From: The Department of Oral Surgery,
(Head: Professor *John Hertz*, M. D.)
The Royal School of Dentistry,
Stockholm, Sweden.

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

II. DISAPPEARANCE MEASUREMENTS OF A DEPOSIT OF Na^{22} INJECTED IN EXPERIMENTAL BONE CAVITIES IN THE RABBIT TIBIA FOR CONTROLLING THE REGIONAL CIRCULATION AFTER THE REMOVAL OF BONE WITH DENTAL ENGINES OPERATING AT DIFFERENT SPEEDS

by

ERIK ÅGREN

It is important in oral surgery, which usually involves making a wound in mucosa, submucosa, periosteum and bone tissue, that the destruction and removal of bone is performed effectively and with care so as to disturb as little as possible the circulation in the injured area. Since, on practical grounds, high speed rotating instruments are being increasingly used in this branch of surgery, it may be of interest to study the effect on the regional circulation of different speeds of rotation under otherwise identical conditions.

In a previous study, comprising the recording of postoperative reactions after the removal of bilateral impacted wisdom teeth in man, the author attempted to form an idea as to whether a high speed drill is more lenient in bone surgery than a conventional drill. The response of the patients to the two methods was practically identical, as indicated by the criteria studied (*Ågren*, 1963).

On the basis of a hypothesis concerning the dynamics of the blood-tissue exchange of diffusible, inert substances *Kety* (1948, 1949), and after him several other investigators, showed that if a radioactive substance is injected into a tissue, its disappearance is dependent on the local circulation. Different tracers have been used, viz. Na^{22}, Na^{24}, J^{131}, Br^{85}, etc. By measuring the disappearance of the tracer with, for example, a scintillation counter under constant geometry, one can obtain an idea of the ability of the tissue to remove or supply diffusible substances and of the adaptations or disturbances which help or hinder the diffusion process. These are called disappearance or clearance measurements. The concept of "clearance constant", or k, created by *Kety* is a measure of the ability of the local circulation to remove or supply freely diffusible substances.

The object of the present study was:

(1) to use this technique, after injection of a deposit of Na^{22} at a well-defined point in experimentally produced bilateral healing bone cavities in the rabbit tibia,

(2) to ascertain the effect of the removal of bone with low speed and high speed drills on the circulation in the immediate vicinity of the bone cavity and in the healing tissue formed in it, and hence

(3) to gain an idea as to whether the two methods differ in their effects on the regional circulation.

EARLIER INVESTIGATIONS

The question of which tissues in and around an injured bone have a part in its healing has been discussed since ancient times. There have always been defendants of contrary opinions on this point (cf. *Keith*, 1917, 1918 *Hertz*, 1936). The bone-forming properties especially of the periosteum have often been discussed. There have been two schools — one which considers that the periosteum is able to form bone, the other that it possesses no bone-forming properties.

Most studies in recent times, however, clearly indicate that both the periosteum and the endosteal cells in the bone marrow and the Haversian canals are bone-forming. According to, for example, *Hertz* (1936) the osteogenic function in the deepest layer of the periosteum adjacent to the bone, the so-called "cambium layer" cannot be denied. This layer, as well as the inner layer of the endosteum, always contains osteogenic cells (*Ham & Leeson*, 1961). *Hertz* considers that the cells of the inner layer of the periosteum and the endosteum in the marrow cavities of bone and the Haversian and Volkmann's canals form a continuous membrane in healthy bone. He found the periosteum to be the most important factor in the healing of fractures, but also that the endosteum and the bone marrow participate in the regeneration processes. The conception of this author is in agreement with the *Hansen—Häggqvist* syncytial concept, according to which various forms of connective tissues including bone form a syncytium, in which can be differentiated an ectoplasm corresponding to what was previously called "ground-substance" and an endoplasm constituting what was called "cells".

The healing of a fracture takes place briefly as follows. After *coagulation of the haemorrhage* at the point of fracture an organization of the *clot* is started through the traumatic inflammation. A *granulation tissue* is formed, rich in collagen fibrils. An osteoblastema differentiates from the undifferentiated connective tissue, in the "ectoplasm" of which collagen fibrils accumulate in bundles, around which osteoblasts form as well. Mineral salts accumulate in the collagen fascicles. An initially *fibrous callus* is converted into a *primary bone callus* which, by resorption and apposition processes, is converted into *mature bone*. Under the influence of its function this mature bone tissue is thereafter transformed into *bone adapted to its function*.

In many respects the healing of a closed bone cavity corresponds to the healing of a fracture. We may take as example the healing of the bone cavity formed after apicoectomy. According to *Axhausen* (1949) this process is roughly as follows. After the wound cavity has filled with blood and the surgeon has covered it with a flap of mucous membrane and periosteum, the clot is *organized* through bundles of young granulation tissue growing in from the periosteum and the spongiosa spaces of the bone and dissolving the clot. In the centre of the granulation tissue, spindle-shaped fibroblasts occur between which one soon notices newly formed *fibrillar connective tissue*. The fibrillar structure of the latter soon disappears through accumulation of organic intermediary substance. *Osteoblasts* appear in the periphery. The fibrillar tissue is replaced by a network of *osteoid tissue.* Mineral salts soon precipitate in central parts of this stroma. This *primary bone callus* is converted under resorption and apposition processes into a secondary bone callus — *mature bone* — which gradually assumes the appearance of the original bone under the influence of function. Thus, on healing of the connective tissue, an almost complete regeneration appears to be possible.

Surgical operations damage the blood vessels, resulting in haemorrhage of varying severity and leading to nutritional disturbances in the normal circulation. Some cells in the operated area become necrotic, others are more or less injured. Depending on the nature of the wound and the extent of the injury, it will always take a certain amount of time before, *e.g.*, the area of a superficial wound decreases as healing progresses or before the strength of a sutured wound starts to increase. This time has by some authors (see surveys by *Arey,* 1936, *Sandblom,* 1944) been called the latent period. This term must be considered a clinical concept. Its duration is variable, usually between one and five days.

The speed of the regeneration processes and the ways in which different factors may affect the healing of wounds have been studied by quantitative methods. Among the indicators used for this purpose are the speed at which the surface of a skin wound diminishes and the tensile strength of healing wounds. Methods of this kind have been used for studying the influence on wound-healing of some local and systemic factors (*Sandblom,* 1944) and the mechanisms of repair of a cutaneous wound (*Carrel,* 1910).

By studying the normal pattern of the vessels and the regional circulation around a healing wound, one can also gain information about the healing of wounds. The arteries have long been considered to have a decisive role in the production of callus, and so in the healing of fractures and bone cavities. As early as the mid-18th century the famous British surgeon *John Hunter* went so far as to state as his belief that the periosteum as such possessed no bone-forming capacity but that arteries alone could form bone (cf. *Keith,* 1917/1918).

Changes in the capillary circulation as a result of trauma can interfere with the healing of bone. *Zederfelt* (1956) found that the tensile strength of sutured skin wounds in rabbits diminished after femoral fracture. He considered this to be due to changes in the capillary circulation. *Zederfelt* (1957) studied the changes in the capillary circulation of the conjunctiva bulbi in albino rabbits after femoral fracture with special regard to the intravascular erythrocyte agglutination and its ability to occlude vessels in the capillary bed. Within a few hours after the fracture he observed intravascular agglutination, as a result of which the capillary circulation was slowed down and was in due course partially stopped. The erythrostasis increased successively during the first day after fracture, and after 24 hours was observable both in the capillaries and in postcapillary venules and arterioles. Three days after the fracture he observed a rather quicker capillary circulation, and the occlusion of the capillaries was of rather shorter duration. Not until 14—16 days after the fracture had the circulation regained its original state. The degree of aggregation and the tendency to occlusion of the capillaries appeared to be related to the severity of the trauma. Thus the latent period during the first days after surgery reported by other authors appears to be related to the aforementioned disturbances of the regional circulation.

The normal pattern of the arteries in the rabbit tibia was studied microangiographically by *Göthman* (1960). The periosteum is nourished from many small artery branches from the soft tissues on the anterior surface of the tibia, the endosteum from branches of the medullary artery. The outer layer of the cortical bone in the tibia obtains its small vessels from the arterial system of the periosteum, and the inner two-thirds from the medullary arteries. There are anastomoses between these two arterial systems.

