

A REPLY IN CONSIDERATION OF WALTER DUBEN AND HEINZ GELBKE'S ARTICLE

Animal experiments concerning the problem of epiphyseal or interstitial osseous growth in length—conclusions on the articles of A. Hellstadius and F. Lacroix, in this issue of Acta orthop. scand.

By

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The investigation with the above title arose chiefly in consequence of my article, "An investigation by experiments on animals of the role played by epiphyseal cartilage in longitudinal growth" in Acta chir. scand. vol. 95, 1947. In this I showed that after extraperiosteal extirpation of the inferior part of the ulnar diaphysis, the epiphyseal cartilage and the inferior ulnar epiphysis of growing animals, longitudinal growth occurred from the resected end of the ulna even though the epiphyseal cartilage had been removed.

I formed the conclusion that growth in length may occur under certain conditions without epiphyseal cartilage. This conflicted with the generally accepted view that no growth in length could take place without epiphyseal cartilage. I also recorded my opinion that the function of the epiphyseal cartilage was largely passive and that it merely constituted a suitable medium, in which the new bone-forming tissue from the diaphysis end could grow. Owing to the successive resorption of the epiphyseal cartilage towards the diaphysis end and new formation towards the epiphysis end this new bone-forming tissue could advance increasingly up to the point when the new formation of epiphyseal cartilage ceased and new bone formation from the diaphysis end merged with the epiphysis.

These conclusions of mine provoked opposition first by Lacroix (Acta orthop. scand. vol. 18, 1949) and now lately by Duben and Gelbke. Both Lacroix and Duben and Gelbke repeated my experiments and like myself they found that the inferior end of the ulna after resection increases in length despite the removal of the epiphyseal cartilage. Therefore it is not so much the result of my experiments which is criticised as the conclusions drawn from them. Lacroix considered

that in those cases where fairly pronounced longitudinal growth occurred, this was due to new formation of epiphyseal cartilage. On the other hand Duben and Gelbke consider that it is not a question of the longitudinal growth but of regeneration. In *Acta orthop. scand.* vol. 20, 1950, I dealt with Lacroix' interpretation above of the longitudinal growth in my experiments. Lacroix also thought that lesser growth in length might take place in the following way: the radius diaphysis, as it grows in length, may via the *membra interossea* displace the periosteum on the diaphysis end of the ulna in the direction of the periphery and thus new bone formation on the prolonged part of the resected end is explained. Duben and Gelbke devoted a number of their experiments to the elucidation of this question and found that the new bone formation cannot be explained in the way that Lacroix sets out.

As far as Duben and Gelbke's article is concerned, I wish first of all to clarify the expression incorrectly used by these authors "interstitial osseous growth in length", which causes some confusion when reading the title of the article and the introductory words in the text. The text says: "Hellstadius recently took up again the old disputed question of interstitial or epiphyseal osseous growth in length". This question is not disputed at all, but has long been fully elucidated and I have never made any approach to it. The term interstitial growth in length refers to the problem whether longitudinal growth of bone may extend within the diaphyses themselves. Metal pins have been inserted into the diaphyses of growing animals at a certain distance from each other and the findings are that this distance does not increase as the bone grows in length but remains constant. Thus it has been proved that no interstitial bony growth takes place but that all longitudinal growth occurs from the ends of the bone. The last author who demonstrated this is, as far I know, Silfverskiöld (*Acta chir. scand.* vol. 75, 1934). Neither my own investigations nor those of the authors deal in any way with the question of interstitial growth in length.

In these investigations, which followed the same methods as my own, (although I employed rabbits and the authors dogs), a growth of $\frac{1}{2}$ –3 cm was obtained from the resected end. The authors describe this as regeneration and consider that it cannot be regarded as longitudinal growth. They draw this conclusion from the fact that the ulna as a whole was no longer than before the operation. The length of the ulna was understood as the distance from the *proc. coronoideus* to the inferior end of the distal epiphysis. To be able to describe this new bone formation as regeneration and not as longitudinal growth, an acceptable explanation is of course required of how such regeneration can possibly be formed. How do the authors consider then that this so-

called regeneration arises? They express themselves in the following way: "The resection bed lies open to granulation tissue which according to the principles of the induction theory can be differentiated into osseous regeneration. The outward form of the callus and later bone which manifests itself roentgenologically as the object under dispute, regeneration, is thus determined through the resection bed". The authors invoke therefore Levander's theory in order to explain the arisal of the aforesaid regeneration. Levander considers that compounds pass from the necrotic bone tissue into the surrounding tissue which there stimulates certain mesenchymal cells towards forming new bone tissue. The authors obviously imagine that such compounds would emerge from the resected ends of the ulna into the gap in the tissue left after the resection of the ulna end and there give rise to osseous tissue. If this were generally so, one would think that much in bone surgery would be simpler and the results more effective than they actually are. Levander's views have moreover aroused criticism from many quarters, and experimental research on animals partly by Heinen, Dobbs and Mason, partly by Lindahl and Orell was not able to verify Levander's induction theory.

