SILICON CONTENT OF BONE CALLUS IN EXPERIMENTAL FRACTURES

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 53, No. 5, pp. 72-75, May, 1962
Original article submitted June 7, 1961

By now, quite a lot is known about the silicon content of organs and tissues of men and animals [1-6]. However, very little has been reported about the silicon content of bone, and the trend of silicon metabolism after fracture has not been investigated.

The object of the present work has been to determine quantitatively the silicon content of regenerating bone at various stages after fracture.

METHOD

We used adult rabbits weighing 2500-2600 g, all kept under identical conditions, and on the same diet. At operation, the right radius was fractured in its middle third. The ulnar bone was not damaged, so that the limb remained straight. Experiments were performed on 95 rabbits, and of these 80 were observed for from 2 to 120 days. At the same time, histological and x-ray investigations of the fractured area were made in all the experimental animals to determine the relationship between silicon content and structural changes at the site of the fracture. For the histological study, preparations of the fractured region were fixed in 10% neutral formalin, and celloidin sections were stained in hematoxylin-eosin, or in van Gieson.

TABLE 1. Amount of Silicon in a Normal Left Radius and Femur (as a percentage of dry weight)

Radius	Femur
0,0012	0,0015
0,0016	0,002
0,0023	0,001
0,0017	0,0025
0,001	0,001
0,0011	0,0017
0,0016	0,0015
0,002	0,001
0,002	0,0015
0,0011	0,0015
0,0013	0,002
0,0009	0,0018
0,00098	0,00072
0,0009	0,00071
0,00095	0,0008
Mean	0,0014

TABLE 2. Silicon Content of the Bony Callus of the Left Radius and Left Femur at Various Times after Fracture (as percentage of dry weight)

Time after operation (in days)	Bony callus	Radius	Femur
2	0,0082	0,0024	0,0018
3	0,027	0,0051	0,0013
4	0,063	0,01	0,003
6	0,05	0,003	0,0018
8	0,016	0,00069	0,00072
10	0,01	0,00077	0,00059
12	0,015	0,002	0,0015
15	0,0055	0,0023	0,0011
18	0,017	0,0021	0,0017
21	0,0056	0,00093	0,00074
25	0,0056	0,0013	0,00042
30	0,0028	0,0018	0,0008
45	0,01	0,0017	0,00082
60	0,0023	0,002	0,00044
90	0,0031	0,0028	0,00095
120	0,0021	0,001	0,00058

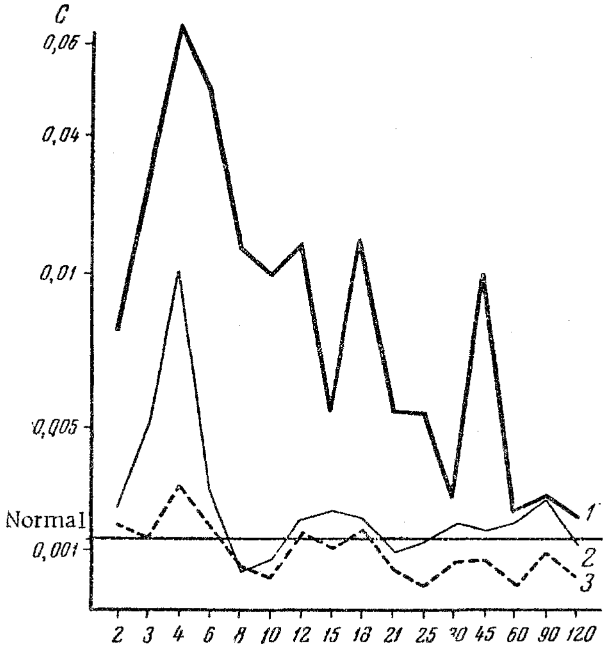
Silicon was determined by emission spectral analysis. Samples of bone tissue were calcined by heating in hydrochloric acid, and were transferred by the drop method on to carbon electrodes; they were then heated in the arc at a current strength of 8a and a potential of 125 v by means of a PS-39 arc generator.

The analysis was made on a ISP-28 spectrograph of moderate dispersion; the inter-electrode distance was 1.5 mm, and the exposure 3 minutes. The silicon line at 2881.57 A was compared with the spectral region of the ultraviolet 0.05 mm distant from it. Photometric measurements were made using a MF-2 microphotometer.

RESULTS

From these results it was shown that in the normal rabbit radius and femur there is 0.0012 and 0.0014% respectively of silicon. As can be seen from Table 1, the amount of silicon in these bones is fairly stable.

It is shown in Table 2 that as early as the second day after the fracture there was 0.0082% of silicon in the bony callus, (6.9 times more than the normal amount) (see figure). The silicon content gradually rose, and by the third day it had reached 0.027%, i.e., 22 times more than the normal amount.