As already stated, *Kety* (1948), and several others thereafter, showed that the quantity of a radioactive substance removed per unit of time from the point of injection into the circulation (the clearance or disappearance) is closely related to the regional circulation and, according to *Kety*, is dependent on the blood flow in the nutrient capillaries. *Kety* also investigated the mathematical laws by which diffusible substances injected into the tissue disappear from the latter. He injected a small quantity of $Na^{24}Cl$ into the gastrocnemius muscle of man at a depth of about

2 cm and recorded the radioactivity every minute until the number of pulses per minute was too small for significant measurement. The radioactivity in the deposit decreased along a single exponential curve. Counts per minute less background corrected for decay of Na^{24} plotted semilogarithmically against time yielded a straight line, the slope of which yields the value of the clearance constant, k, a quantitative measure of the total ability of the local regional circulation to remove freely diffusible Na^{24} ions.

Theoretical, technical, biological and medical aspects of disappearance measurements have been presented by *Odeblad, Westin & Englund* (1959).

Apart from *Kety's* work, there is a considerable amount of experimental information on the relation between blood flow and the constant k from disappearance measurements in muscle tissue and subcutaneous tissue. On the other hand, the present author has been able to trace only three papers on the disappearance of radioactive deposits in bone tissue.

Brodin (1956) injected a deposit of J^{131} into the bone marrow of a rabbit's tibia in order to find out whether any change occurred in the bone marrow or in the perichondral surface of the epiphyseal cartilage after a growth-stimulating operation. He studied the local circulation with a scintillation counter over the deposit, but found that the method was not sufficiently developed to give information in this respect.

Bernascheck (1956) after injection of a deposit of J^{131} into the callus in 16-day-old fractures of the femur in rats, observed an increase of blood flow in the fractures of animals treated with substances causing vascular dilatation as compared with that of the controls.

Göthman (1960) studied the venous transport of a deposit of Na^{22} injected into the bone marrow of undamaged and fractured tibiae in rabbits. His study indicates an increase in the regional circulation outside the tibia in 3—4 week-old fractures and that the circulation in the bone marrow increases at a later stage of the healing.

The healing of surgical wounds has been studied by disappearance measurements by, among others, *Weiber* (1957, 1959). He injected a deposit of Na^{24} and J^{131} into the rectus muscle between the layers of fascia in the abdomen of rabbits and measured the disappearance rate. He found that the rate increased during the first days in a normally healing wound, reached a maximum about the fifth day, and then decreased somewhat. He concluded that since the disappearance rate is a measure of the local circulation, the latter appears to be built up in a healing wound during the first five days, which corresponds to the "lag period" (latent period). According to *Weiber*, disturbances in wound healing as well as infections are reflected by the clearance constant. In infected wounds the disappearance rate decreased during the first days, and not until the seventh day did the circulation show signs of restoration. As the standard deviation of the measurements was fairly large the diagnostic use of individual determinations is somewhat questionable. Therefore it was necessary to use a relatively large group of animals.

AUTHOR'S INVESTIGATION

Material and method

Material

Thirty-one white rabbits, male and female, were used for the experiments. The animals weighed between 2,400 and 3,730 g and were 10—12 months old. The experimental groups consisted of 20 rabbits. The circulation in the actual region was controlled in a group of 11 unoperated animals. Before the experimental period the rabbits spent 3 weeks in their cages for control of their state of health. No animals were used which did not maintain or increase their weight during this period. They were all kept on a diet consisting of crushed oats, Swedish turnips and hay.

In the experimental group, as already mentioned, the tibiae were chosen as the sites of the bone cavities. The animals were used as their own controls. The cavities were produced in each case, by drawing of lots, in one hind leg by means of a high speed dental engine with a turbine-powered handpiece having a loaded speed of about 48,000 r.p.m.[1]), in the other hind leg by means of a dental engine of conventional loaded speed of about 8,000 r.p.m.[2]). In the experimental group animals were picked out for measurement 3, 4, 7 and 9 days after operation.

[1]) Atlas Copco Dental Air Rotor, Atlas Copco, Stockholm, Sweden.

[2]) Svedia Technomotor No. 8186, Svedia, Stockholm, Sweden.

Many animals had to be excluded from the experiments because of broken legs, death from anaesthesia or technical mishaps in injection of the radioactive isotope and so on. For instance, the isotope solution occasionally flowed back on withdrawal of the needle, so that a deposit might remain in the skin. Weight records and some other data for the animals are given in Tables I and II.

Table I

Experimental group.

Weight records for 20 white rabbits.

Animal No.	Sex	Period of observation prior to operation, days	Weight at beginning of prior period, g	Weight on day of operation, g	Weight on 9th day after operation, g
14	♀	21	3,590	3,590	3,460
26	♂	19	2,450	3,000	2,990
29	♂	37	2,140	2,600	2,540
30	♂	21	2,750	2,900	2,875
32	♀	20	2,650	3,100	2,900
34	♀	29	3,090	3,200	3,300
36	♀	22	3,810	3,710	3,750
37	♀	22	3,120	3,060	2,950
40	♂	27	3,290	3,370	3,500
41	♂	27	2,400	2,760	2,640
42	♂	34	3,370	3,550	3,560
43	♂	34	3,100	3,200	3,240
44	♂	34	2,610	3,000	2,950
52	♀	24	3,520	3,700	3,450
54	♀	19	2,620	2,850	2,700
59	♂	156	2,100	3,200	3,250
67	♂	14	3,280	3,380	3,650
68	♂	21	3,000	3,270	3,600
69	♂	21	3,180	3,500	3,540
70	♂	21	3,450	3,730	4,010

In all cases except Nos. 14, 40 and 54 the wounds were clinically satisfactory on the third day after operation. The left and right hind legs of rabbits Nos. 14 and 40 were clearly swollen without any sign of infection. The temperature of the skin round the wounds was 34°—35°. (Normal skin temperature in this region seems to be 35°—36°.5 C, indicated by measurements from 3 animals). In rabbbit No. 54 a haematoma was visible. This was resorbed on the fifth day.

Table II

Weight records for 11 unoperated white rabbits for control of the normal circulation.

Animal No.	Sex	Period of observation prior to operation, days	Weight at beginning of prior period, g	Weight on day of operation, g	Weight on 9th day after operation, g
49	♀	33	3,450	3,610	3,620
80	♀	21	2,930	3,000	3,200
81	♀	21	3,100	3,300	3,370
82	♂	22	2.800	2.975	2,900
83	♂	22	3,000	3,090	3,180
84	♂	23	2,520	2,710	2,950
85	♂	23	2,550	2,700	2,870
86	♂	24	2.500	2,600	2,790
87	♂	24	2,400	2,400	2.440
88	♂	25	2,450	2.550	2,630
89	♀	25	2,700	2,950	3,100

In another group measurements were made on unoperated animals. These animals were anaesthetized and the skin over the hind legs was prepared in the same manner as for the experimental group with the exception that no wound and no cavity was made. The same deposit of Na^{22} was injected into the left and right hind legs and in the same place as on the animals in the experimental group. Pulse counting was then performed in the same manner as on the experimental animals.

Anaesthesia

Anaesthesia was performed by injecting a 6 per cent solution of pentobarbital sodium (0.5 ml per kg body weight) into one of the ear veins, followed by ether to an appropriate depth. This combination proved to give an anaesthesia suitable both for the surgical work and for the isotope experiments. If for any reason the ear veins could not be used, peritoneal administration was employed instead.

Surgery

The hair was cut off from the area of operation, which was then washed with a 1 per cent benzalkonium chloride solution and alcohol. Under routine aseptic precautions a 3 cm incision was drawn from the anterior border of the tibia, which is formed by a stout ridgelike elevation, the tuberosity of the tibia, along its anterior border through cutis, fasciae, muscles and periosteum

Fig. 1 a. The bone cavity.

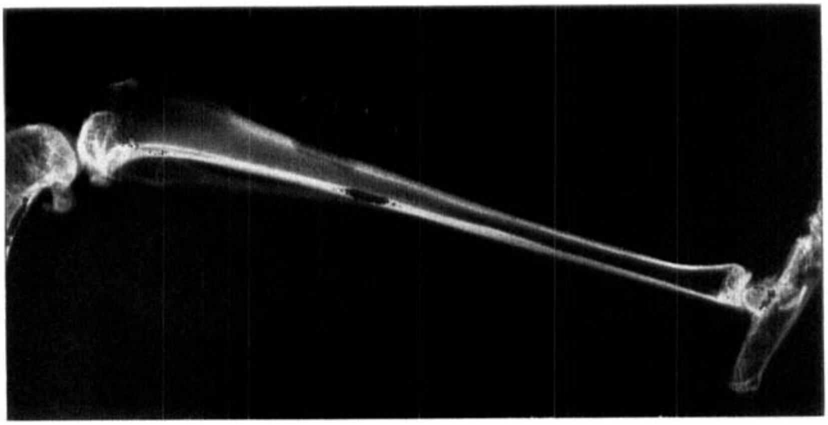

Fig. 1 b. X-ray photograph of the bone cavity.

to the bone. The musculature was stripped away from the tibia and held aside with retractors so that the anterior border of the tibia was rendered well visible. No vessels were ligated, any haemorrhage being controlled by a sponge and gentle pressure.

