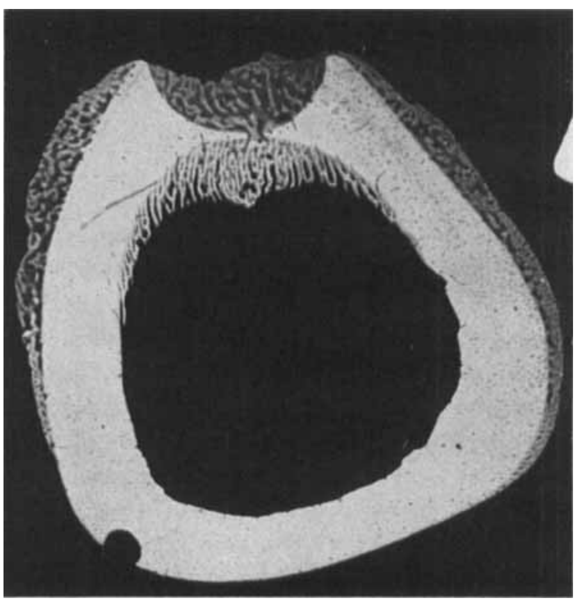

Fig. 7 B.

Fig. 8 A. Exostotic bone formation from the cavity. 20 days, 48,000 r.p.m., microradiograph. × 20. B. The cavity well filled with new bone. Inflammatory focus outside the cavity in the soft tissue. 20 days, 48,000 r.p.m. × 32. C. Endosteal reactive bone has formed beneath the cavity as a reinforcement. 20 days, 48,000 r.p.m. × 32.

healing in the fibula in guinea pigs, up to the 10th day, the process of regeneration was less pronounced near the fracture line than at some distance from the fracture. *Hertz* (1936) called this phenomenon »distant periosteal reaction» and regarded it as »attributable to static conditions». In the present study this phenomenon was also observed at the sites for the attachments of the muscle fibres. This is considered as a physiological reinforcement in order to restrain the movement stress depending on a biomechanical effect.

Fig. 8 B.

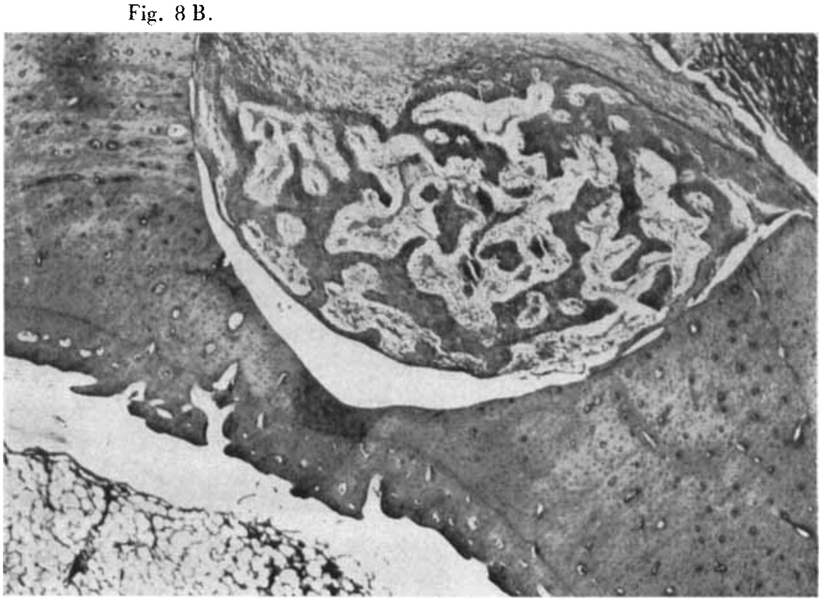

Fig. 8 C.