When I was carrying out my experiments, I too was aware that regeneration might possibly be concerned. I found it difficult to imagine that this could occur in any other way but that a number of periosteal islands were left on the *membra interossea* after resection, giving rise to new bone formation. As stated above resection was performed extra-periosteally on the diaphysis at various distances from the epiphyseal line, and then the distal part of the diaphysis including the periosteum, the epiphyseal cartilage and the epiphysis were removed. The epiphysis was taken away to prevent any union between the epiphysis and the diaphysis, as this would have automatically arrested further longitudinal growth. If regeneration had been involved, one could imagine that the newly formed bone tissue would replace the resected part of the diaphysis and thus advance as far as the old epiphyseal line, but no further. In two of my experiments (exp. 5 and 6) new bone formation advancing from the diaphysis end had grown in the one case 9 mm, and in the other case 10 mm down past the old epiphyseal line. Hence the idea of regeneration could be dismissed. If Duben and Gelbke's experiments are examined more closely it will be found in the great majority of cases that the new bone formation growing out from the diaphysis end has crossed the old epiphyseal line by amounts varying up to 23 mm (test 5). To consider, as do the authors, that regeneration from the diaphysis is also capable of replacing the epiphysis is asking much indeed. The epiphysis leads, one may say, a life of its

own. It has its own method of growth which has nothing to do with the growth mechanism of the diaphysis. Regeneration of the epiphysis demands that a part of the epiphysis remains, from which the regeneration may proceed.

The authors write further: "Hellstadius observed from his rabbits that the formation regenerated was all the shorter the further proximally the resection site was placed". On account of this alleged observation by myself the authors made two tests, (tests 7 and 8), in which a larger part of the diaphysis was removed than in their previous tests. They show that the so-called regeneration was no less than in those tests where the diaphysis resection was performed closer to the epiphyseal cartilage.

In this connexion however my observations were not precisely as the authors have stated. In those cases where I performed the resection on the lower half of the ulnar diaphysis the growth in length was actually largest in the experiment where the resection site lay furthest proximally of the epiphyseal line and where therefore the largest resection was performed (exp. 5). On the other hand, in the two cases (exps. 7 and 8), where the resection was made above the middle of the ulnar diaphysis, no longitudinal growth at all was noted. If the tests of the authors are examined more closely (tests 7 and 8), it will be found that in the one test (test 7) the resection was carried out 2.4 cm proximally of the epiphyseal line, that is, in the inferior half of the ulnar diaphysis. In the second test (test 8) it is stated that the resection was performed "in the middle of the ulnar shaft". One does not know therefore in this case whether the resection was made above or below the middle of the ulnar diaphysis. It would have been interesting in this connexion if the authors had carried out the resections strictly in the upper half of the ulnar diaphysis.

The authors further reason that if growth in length occurs after a resection of the double bone in the forearm, it should also occur after a similar resection of a long bone which has no parallel bones. Thus the authors resected the lower end of the femur in a similar way to the ulna but did not obtain any so-called regeneration from the resected end of the femur. A different result was hardly to be expected. After such an operation the diaphysis end sinks down in the knee joint and comes to rest probably against the upper articular surface of the tibia. Such conditions do not provide any opportunity for newly-formed osteoid tissue to grow forward from the diaphysis end in the longitudinal direction of the bone. In order that such soft osteoid tissue may advance in growth it must have the opportunity to grow into a loose, easily penetrable tissue which does not place any

considerable mechanical obstacle in the way of such forward growth. One has only to see how the interposition of soft parts in fractures can prevent the callus tissue from growing forward. Therefore no longitudinal growth takes place after amputations either. It was also for this reason that I carried out my animal experiments on the ulna. The radius serves as a support there and arrests any collapse of the operative site, so that the newly-formed osteoid tissue does not meet any considerable mechanical obstacle to its forward growth.

S U M M A R Y

In summing up I should like to point out that the authors' experiments did show, as did my own, that after extraperiosteal resection of the lower end of the ulna proximally to the epiphyseal line—thus despite the absence of epiphyseal cartilage—growth of bone proceeds from the end of the ulna in a distal direction along the longitudinal axis of the bone, and that this in several instances extends more or less far beyond the site of the previous epiphyseal line. The latter observation suggests that we are here concerned with longitudinal growth. In other respects, from the authors' experiments nothing emerges respecting the question of longitudinal growth or regeneration. Also, these experiments do not lend support to Lacroix's interpretation of the cause of the longitudinal growth in my experiments.

R E S U M E

En résumé, je désirerais relever que les expériences des auteurs ont montré comme les miennes qu'après une résection extrapériostale de l'extrémité inférieure du cubitus proximale à la ligne épiphysaire—et malgré l'absence du cartilage de conjugaison—la croissance de l'os se produit de l'extrémité du cubitus en direction distale le long de l'axe longitudinal de l'os et que dans plusieurs cas elle s'est étendue, plus ou moins, au-delà de la localisation de l'ancienne ligne épiphysaire.

Cette dernière observation fait supposer qu'il s'agit ici d'une croissance longitudinale. Les expériences des auteurs ne font rien ressortir en ce qui concerne la question de la croissance longitudinale ou de la régénération. Ces expériences ne fournissent aucun appui à l'interprétation de Lacroix sur la cause de la croissance longitudinale dans mes expériences.

ZUSAMMENFASSUNG

Zusammenfassend möchte ich hervorheben, dass sowohl die Versuche der Verfasser, als auch meine eigenen, zeigten, dass nach extra-periostaler Entfernung des unteren Endes der Ulna proximal zur Epiphysenlinie – d.h. trotz des Fehlens des Epiphysenknorpels – das Wachstum des Knochens in distaler Richtung entlang der Längsachse des Knochens fortschreitet und dass dieses in mehreren Fällen sich mehr oder weniger weit über den ursprünglichen Sitz der Epiphysenlinie hinausstreckt. Die letzere Beobachtung macht es wahrscheinlich, dass wir es hier mit einem Längenwachstum zu tun haben. In anderer Hinsicht geht jedoch nichts bezüglich der Frage Längenwachstum oder Regeneration aus den Versuchen des Verfassers hervor. Diese Versuche unterstützen ausserdem die Auffassung, die Lacroix über die Ursache des Längenwachstums hat, nicht.