One centimetre below the tuberosity of the tibia in one hind leg a 1 cm long cavity was then drilled in the bone at the anterior border of the tibia until the bone marrow was faintly visible at the bottom of the cavity. This was done with a No. 8 carbide bur, the operation field being sprayed with sterile physiological saline (Figs. 1 a, b). The wound was closed with interrupted catgut sutures (plain No. 5/o) in the fasciae and the muscles with the stitches 5 mm apart (Fig. 2). The incision in the skin was closed

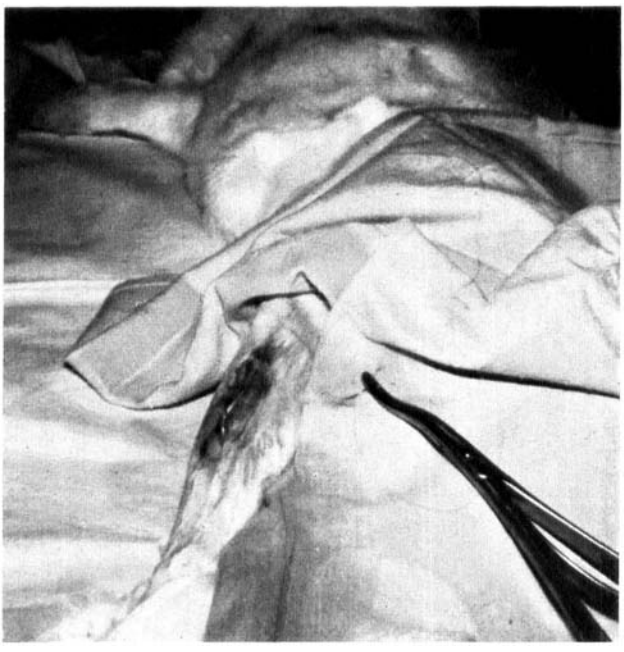

Fig. 2. The muscles and the fasciae were closed with 5 interrupted catgut sutures.

with 5 interrupted thin steel wire sutures also with the stitches 5 mm apart. The sutures were not removed until the experiments had been concluded. Immediately thereafter the same surgery was performed in the right hind leg with the only difference that the other type of dental engine was used for the bone surgery.

The radioisotope solution

The Na^{22} solution was supplied as an aqueous solution of sodium chloride[1]). For the experiments this solution was transferred to a physiological solution of $Na^{22}Cl$ by adding pure sodium chloride in powder form. As a small volume was necessary in order to increase the local hydrostatic pressure as little as possible, the solution was adjusted so that $\approx 5\ \mu C = 0.003$ ml. This volume was the dose injected every time. It is important to keep the volume constant in all experiments that are to be compared.

Injection technique

Throughout the experimental period an "Agla" Micrometer syringe[2]) (Fig. 3) was used, permitting injection with an ac-

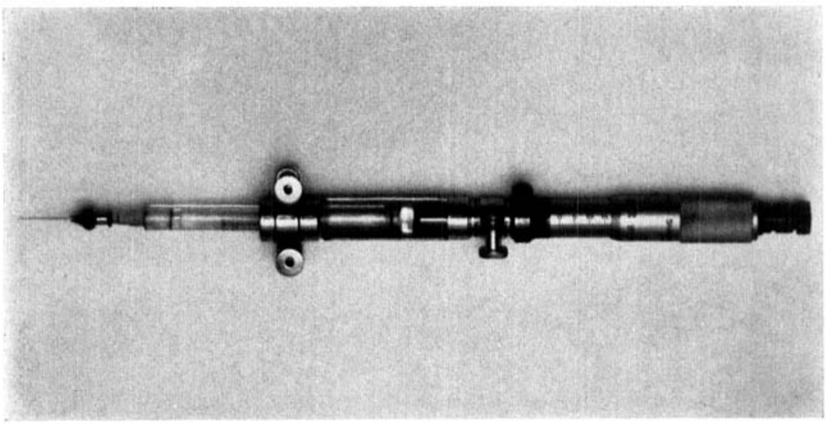

Fig. 3. The "Agla" Micrometer syringe used for the injection of the radioactive solution.

curacy such that volumes as small as 0.003 ml could be measured with an error of ± 2.55 % as judged by weighing 10 separate doses of 0.003 ml. Leakage between the plunger and the barrel of the syringe was effectively controlled by oiling the plunger with silicon grease under aseptic conditions before every experiment. Needles of the same size, No. 20 Record needles of 0.5 mm outer

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[1]) From the Radio-chemical Centre, Amersham, Bucks., England.

[2]) Borroughs Wellcome & Co.

diameter and 19 mm length were found to be suitable for the purpose, diminishing backward leakage into the tissues. Before use the syringe, the needles and the silicon grease were sterilized in an autoclave. At the end of each experiment syringe and needles were cleansed in running tap water, ethanol and ether, and then stored in physiological saline for an hour in order to reduce possibilities of contamination.

Fig. 4. The tuberosity of the tibia and the lower border of the cavity were marked on the skin before the measurements were started.

The tuberosity of the tibia, like the lower border of the cavity, were marked on the skin (Fig. 4). With the animal on its back, the fore legs were fixed to the operating table with a gauze bandage; the hind leg in which the injection was to be made was fixed with bags containing lead shot (Fig. 5). The needle was inserted obliquely in the longitudinal direction of the wound. The needle was then advanced until the tip was situated in the lower angle of the cavity (Fig. 6 a). The accuracy of the deposit could be

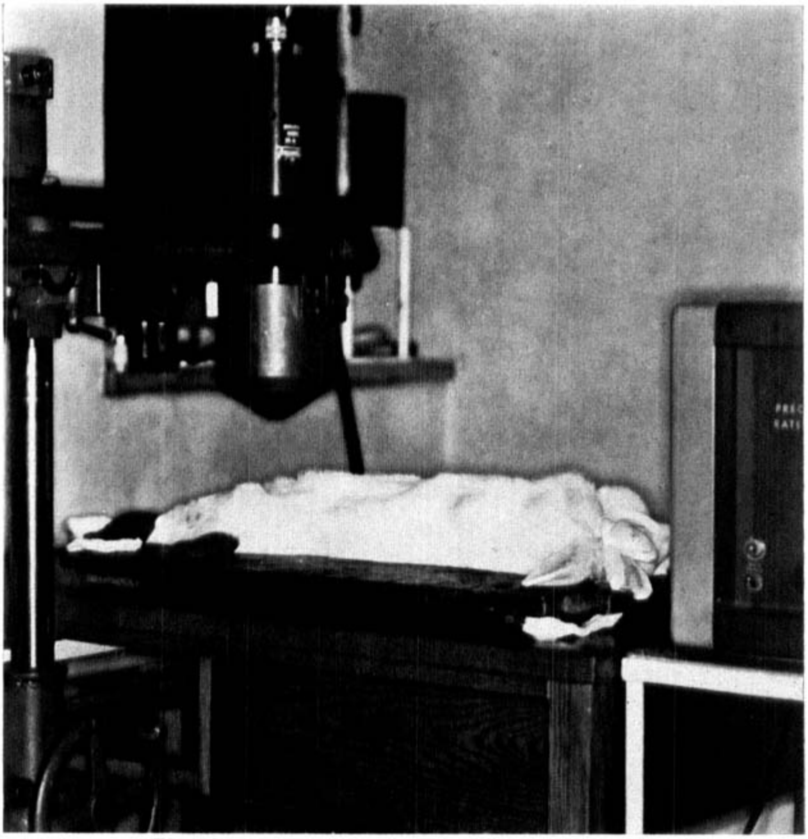

Fig. 5. Animal in position for measurement.