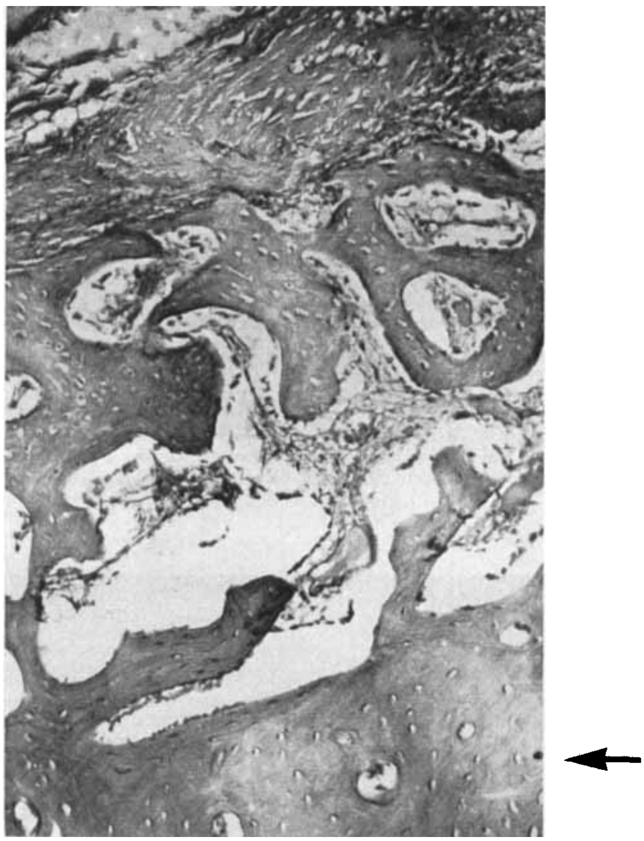

Fig. 9. Bone spicules growing from the fundus of the cavity (arrow). 30 days, 8,000 r.p.m. × 125.

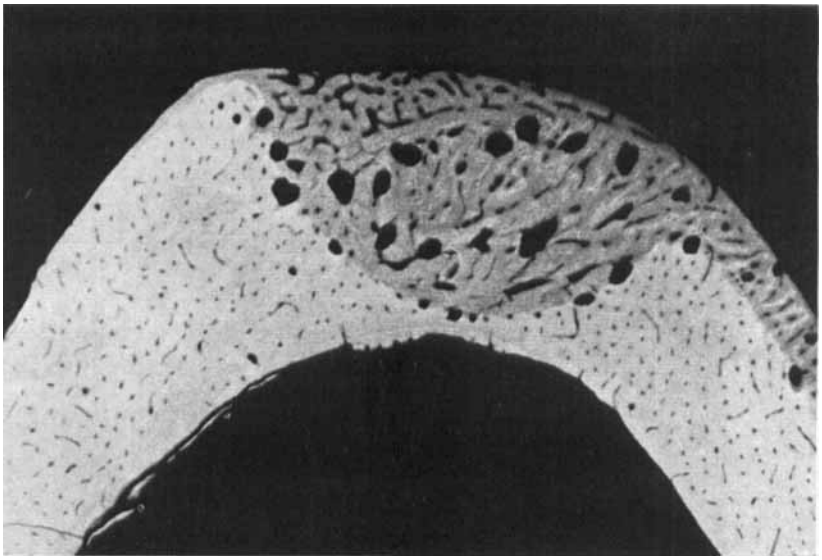

Fig. 10 A.

Fig. 10 A. The defect filled with new bone. Endosteal bony reinforcement. 40 days, 8,000 r.p.m., microradiograph. × 20. B. The same as Fig. 10A. 40 days, 48,000 r.p.m. No difference can be noticed between the two speeds in the appearance of the bone. Microradiograph × 20. C. Distant periosteal reinforcement outside the cavity. 40 days, 48,000 r.p.m. Microradiograph. × 20.

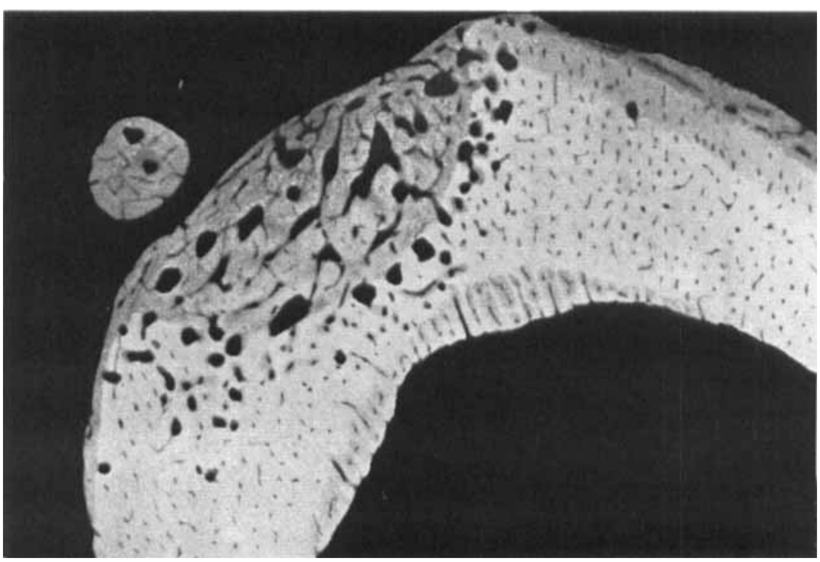

Fig. 10 B.

