

Communication on Regeneration of Bone.

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The following experiments, illustrative of the part played by the various structures in the regeneration of bone, were performed upon young animals of two different varieties of the canine species, which were still in their developmental period, two to four months. The specimens were secured from 6 to 12 weeks after the experiments had been performed, consequently the animals would then be from three to six months old.

A.—The periosteum removed from the entire circumference of the right radius, the bone remaining *in situ*.

B.—A circle of periosteum removed from the entire circumference of the shaft of right radius and a silver ring placed upon the denuded bone.

D and E.—Bone grafting from right radius.

F and G.—Transplantation of bone *en masse* from right radius.

J.—Preservation of periosteum. Removal of part of shaft of right radius. Protection of divided ends of bone and medullary tissue by decalcified turkey bone.

K.—Preservation of periosteum and removal of underlying bone of right radius to test the osseous reproductive capacity of this membrane.

A.—The Periosteum Removed from the Entire Circumference of the Right Radius, the Bone Remaining in situ.

Dog A had the periosteum removed from the entire shaft of the right radius, leaving only $\frac{1}{4}$ inch of periosteum on the diaphyseal side of the epiphyseal lines.

The operation was practically bloodless, aseptic healing ensued without visible scar or adherent cicatrix. Along with this specimen there is the corresponding left radius for comparison.

Description of specimen as seen about 12 weeks afterwards:—

The shaft of the bone was found to be entirely covered with a layer of newly formed connective tissue, closely investing the bone and adhering to it much more firmly than periosteal tissue. It was found more difficult to detach this fibrous layer from the bone than normal periosteum. The bone was quite healthy and had acquired an abundant new blood supply. It had, however, not increased circumferentially to the same extent as its fellow on the left side.

B.—*A Circle of Periosteum Removed from the Entire Circumference of the Shaft of Right Radius and a Silver Ring placed upon the Denuded Bone.*

Dog B had a circle of periosteum, comprising the whole circumference of the right radius and measuring $\frac{1}{2}$ inch in breadth, raised from about the middle of the shaft. A flattened silver ring was made to encircle the denuded bone at this part.

The operation was bloodless, the wound healed aseptically without visible scar and without adherent cicatrix. The bones of the left limb are preserved for comparison.

Description of specimen as seen 12 weeks after :—

The right radius was covered—at the part that had been denuded of the periosteum—with a newly formed connective tissue which was more firmly attached to the bone than that of the normal periosteum on the shaft above and below this part. After denuding the bone from this newly formed connective tissue and from the periosteal covering, there was no trace of the silver ring to be seen. The shaft of the bone was smooth all over and if the wire still existed it must have become enveloped in the bone. There was, however, a thickening of the shaft at one part and it was considered probable that the silver ring lay underneath. The bone was scraped through in a vertical direction and after penetrating the bone for about $\frac{1}{8}$ inch, the silver ring was exposed, completely buried in firm osseous tissue. Three other apertures were scraped through at different parts of the circumference of the shaft so as to expose the silver ring at each. The thickness of the new bone covering the wire in front was fully $\frac{1}{8}$ inch and it was a little less behind. Thus, the silver ring placed upon the bone denuded of periosteum had in three months become completely enveloped in newly formed bone, $\frac{1}{8}$ inch in thickness.

The shaft operated on is smaller in circumference than its fellow in left limb, the diminution in bulk being most apparent at the part which was denuded of periosteum—but the new bone at this part is denser than that on the other parts of the shaft which were not operated on.

D and E.—*Bone Grafting.*

Two dogs, named D and E, of different species, had the periosteum entirely removed from the right radius, after which a circle of bone including the whole circumference of the shaft was removed from each. These circles of bone being kept apart were each divided into small fragments, and those removed from animal D were placed in the gap left in the radius of E, while those from animal E were placed in the gap left in the radius of D.

No bleeding, aseptic healing without visible scar. Osseous union solid at end of fifth week. The left fore limb of each is preserved for comparison.

Description of specimens as seen 12 weeks after transplantation of bone grafts:—

Right Radius of D.—Layer of fibrous tissue covering whole of shaft of right radius and so firmly attached that scalpel as well as periosteal elevator were required to denude the bone. Shaft is entire and continuous from one epiphysis to the other, but there is great thickening at the part where the graft from neighbouring bone was introduced. In marked contrast to the dense, firmly adherent new formation of connective tissue surrounding the right radius on this limb was the thin periosteal covering of the left radius which shelled with great ease on the application of the periosteal elevator.

Description of specimen E is very similar to that of D.