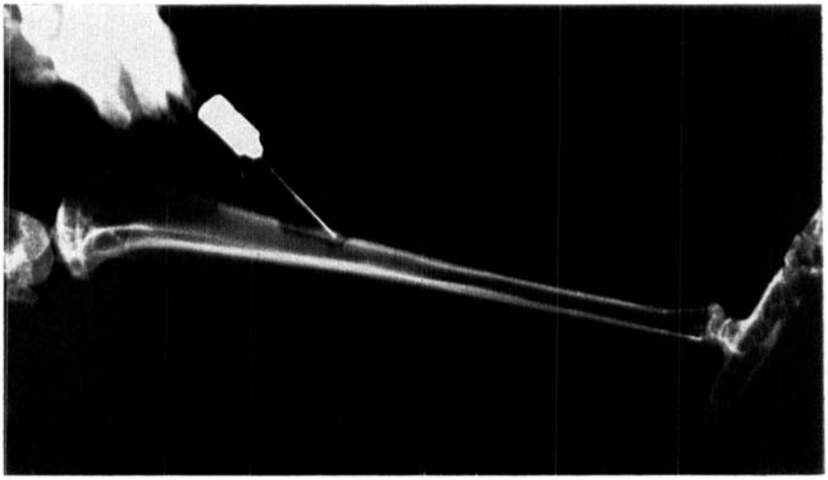

Fig. 6 a. The deposit was injected into a well defined point in the lower angle of the cavity.

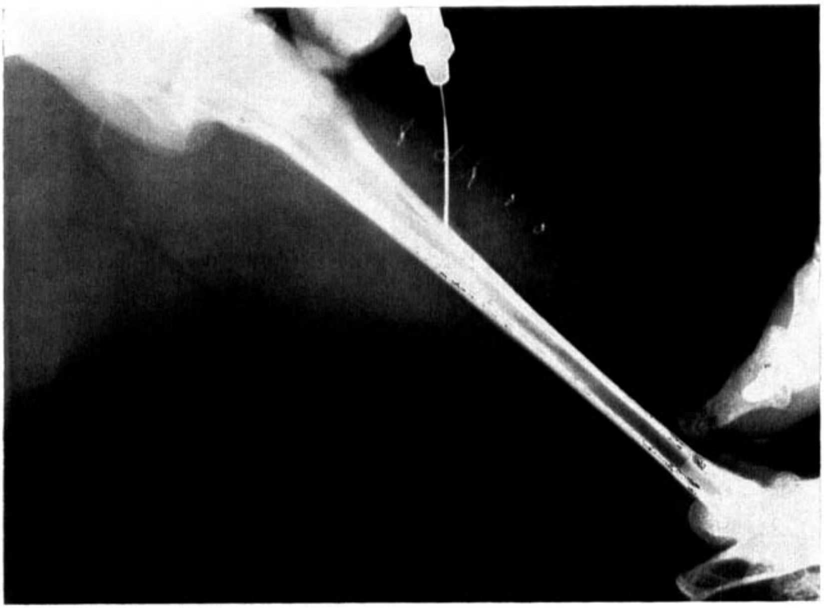

Fig. 6 b. A check of the position of the needle in the cavity was always made before injection of the deposit.

controlled by the fact that the operator could move the leg with the needle (Fig. 6 b). After some experience it was possible to inject the radioactive deposit exactly into the same well-defined point of the leg. A volume of 0.003 ml of $Na^{22}Cl$ was the quantity which the cavity was calculated to be able to accommodate. In the control group, the same volume of the radioactive solution was injected into the same site as in the operated animals with the point of the needle in the periosteum close to the anterior border of the tibia.

Equipment for recording radioactivity and measuring technique

The activity was measured by means of a scintillation counter of type Tracerlab to which a Tracerlab precision ratemeter was connected (Figs. 7 a, b). The time constant was set at 10 seconds. The operating voltage was 1,000 V. The scintillation counter was surrounded by a 4 cm thick cylindrical lead shield as described by *Forsslund* (1961). The collimator channel was 6.2 cm long

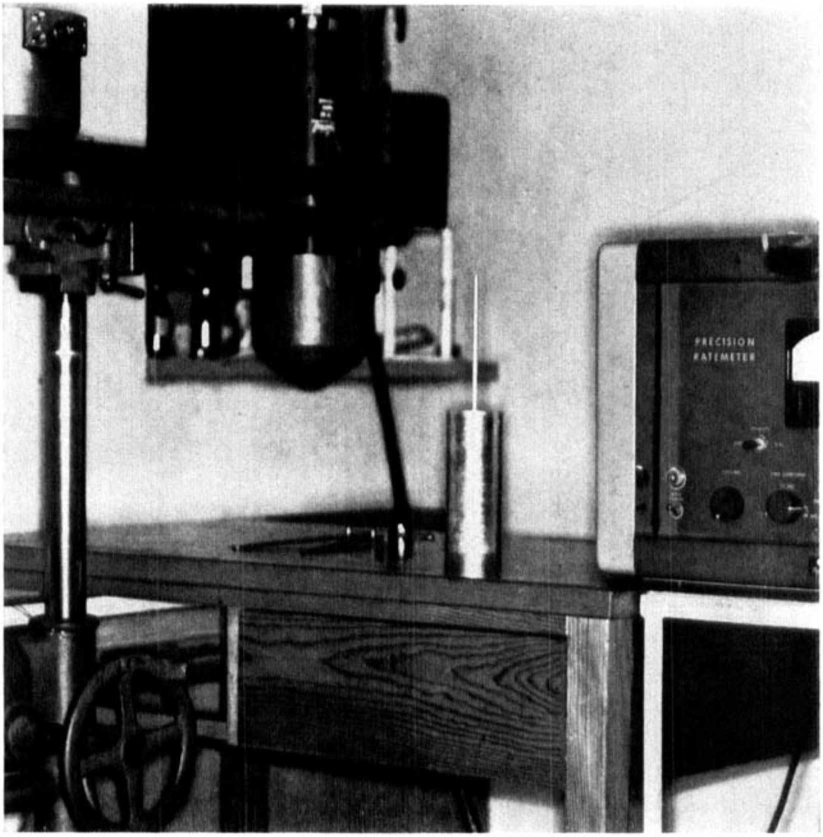

Fig. 7 a.
Equipment for recording radioactivity.

and had a 1.7 cm dia. aperture. The collimator could be easily raised and lowered, and with the aid of a specially designed indicator the radioactive deposit could be accurately centred in relation to the detector crystal (Figs. 8 a, b). The distance between the aperture and the deposit could be quickly determined with a specially designed pair of callipers (Fig. 9). In this way it was easy to maintain a constant geometry during the experiments. With the lead shield and collimator used the physical background was 400—700 counts per minute. The room temperature varied between 19 and 21° C. The counting rate was read every half minute for 15—20 minutes. The counting could be started 1½—2 minutes after the injection, which was the time required to adjust the

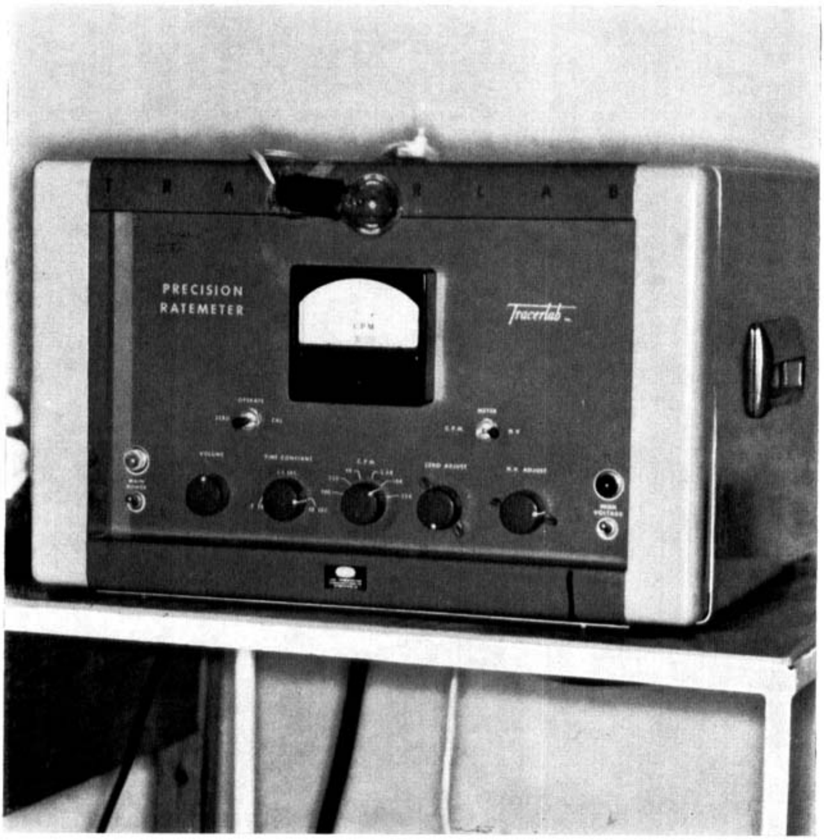

Fig. 7 b.
Equipment for recording radioactivity.

distance of the scintillator from the deposit so that the total recorded counting rate, including pulses from deposit and background, amounted to about 10,000 counts at the moment of starting the experiment.