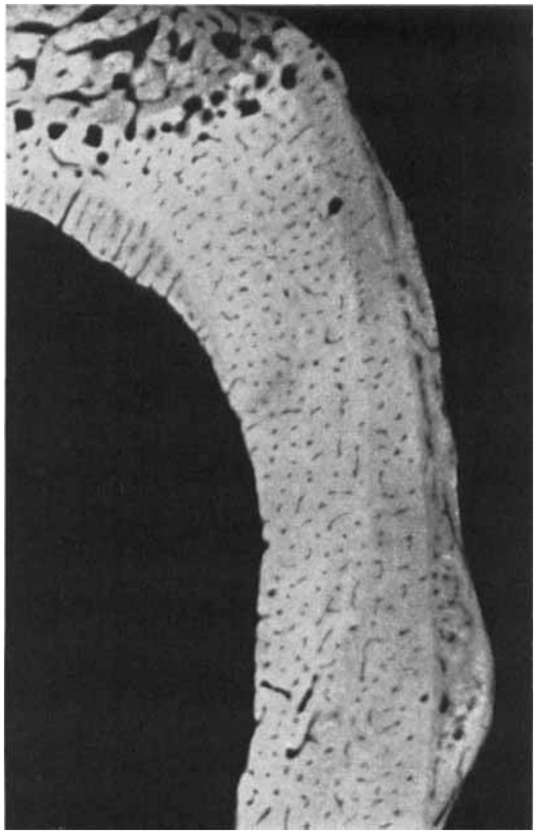

Fig. 10 C.

The value of early and frequent observations in investigations involving the dynamics of biological tissues was clearly demonstrated by this study. It is necessary to distinguish between physio-pathological (wound-healing) and biomechanical (muscle activity) effects on the bone tissues.

ACKNOWLEDGEMENTS

Our thanks are due to Professor A. Ingelman-Sundberg, Department of Obstetrics and Gynecology at Sabbatsbergs Hospital, Stockholm, Associate Professor E. Odeblad, Head of the Isotope Laboratory at the department and Miss Gerd Sjösteen.

Our thanks are also due to Professor G. Bergman, Department of Oral Histopathology, Karolinska Institutet, School of Dentistry, Stockholm, for putting the facilities of his department to our disposal, to Assistant Professor P. O. Lind and Mrs. B. Kihlman for technical assistance with the microradiographs.

Financial support for this study from Svenska Tandläkare-Sällskapet (the Swedish Dental Society), Stockholm is gratefully acknowledged.

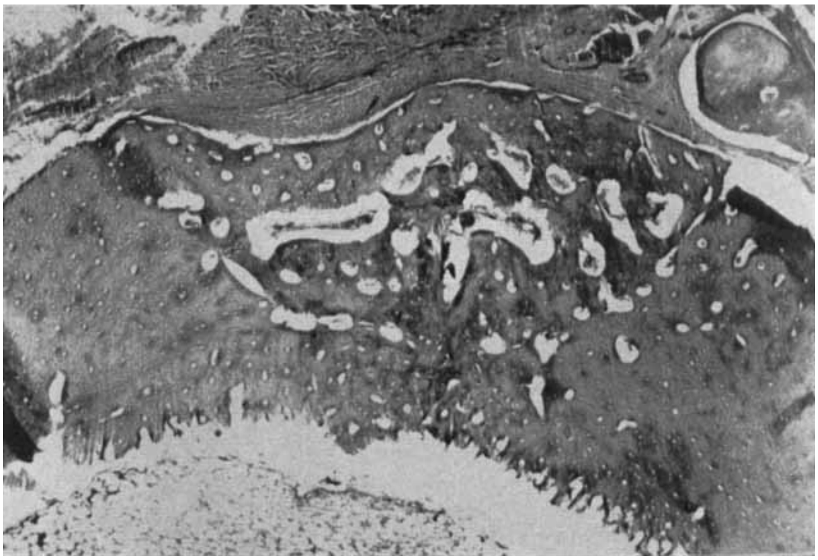

Fig. 11. The cavity refilled and the bone remodelled. 40 days, 48,000 r.p.m. × 32.