Right radius of E.—Dense layer of new formation of fibrous tissue covering bone and firmly adherent to the shaft. Shaft united throughout, but presents large irregular node at seat of bone grafting.

F and G.—*Transplantation of Bone en masse.*

Two dogs, F and G, of different species had the periosteum entirely removed from the right radius, after which the greater portion of the shaft of the right radius, extending from near the proximal to near the distal epiphyses was removed *en masse* and transplanted, the shaft of the right radius of F being inserted into the gap in the shaft of G, and the shaft of the right radius of G being introduced into the gap in the radius of F.

No vessels requiring ligation. Aseptic healing, leaving no visible or adherent scar. Bone firm at end of four weeks, and subsequently increase in circumference was in F detected through soft tissues. The left radii are preserved for comparison.

Description of Specimens.—Right radius of F seen 11 weeks and 1 day after transplantation. New formation of dense connective tissue closely adhering to the bone and with difficulty elevated therefrom. The shaft, continuous with the epiphyses and firmly united thereto, is greatly increased in circumference, and is much thicker than the radius of the left limb from which the normal periosteum is easily raised in one piece by the elevator.

G.—Right radius of G seen 20 weeks and 4 days afterwards. Newly formed connective tissue closely adherent to the transplanted shaft. The diaphysis is united throughout, and so perfect is the union at either end that the insertion can scarcely be made out. It looks like a well formed normal shaft.

Dog J.—*Preservation of Periosteum, Removal of Part of Shaft and Protection of Medullary Tissue and Divided Ends of Bone.*

The periosteum from the right radius was elevated, carefully preserved and left *intact*. There was no attempt made to free the periosteum from plaques of bone which may have adhered to it during separation. $2\frac{5}{8}$ of the denuded shaft of the right radius was then removed and put aside. In its place a perforated, decalcified turkey bone drainage tube was inserted into the gap in the shaft under the periosteum. The proximal and distal portions of the shaft with their open medulla were introduced into either end of the turkey bone tube with the hope that any extrusion of ossific matter, either from the divided ends of shaft or from the medulla, would be thus preserved from the pressure of the surrounding tissues and be permitted to grow.

Almost bloodless. Aseptic healing, no visible scar and no adherent cicatrix. Dog ran about a great deal, and ulna became bent from lack of support of radius.

Description of Specimen as seen 10 Weeks after.—The ulna was found bent at junction of middle and lower thirds. In the part of the radius from which the shaft had been removed there was no apparent trace of periosteum or decalcified turkey bone tube, but where the tube had been placed there was a dense mass of fibrous tissue about $\frac{1}{4}$ inch in thickness, which covered the underlying osseous tissue, and adhered to the ulnar periosteum. This connective tissue mass was continuous superficially with the periosteum on the shaft above and below the part from which the bone had been removed, while at its deeper part it was connected with the two extremities of the old shaft and with portions of new bone projecting from the cut edges of the old, which had formed an irregular bridge between the two cut osseous surfaces, measuring $1\frac{1}{2}$ inches in length, and from $\frac{1}{4}$ to $\frac{3}{8}$ inch in breadth. On the proximal side of this bridge there was a very thin osseous layer adhering to the ulna, and to the upper part of radius, the remainder of the gap being made up of dense fibrous tissue.

The difference in length between the right radius and the left radius is $\frac{3}{4}$ of an inch—the measurement being in a straight line ($5\frac{1}{2}$ left; $4\frac{3}{4}$ right).

Dog K.—*Preservation of Periosteum and Removal of Bone.*

Shaft of radius removed sub-periosteally to the extent of $1\frac{3}{4}$ inches; the periosteum being carefully preserved and being left *in situ*. There was no attempt made to detach plaques of bone which might have adhered to the

periosteum during its separation. At the upper extremity of the bone shaft, an irregular spike-like process of bone was left. The wound was then closed, the soft tissues being allowed to coalesce. A case of plaster of Paris was applied loosely to prevent outward pressure.

No bleeding. Aseptic wound healing, leaving no visible cicatrix, and no adherent scar. After removal of plaster four weeks subsequently, there was no apparent union, a gap being detected between the extremities of the radius. At end of six weeks gap quite marked. Ulna markedly bending.

Examination of Specimen 10 Weeks After.—The right ulna had markedly bent, and this bending had lessened greatly the interval which would otherwise have existed between the two extremities of the un-united radius. At the part from which the bone had been removed and the periosteum had been left *intact* there was a gap, void of osseous formation, but filled with dense connective tissue. When this was turned aside, the proximal portion of the bone was seen to be flattened laterally, a new formation of bone continuous with the shaft projecting toward the gap. A somewhat similar formation had taken place below.