When the raw counting data were plotted against time on a millimeter graph, a curved relation was regularly obtained. The animal background, rising during the measurements and also with the number of experiments on each animal, was corrected according to *Westin* (1957) and *Odeblad, Westin & Englund* (1959), who determined the theoretical basis for calculation of

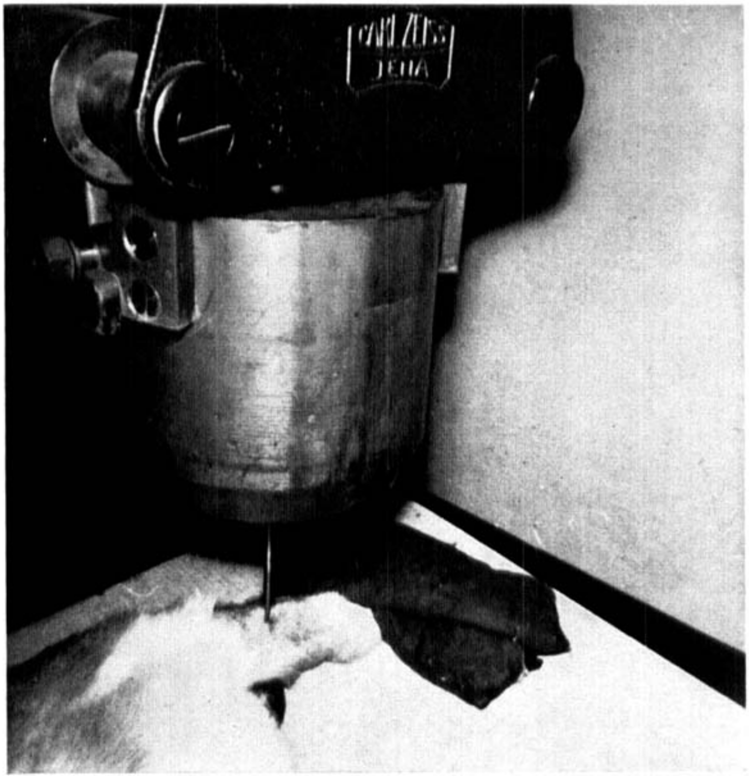

Fig. 8 a.

A specially designed indicator for centering the raidoactive deposit in relation to the detector crystal.

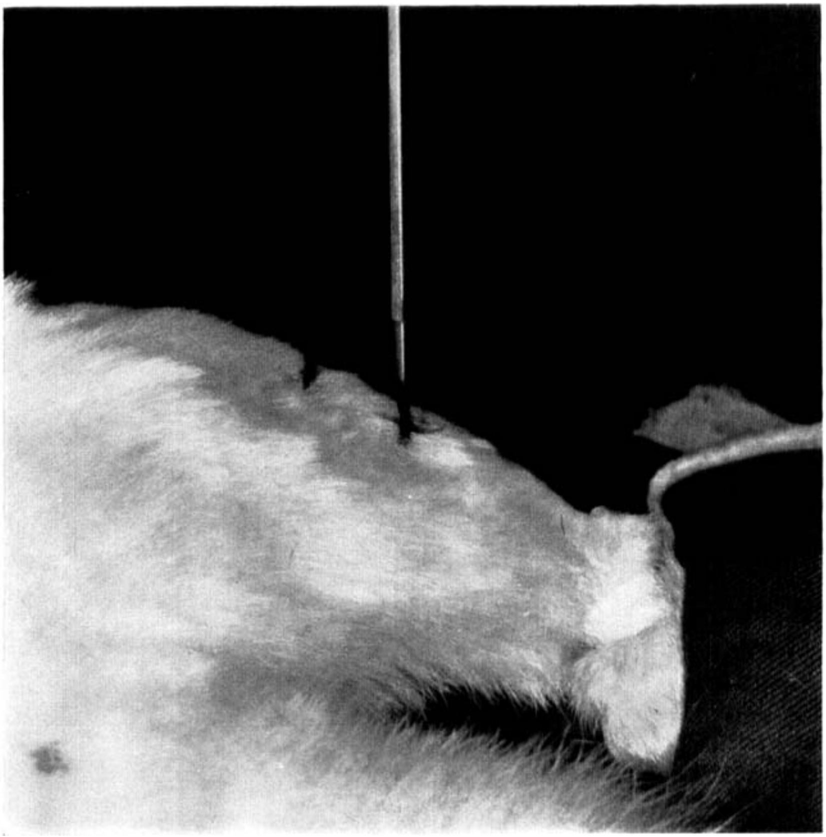

Fig. 8 b.

Legend see page 278.

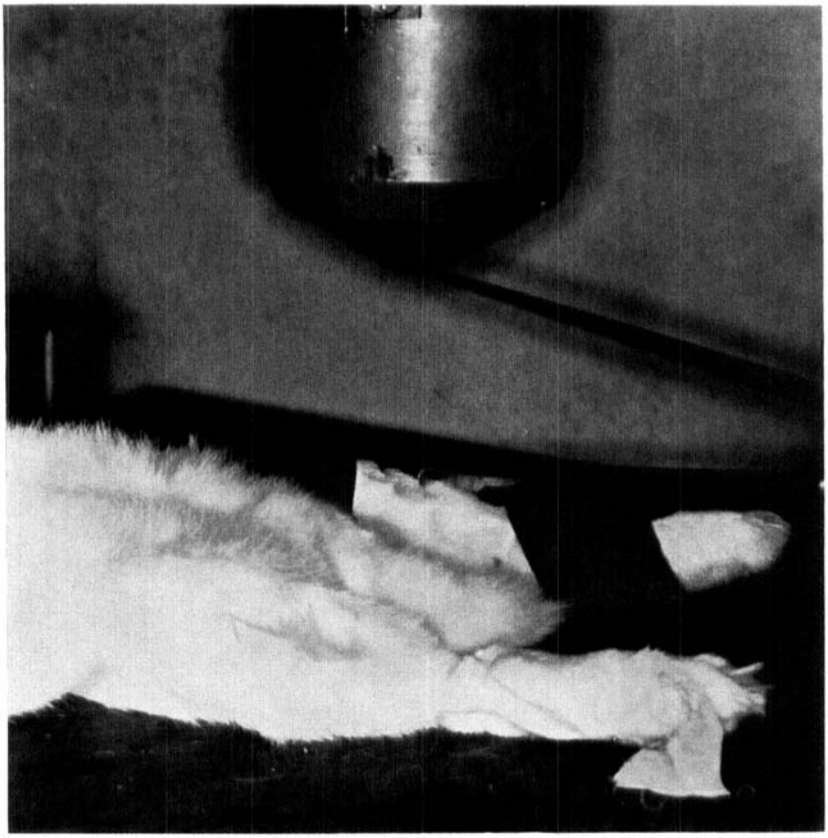

Fig. 9. The distance between the aperture of the collimator channel and the deposit was always checked before the measurements were started.

the final animal background (Fig. 10). According to these authors the raw data, or the total pulses recorded every half minute, consist of pulses from the deposit to be measured, pulses from the physical background and residual background from earlier injections, pulses from background due to radioactivity resorbed from the deposit and now circulating in the blood, and pulses from background due to locally metabolized radioactive sodium. All these factors are included in the concept "rising animal background", which must be known in order to calculate the disappearance constant. It would be possible to determine the final *in vivo* counting rate of animal background, but that would be