SUMMARY

Experimental cavities were produced in the tibia of nine adult healthy rabbits by using a 48,000 r.p.m. and a 8,000 r.p.m. dental engine, respectively. The tissue reactions were studied by microradiography and light microscopy at 0—3—5—7—10—15—20—30—40 days.

An inflammatory reaction was found in the soft tissues surrounding the injury. The bone marrow contained congested capillaries and intercellular fibrin clots. The bone defect was filled with hemorrhage, bone splinters and debris. The clot was transformed to granulation tissue, collagenous organization took place, and bone formation started.

In the bone a reaction was observed already after *three days*, when the endosteal osteoblasts beneath the cavity formed a fringe, which after five days appeared as osteoid spicules. They were subsequently mineralized.

After *5 days* bone formation appeared at the sides of the tibia at the level of the muscle attachments and at *7 days* diagonally to the defect at the outside of the tibia.

At the *10th day* the first signs of bone healing of the defect was apparent. The bone trabecules started from the margin of the cavity with extensions

into the defect. At the *15th day* the cavity was almost completely filled with coarse trabecular bone, the outgrowths coming from the walls and the fundus of the cavity.

After *40 days* the cavity was filled with new bone and the tibia remodelled.

It was thus demonstrated that the initial reaction of the injured bone consisted of a physiologic reinforcement of the weakened tibia in order to restrain movement stress. The bone healing rate was lower. These two phenomena might interfere and create a complicated situation in interpreting the healing reactions.

There was no essential difference between the two speeds of rotation, which was in accordance with the results from human and animal experiments in the two previous studies. In both cases, if the operative procedures were mild, no resorption of the bone took place, but the apposition started immediately. This stresses the importance of using a surgical technique adapted not to produce unnecessary damage with subsequent necrosis.

The value of early and frequent observations in histologic investigations involving the dynamics of biological tissues and the necessity to remove block sections of surrounding bone, was clearly advocated by this study.

RÉSUMÉ

ABLATION DE TISSU OSSEUX AVEC LE TOUR DENTAIRE CONVENTIONNEL OU AVEC LE TOUR DENTAIRE A GRANDE VITESSE EN CHIRURGIE MAXILLAIRE. III. ÉTUDE HISTOLOGIQUE ET MICRORADIOGRAPHIQUE SUR LA RÉGÉNÉRATION OSSEUSE CHEZ LE LAPIN

Au cours d'expériences faites sur neuf lapins adultes en bonne santé, des cavités ont été produites dans le tibia au moyen d'un tour électrique dentaire tournant à 8000 t/min et d'un tour dentaire tournant à 48.000 t/min. Les réactions des tissus ont été suivies par microradiographie et par microscopie optique au bout de 0—3—5—7—10—15—20—30— et 40 jours.

On a trouvé dans les tissus mous environnant la lésion une réaction inflammatoire. La moelle osseuse contenait des capillaires engorgés et des caillots intercellulaires de fibrine. La plaie osseuse était comblée par l'hémorragie, par des fragments osseux et des débris. Le caillot se transformait en tissu de granulation, une organisation collagène prenait place et la formation osseuse débutait.

Dans l'os, on observait déjà une réaction *au bout de trois jours*, les ostéoblastes endo-osseux situés au-dessous de la cavité formant alors une frange qui, *au bout de cinq jours*, se présentait comme des aiguilles ostéoides. La minéralisation se produisait ensuite.

Au bout de cinq jours, la formation osseuse commencait sur les parois du tibia, au niveau des insertions musculaires, et, *au bout de sept jours* en diagonale par rapport à la plaie à la partie externe du tibia.

Au dixième jour, les premiers signes de cicatrisation de la plaie osseuse apparaissaient. Les travées osseuses, partant des bords de la cavité, se développaient vers l'intérieur de la plaie. *Au quinzième jour* la cavité était presque entièrement remplie par un tissu osseux grossièrement trabéculaire se développant à partir des parois et du fond de la cavité. *Au bout de quarante jours* la cavité était comblée de tissu osseux régénéré, et le tibia avait retrouvé sa forme.