Changes in the amount of silicon present in the callus during its formation. 1) Bony callus; 2) left radius; 3) left femur.

The morphological changes in the fractured region consisted mainly of an inflammatory infiltration, destructive changes of cells and tissue, and signs of the organization of a hematoma made up of delicate precollagenous fibers between the cells.

The maximum amount of silicon in the developing callus occurred on the 4-6th day after the fracture. The amount was then 0.063-0.050%, which was 40-50 times more than normal. At this time, in histological sections the connective tissue fibers between the ends of the fragments were very dense, and in them collagenous structures preponderated, and covered the whole region of the fracture. In the periosteum there were marked proliferative changes and outgrowths of cambial cells.

The maximum silicon content of the developing callus therefore coincided with the maturation of the organic matrix through the formation of collagenous fibers and the multiplication of cells in the damaged area.

Eight - fifteen days after the fracture, the amount of silicon had been reduced 3-10 times below its previous value, and varied between 0.0055 and 0.016%, representing an amount 4.3-10.4 times normal. At the time of the relative reduction of the amount of silicon in the regenerated bone, the morphological changes in the fractured region showed a reorganization of the bony and cartilagenous callus and its replacement by coarsely fibered bony trabeculae. The cartilagenous cells were in a state of rapid division, and mitoses were frequently seen. The replacement of the regenerated cartilage by bony trabeculae was specially noticeable by the 15th day, when there was an intense growth of vessels into the bony callus and a vascular resorbtion of the cartilagenous regenerated portion. At this time fundamental changes were shown in x-ray pictures. The depth of the periosteal shadow had increased considerably in comparison with the previous exposures. All this evidence indicated an intense calcification of the callus. Therefore the formation of the bony and cartilagenous callus, and its reorganization and calcification were associated with some reduction in the amount of silicon in the regenerating area.

By the 21-30th day, in the regenerated bony callus the amount of silicon varied between 0.0028 and 0.0056%, which was only 2.2-4.5 times the normal amount. In histological preparations, the sites of fracture were indicated by the bony and cartilagenous callus at the stage of reorganization and replacement by bony trabeculae, which by the 30th day completely filled the fracture. From x-ray pictures a very dark shadow of the periosteal callus could be seen, which at this time had already joined the cortical layer of fragments of the parent bone.

By the 45th day, in the newly formed bony tissue, at the site of the previous fracture there was a second rise in the amount of silicon to 9 times above normal (0.010%). At this time the morphological changes consisted in the formation of bony trabeculae at the site of the fracture, and there was no cartilagenous tissue. X-ray studies showed that at the previous fractured region there were changes indicating the absorption of the excess bony callus. Apparently the second peak in the amount of silicon which we found in the newly formed bony tissue was associated with an increase of the metabolic processes involved in the absorption of the excess callus.

By the 60-120th day, in the new bony tissue, at the site of the previous fracture, the amount of silicon varied between 0.0021 and 0.0031%, representing 1.5-3.2 times the normal amount. At this time, histological examination of the site of the fracture showed a definite cortical layer in the form of a plate at the stage of reorganization. X-ray pictures showed a complete restoration of the form and structure of the bone over the whole of its length.

The maximum amount of silicon in the left radius occurred on the 3-6th day, i.e., at the period of maximum silicon content. By the 8-10th day, the concentration of silicon in the left radius had fallen just as it had in the regenerating area, and fluctuated within the limits of the upper values of the normal amounts (see Table 2).

In the left femur, which was far removed from the fracture, by the 4th day the amount of silicon was 2.4 times above normal, i.e., the maximum amount of silicon in the left femur coincided with the maximum increase of concentration of silicon in the callus. Subsequently, the amount of silicon varied, remaining usually below the normal value except for the 12th and 18th days when in the left femur it rose to an amount 1.2-1.9 times above normal.

Thus the healing process of a fractured bone shows definite variations in the amount of silicon which are related to the recovery stage.

SUMMARY

The paper deals with the amount of silicon in regenerating bone and in other parts of the skeleton at different periods during the healing of a fracture. Measurements were made by emission spectral analysis. Observations were made on a fracture of the radius. Histological and x-ray methods were used to relate the silicon content of the bony callus to the morphological changes involved in regeneration. The maximum amount of silicon present in the regenerating bone occurred in the early stages, when the amount was greater than normal; the increase coincided with maturation of the organic periosteal matrix consisting of collagen fibrils, and was accompanied by intense cellular proliferation in the periosteum. Similar variations of the silicon content occurred in the opposite limb and in remote skeletal regions, which indicates that silicon may migrate from other areas of bone into the fracture zone.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**