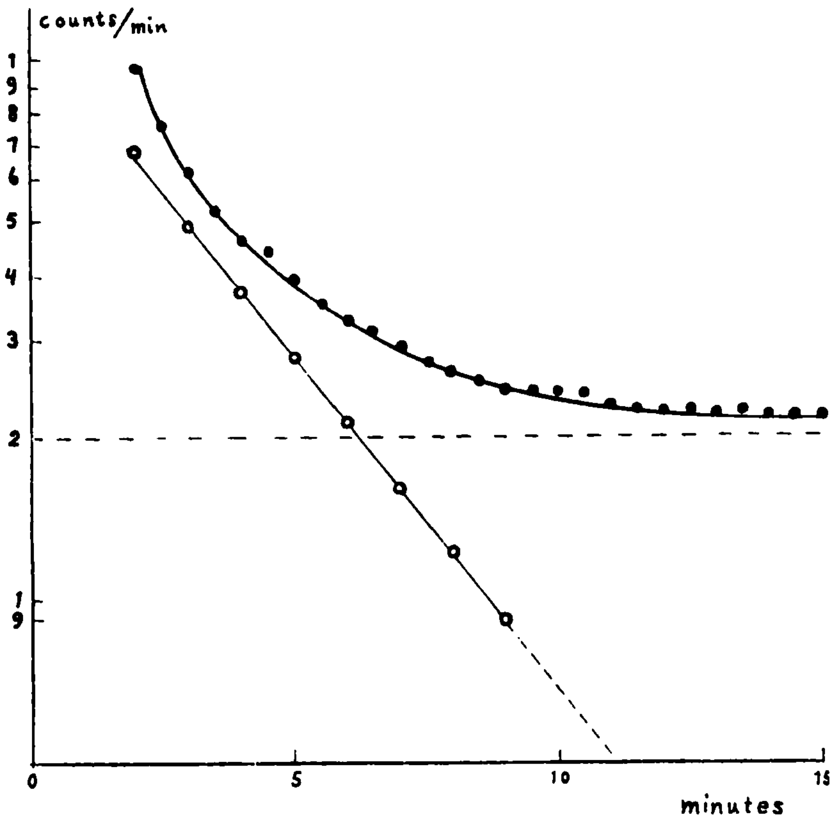

Fig. 10. An example of a disappearance measurement. Rabbit No. 86, left hind leg, total physical and biological background = 3,000 cts/min., $k = \frac{0.693}{T\frac{1}{2}} = 0.28$. T½ = clearance halftime in min. The exponential curve is converted to a straight line, the slope of which yields the value for the clearance constant k.

too timeconsuming. Theoretically this factor can be approximately calculated, but in practice it is best to proceed by trial and error. This value substracted from the raw data plotted against time on a semilogarithmic graph gives a straight line, the slope of which yields the value for the clearance constant k or $k = \frac{0.693}{T\frac{1}{2}}$ where 0.693 is the natural logarithm of two and T½ the clearance half life.

Results

The results are shown in Fig. 11 and Tables III and IV. As will be seen, the mean clearance constants, k, in the two experimental groups follow one another very closely, forming an upward arched curve. Admittedly the constants in the 8,000 r.p.m. group

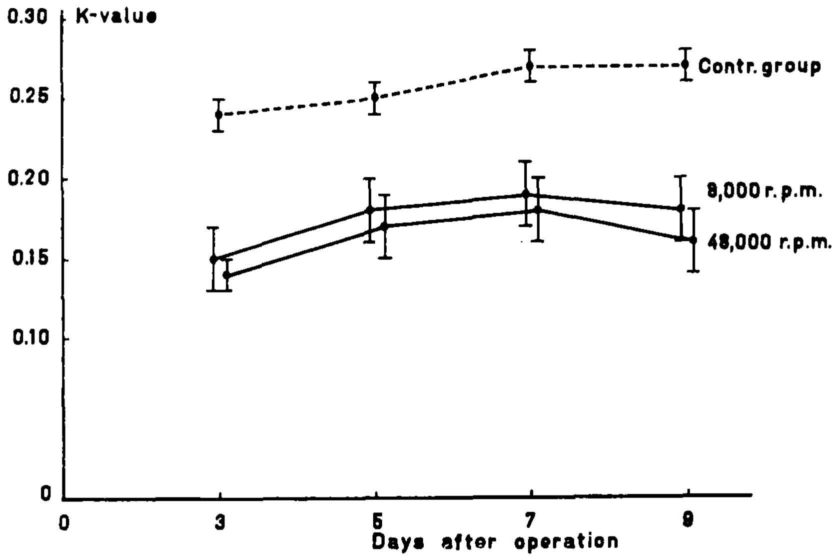

Fig. 11. Mean k-values in the two experimental groups (20 rabbits) and the unoperated group of animals for controlling the normal regional circulation (11 rabbits, 22 measurements). The standard error of the mean is indicated.

were slightly higher than in the 48,000 r.p.m. group at every observation. The *t* test, however, showed no statistical difference between the two groups, the methods appearing to be fairly equivalent in their effects on the circulation in the operation area and hence on the healing process.

In a group of unoperated animals in which the deposit was injected into the periosteum at roughly the same point of the tibia as in the experimental groups, the k values were considerably higher than in the latter, as is seen from Fig. 11. The order of magnitude of these k values is about the same as reported by *Odeblad et al.* (1956) for such vascularized organs as the ovaries

Table III

The clearance constant, k, of Na^{22} deposits in the wounds in the experimental groups on various days after operation. 20 white rabbits.

Rabbit	8,000 r. p. m.				48,000 r. p. m.			
	Day after operation							
No.	3 rd	5 th	7 th	9 th	3 rd	5 th	7 th	9 th
14	0.11	0.24	0.10	0.14	0.11	0.23	0.17	0.10
26	0.15	0.22	0.13	0.19	0.07	0.22	0.15	0.23
29	0.13	0.26	0.41	0.24	0.18	0.13	0.30	0.18
30	0.17	0.20	0.17	0.42	0.23	0.31	0,14	0.13
32	0.14	0.22	0.23	0.15	0.26	0.15	0.14	0.17
34	0.14	0.16	0.33	0.25	0.07	0.28	0.31	0.30
36	0.17	0.27	0.17	0.20	0.10	0.16	0.13	0.19
37	0.09	0.08	0.10	0.16	0.11	0.17	0.08	0.16
40	0.12	0.12	0.26	0.15	0.17	0.13	0.13	0.16
41	0.08	0.11	0.17	0.15	0.15	0.09	0.14	0.18
42	0.10	0.10	0.05	0.00	0.10	0.06	0.02	0.00
43	0.13	0.21	0.16	0.14	0.09	0.06	0.16	0.08
44	0.06	0.11	0.09	0.08	0.06	0.10	0.10	0.11
52	0.19	0.17	0.31	0.13	0.14	0.24	0.28	0.28
54	0.18	0.14	0.13	0.22	0.15	0.20	0.27	0.21
59	0.43	0.32	0.30	0.10	0.21	0.20	0.24	0.06
67	0.07	0.07	0.19	0.20	0.09	0.16	0.11	0.16
68	0.11	0.17	0.13	0.14	0.15	0.05	0.22	0.11
69	0.19	0.13	0.17	0.24	0.19	0.14	0.22	0.18
70	0.21	0.19	0.16	0.19	0.25	0.24	0.19	0.14
Mean	0.15	0.18	0.19	0.18	0.14	0.17	0.18	0.16
S. D.	0.08	0.07	0.09	0.08	0.06	0.07	0.08	0.07
Standard error of the mean	0.02	0.02	0.02	0.02	0.01	0 02	0.02	0.02

of rabbits (k $= \approx$ 0.25). This indicates that the operation caused a fairly considerable disturbance of the regional circulation in both experimental groups.

Certain differences between the experimental groups are also apparent at the different observations (Fig. 11). It would be tempting to interpret these differences as being connected with the healing process, but as the group of unoperated animals showed deviations of roughly the same order from one observation to another, they can hardly be ascribed to the healing of the wound.

Nor did *t* test of the k values of the experimental groups on the third and seventh days after operation, when the discrepancy

Table IV

The clearance constant, k, of Na^{22} deposits in the periosteum of the tibia in 11 white rabbits for control of the regional circulation in intact tissue. The injections and the measurements were performed at intervals of 2 days.