Il a ainsi été mis en évidence que la réaction initiale de l'os après la lésion a consisté en un renforcement physiologique du tibia affaibli, dans le but de limiter les contraintes dues au mouvement. La vitesse de cicatrisation osseuse était moins grande. Ces deux phénomènes peuvent, par leur combinaison, compliquer l'interprétation de la réaction de cicatrisation.

Il n'y avait pas de différence essentielle entre les effets des deux vitesses de rotation, ce qui confirme les résultats d'expériences sur l'homme et sur l'animal faites au cours des deux études précédentes.

La présente étude a nettement montré l'importance qu'il y a à ce que les observations faites pendant les études histologiques concernant la dynamique des tissus biologiques soient commencées à un moment précoce et exécutées à maintes reprises, et montré la nécessité de faire des prélèvements en bloc du tissu osseux avoisinant.

ZUSAMMENFASSUNG

TURBINENMOTOREN ODER MASCHINEN VON KONVENTIONELLER GESCHWINDIGKEIT ZUR KNOCHENABTRAGUNG IN DER KIEFERCHIRURGIE. III. EINE HISTOLOGISCHE UND MIKRORADIOGRAPHISCHE UNTERSUCHUNG ÜBER DIE BILDUNG VON OSSÖSEN REPARATIONSGEWEBEN BEI KANINCHEN

An der Tibia von 9 erwachsenen Kaninchen wurden Eingriffe mit Bohrmaschinen von 48.000 U/m und 8.000 U/m vorgenommen. Die Tiere waren ihre eigenen Kontrollen. Nach 0—3—5—7—10—15—20—30—40 Tagen wurde die Reaktion des verletzten Gewebes mit Hilfe von Mikroradiographie und Lichtmikroscopie untersucht.

In dem die Wunde umgebenden Weichgewebe entstand eine entzündiche Reaktion. Das Knochenmark enthielt eine Ansammlung vom Kapillaren und intercelluläre Fibrinklumpen. Der Knochendefekt war mit Blut, Knochensplittern und Debris gefüllt. Das Koagel wurde in Granulationsgewebe

überführt, es entwickelte sich eine Kollagene Organisation und die Knochenneubildung begann.

Im Knochen konnte bereits nach drei Tagen eine Reaktion beobachtet werden. Die endostalen Osteoblasten in der Nähe der Kavität bildeten einen Saum der nach fünf Tagen zu osteoider Spiculabildung führte. Diese wurde später mineralisiert.

Nach fünf Tagen zeigte sich an den Seiten der Tibia am Platze der Muskelansätze eine Knochenneubildung, die am siebten Tage auch diagonal vom Defekt an der Aussenseite der Tibia auftrat.

Am zehnten Tage traten die ersten Zeichen einer Knochenheilung des Defektes auf. Vom Kavitätenrand aus entwickelten sich Knochentrabekel in Richtung der Defektmitte.

Am fünfzehnten Tage war die Kavität nahezu vollständig mit grobgeflechtigem trabeculärem Knochen gefüllt, der sich vom Rande und Boden der Kavität aus entwickelt hatte. Nach 40 Tagen war die Kavität mit neuem Knochen gefüllt und die Form der Tibia wiederhergestellt.

Es konnte also gezeigt werden, dass die erste Reaktion des verletzten Knochens in einer physiologischen Verstärkung der geschwächten Tibia besteht mit dem Ziele die Bewegungsbelastung zu verringern. Die Knochenheilung dagegen geht langsamer vor sich. Diese beiden Phänomene können interferieren und die Interpretation der Heilungsreaktion erschweren.

Die obengenannten Beobachtungen zeigen dass kein essentieller Unterschied zwischen den beiden Umdrehungsgeschwindigkeiten besteht. Diese Beobachtung steht in Übereinstimmung mit den Resultaten der beiden früheren Tier- und Homoversuchen.

Der Wert einer frühzeitigen und laufenden Beobachtung bei histologischen Untersuchungen der Dynamik von biologischen Geweben und die Notwendigkeit der Blockresektion der umgebenden Gewebe wird durch diese Untersuchung unterstrichen.

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