Rabbit	Day after operation							
No.	1 st	3 rd	5 th	7 th	1 st	3 rd	5 th	7 th
	Left hind leg				Right hind leg			
49	0.17	0,18	0.14	0.26	0.17	0.17	0.15	0.27
80	0.28	0.32	0.29	0.28	0.28	0.28	0.26	0.27
81	0.22	0.35	0.26	0.31	0.29	0.18	0.15	0.18
82	0.32	0.35	0.38	0.30	0,31	0.28	0.34	0.30
83	0.27	0.26	0.21	0.28	0.19	0.31	0.28	0.28
84	0.28	0.20	0.27	0.24	0.21	0.34	0.31	0.20
85	0.22	0.26	0.41	0.22	0.19	0.14	0.14	0.26
86	0.26	0.28	0.24	0.21	0.26	0.23	0.31	0.29
87	0,20	0.25	0.26	0.28	0.27	0.27	0.30	0.29
88	0.23	0.20	0.36	0.31	0.23	0.30	0.30	0.30
89	0.30	0.26	0.35	0.32	0.18	0.13	0.25	0.35

	1st	3rd	5th	7th
Mean	0.24	0.25	0.27	0.27
S. D.	0.05	0.07	0.04	0.04
Standard error of the mean	0.01	0.01	0.01	0.01

between the k values was greatest, reveal a statistical difference. This indicates that no marked improvement of circulation occurred during the observation period. Even nine days after the operation the regional circulation had not returned to the preoperative status compared with the circulation in intact tissue in the same region.

Discussion

Briefly the object of this study was to see whether any differences in circulational disturbance occurred through the use of high or low speed drills for the destruction and removal of bone in surgical work. This was done by measuring the disappearance of a deposit of Na^{22}. Since the disappearance rate is a measure of the regional circulation *(Kety)* and the circulation is disturbed by operation owing to injury to blood vessels, haemorrhage and associated nutritional disorders, etc., these disturbances should be reflected in the disappearance constant. In normal healing it is known that the blood supply is increased in the injured area through ingrowth of capillaries which also must increase the disappearance rate. In complications such as infections, on the other hand, it diminishes fairly considerably (*Weiber*, 1957). The disappearance constant may therefore be considered to constitute an indirect measure of the healing in an operated region and to provide means of comparing the effects of different factors on the healing of a wound in numerical terms. In the present study it was verified that registration of the disappearance rate can be used as a test of the healing of bone cavities in experimental work.

No appreciable difference was found between the two methods in this study. On the contrary the k values in the two experimental groups closely followed one another (Fig. 11), indicating a very similar disturbance of the circulation during the observation period. The variable factor in an otherwise standardized operation technique — the difference in speed of rotation — resulting in a roughly 2—3 minutes longer operation time and in increased pressure owing to the greater difficulty of controlling the low speed drill, does not appear to have been significant.

It may be discussed how a control group as regards the normal circulation should be selected. Since the primary object was to check for differences in the circulation after removal of bone with high and low speed drills, it was decided to use the animals as their own controls as regards the operations rather than to produce a bone cavity in one hind leg and use the other leg for control of the regional circulation. Also general disturbances occur in the capillary circulation very soon after operation *(Zederfelt)*, which might influence the determination of the k value in the unoperated leg.

On the unoperated animals the circulation was checked in the periosteum in the anterior part of the tibia in the same region where the operations were made, while on the operated animals the k values were recorded for the granulation tissue growing into the bone cavity. *Göthman*'s microangiographic studies, however, showed a very intimate circulatory relation between the periosteum and adjacent muscular and osseous tissues. The k values of the periosteum and granulation tissue should therefore reflect the circulatory condition also in the vicinity of these tissues, and injury to the periosteum, the soft parts around the bone cavity and the marrow spaces of the bone should affect the disappearance constant and so the healing process.

The time required for the regional circulation to regain its normal state by healing of abdominal wounds in the rabbit, as found by *Weiber* in disappearance measurements, was considerably exceeded in the present study. It is reasonable to imagine, however, that it takes a longer time for the circulation to recover after an operation in skin, muscles, periosteum and bone of the hind legs than in abdominal skin and muscles. In *Weiber*'s study, illustrating the healing of a wound in soft tissue in the rectus abdominis muscle of the rabbit, the circulation was found to be normalized 7 days after operation. However, in the present study of the healing of a wound in soft tissues, as well as in the bone, the circulation had not regained its normal state on the 9th postoperative day. Perhaps it will never do so (Fig. 12).

The disturbances of the regional circulation appear to be more in accordance with the circulatory disturbances observed by *Zederfelt* after fracture of rabbit femur, when, as in the present investigation, the periosteum was injured as well. As already mentioned, *Zederfelt* reported that it took 14—16 days after fracture before the preoperative condition of the circulation was restored. No data from that period are, however, available in the present study.

For technical reasons no measurements were made on the first day after operation. The relatively high k value on the third day after operation (0.14 and 0.15), however, indicates some regeneration of the circulation after this time. For the k value was then roughly twice as high as in subcutaneous clearance tests with sodium on animals treated with hyaluronidase which is very effective in promoting resorption (*Franke et al.* 1950).

It would have been interesting if the animals had also been picked out for measurement on the 1st and on the 15th or 20th days after the operation. As the hind legs of the rabbit are very sensitive and they were considerably weakened by the operations, and therefore the risk of fracture with great mortality of animals

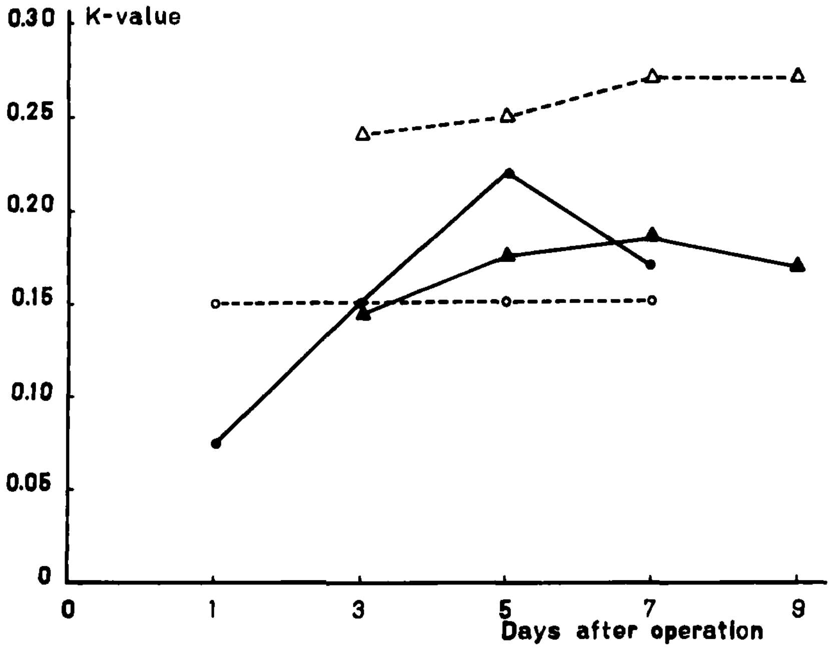

Fig. 12. Differences in healing of a soft tissue wound (*Weiber*, 1959) and a combined soft tissue and bone wound (the present study) in white rabbits. In Weiber's study the regional circulation was found to be normalized 7 days after operation. In the present study the circulation had not regained its normal state on the 9th postoperative day.

The normal regional circulation in intact tissue ○ — ○ Weiber's study
The circulation on various days postop. ● — ●
The normal regional circulation in intact tissue △— — — —△ present study
The circulation on various days postop. ▲— — — —▲

was too large, no experiments were made on the 1st day. It would be interesting to obtain information on the restitution of circulation also 15—20 days after operation. In fact, the problem is so interesting that it should be the object of further study.

Knowledge of wound healing depends to a great extent upon observations of laboratory animals. The applicability to man of the results of many such experiments remains unproved. However, the technique in the present study can be adapted to such experiments in order to investigate, for instance, the speed of regeneration of bone in cavities formed after operations on the jaws of man. With the help of isotopes such as F^{18}, Ca^{47} and Sr^{85}, which, because of short half lives, suitable radiation and bone-seeking properties can be used in experimental human work, it might be possible to carry out such an investigation. The problem of possible genetic damage must of course be taken into consideration (cf. *Ericsson & Malmnäs*, 1962).

SUMMARY

The purpose of this study was to ascertain the effect of the removal of bone with low speed and high speed drills (8,000 r.p.m. and 48,000 r.p.m.) on the circulation in the immediate vicinity of the bone cavity and in the healing tissue formed in it. This was done by means of the disappearance technique after the injection of a deposit of Na^{22} at well defined points, in experimentally produced bilateral, primary healing, bone cavities in the tibiae of white rabbits. The aim was also to gain an idea, expressed in numerical terms as to whether the two methods differ in their effects on the regional circulation.

Thirty-one white rabbits, male and female, weighing between 2,400 and 3,730 g were used for the experiments. The experimental groups consisted of 20 white rabbits, and the circulation in the region concerned was controlled in a group of 11 unoperated animals. The cavities in the tibia were produced in each case after drawing of lots. Disappearance measurements were made 3, 5, 7 and 9 days, respectively, after operation. The activity was recorded with a scintillation counter and the disappearance rate was calculated according to *Kety*. The results may be summarized as follows:

1. Student's *t* test showed no statistical difference between the effects of the methods during the period of observation; they seemed to have a fairly similar effect on the circulation in the operation area.
2. The operation produced a fairly considerable disturbance of the regional circulation, which differed statistically from the normal circulation in intact tissue in the same area. No marked improvement of the circulation in the operation area occurred during the observation period. Nine days after opera-

tion the circulation had not returned to the status in intact tissue in the same area.

3. The time required for the regional circulation to be built up again by healing of abdominal wounds in the rabbit, reported by earlier authors to be five days, is longer when the operation affects both soft and hard tissues as in this study. In such cases the circulation may even never regain its original state.
4. A procedure has been worked out which enables us directly to compare different factors, local as well as systemic, and their influence on the regional circulation in the healing of bone cavities in experimental work. The values are expressed in numerical terms, thus permitting direct quantitative analysis.

The practical result of these experiments is that, under the conditions employed, the two speeds of rotation appear to have very nearly the same effect on the circulation and may therefore be considered as equivalent from the point of view of traumatization. Just as important as the care and efficiency needed in destruction and removal of bone is the careful handling of the periosteum and adjacent soft tissues so that they are not unnecessarily torn or damaged by retractors or other instruments.

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RÉSUMÉ

MACHINES DENTAIRES A HAUTE RAPIDITÉ OU A RAPIDITÉ CONVENTIONELLE POUR L'ÉLOIGNEMENT, D'OS EN CHIRURGIE MAXILLAIRE

Le but principal de cette étude était d'étudier l'effet de l'éloignement de l'os avec des fraises de haute et de basse rapidité (soit 48.000 rpm et 8.000 rpm), et de voir s'il y a entre les deux mé-

thodes une différence dans l'effet sur la circulation régionale, exprimée en des termes numériques. A cette fin, on s'est servi de la technique de disparition, ayant préalablement injecté un dépôt de Na^{22} dans des endroits bien définis dans des cavités d'os primairement curatives produites bilateralement de façon expérimentale dans la tibie de lapins blancs.

Trente et un lapins blancs, mâles et féminins, pesant entre 2.400 et 3.730 grammes, étaient utilisés pour l'expérience. Les groupes expérimentaux étaient composés de 20 lapins blancs, et la circulation dans la région actuelle fut contrôlée dans un groupe de 11 animaux non opérés. Les cavités de la tibie furent produites en chaque cas après un tirage au sort. Des enregistrements de la disparation ont été faits 3, 5, 7 et 9 jours après l'opération. L'activité fut mesurée avec un compteur de scintillation et le degré de disparation fut calculé selon *Kety*. Les résultats peuvent être résumés de la manière suivante:

1. Le test *t* de Student n'a pas montré de différence statistique entre les méthodes pendant la période d'observation; elles semblaient avoir un effet assez pareil sur la circulation dans la région opérée.
2. L'opération a produit une perturbation assez considérable dans la circulation régionale, qui montrait une différence statistiquement significative de la circulation normale dans le tissu intact de la même région. Aucune amélioration marquée de la circulation dans la région opérée n'eut lieu pendant la période d'observation. Neuf jours après l'opération, la circulation n'était pas rétablie au niveau de celui du tissu intact de la même région.
3. Le temps requis par la circulation régionale pour atteindre le même niveau qu'avant par la guérison des blessures abdominales du lapin, calculé d'être cinq jours par des auteurs antérieurs, est beaucoup plus long quand l'opération comprend à la fois des tissus mous et durs, et dans des cas pareils la circulation peut ne jamais retourner au niveau original.
4. On a élaboré une procédure, qui permet de comparer directement les facteurs différents, locaux ainsi que systémiques, et leur influence sur la circulation régionale dans la guérison des cavités d'os en travail expérimental. Les valeurs sont ex-

primées en termes numériques, ainsi permettant une analyse quantitative directe.

Le résultat pratique de ces expériences est, par conséquence que, sous les conditions employées, les deux rapidités de rotation semblent avoir un effet entièrement pareil sur la circulation et peuvent ainsi être considerées comme équivalentes du point de vue de traumatisation. Aussi important que la prudence et l'efficacité nécessaires dans la destruction et dans l'éloignement de l'os est le traitement prudent du periosteum et des tissus mous voisins de sorte qu'ils ne soient pas blessés par des retracteurs ou par d'autre instruments.

ZUSAMMENFASSUNG

TURBINENMOTOREN ODER MASCHINEN VON KONVENTIONELLER GESCHWINDIGKEIT ZUR KNOCHENABTRAGUNG IN DER KIEFERCHIRURGIE

Die Aufgabe dieser Untersuchung war, die Auswirkung der Knochenentfernung mit Bohrern, die mit normaler bezw. hoher Geschwindigkeit (8.000 bezw. 48.000 Umd./Min.) arbeiteten, auf die Zirkulation in unmittelbarer Nähe der Knochenkavität sowie im Heilungsgewebe innerhalb derselben festzustellen. Für diese Untersuchung wurde die Disappearance-Technik nach Injektion eines Depots Na^{22} an einem genau bestimmten Punkt experimental geschaffener, primär heilender, bilateraler Knochenkavitäten der Tibiae weisser Kaninchen angewandt. Damit sollte ein Einblick erhalten werden, ob die beiden Methoden sich in ihren Auswirkungen auf die regionale Zirkulation — zahlenmässig ausgedrückt — unterscheiden.

Einunddreissig weisse Kaninchen, männliche und weibliche, im Gewicht von 2400 bis 3730 g wurden für diese Versuche verwendet. Die Experimentalgruppen bestanden aus 20 weissen Kaninchen, und die Zirkulation in der betreffenden Region wurde an einer Gruppe von 11 nicht operierten Kaninchen kontrolliert. Die Kavitäten in der Tibiae wurden entsprechend einem jeweils gezogenen Lose hergestellt. Disappearance-Messungen wurden 3, 5, 7 und 9 Tage nach der Operation ausgeführt. Die Aktivität wurde mit einem Scintillator-Rechner registriert und die Disappearancequote nach *Kety* berechnet. Die Ergebnisse können folgendermassen zusammengefasst werden:

1. Der *t*-Test nach Student zeigte keinen statistischen Unterschied der Methoden innerhalb der Beobachtungsperiode. Sie schienen einen ziemlich gleichen Effekt auf die Zirkulation in der Operationsgegend zu haben.

2. Die Operation rief eine ziemlich erhebliche Veränderung der regionalen Zirkulation hervor, die sich statistisch von der Zirkulation in unversehrtem Gewebe desselben Gebietes unterschied. Innerhalb der Beobachtungszeit erfolgte keine merkbare Verbesserung der Zirkulation im Operationsgebiet. Neun Tage nach der Operation war die Zirkulation nicht zu dem Status des intakten Gewebes desselben Gebietes zurückgekehrt.

3. Die für den Wiederaufbau der regionalen Zirkulation bei der Heilung abdominaler Wunden des Kaninchens benötigte Zeit ist von früheren Autoren mit 5 Tagen angegeben worden. In dieser Untersuchung, aber, wenn die Operation sowohl Weich- als auch Hartgewebe umfasst, ist die Zeit für den Wiederaufbau der regionalen Zirkulation länger. Vielleicht kann es vorkommen, dass die Zirkulation niemals wieder ihren ursprünglichen Zustand erreicht.

4. Eine Methode wurde ausgearbeitet, die uns in Stand setzt, direkt verschiedene Faktoren, örtliche sowie allgemeine, und deren Einfluss auf die regionale Zirkulation bei der Heilung experimentell gesetzter Knochenkavitäten, zu vergleichen. Die Werte werden zahlenmässig ausgedrückt und erlauben so eine direkte quantitative Analyse.

Das praktische Ergebnis dieser Untersuchung ist, dass unter den angewandten Bedingungen die zwei Bohrgeschwindigkeiten einen sehr gleichen Effekt auf die Zirkulation haben und daher im Hinblick auf die Traumatisierung als gleichwertig angesehen werden können. Genau so wichtig wie die Vorsicht und Effektivität bei der Zerstörung und Wegnahme von Knochen ist es, dass Periost und angrenzende Weichteile sorgfältig behandelt und nicht unnötig durch Retraktoren oder andere Instrumente verletzt oder beschädigt werden.

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