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GROWTH DISTURBANCES OF THE PROXIMAL END OF THE FEMUR

An Animal Experimental Study with Tetracycline

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It is well known that certain disturbances such as congenital coxa vara, epiphyseolysis, and Legg-Perthes-Calvé disease cause typical growth disturbances at the proximal end of the femur in growing children (Langenskiöld et al. 1957, 1962, Pylkkänen 1960). In all cases where the epiphyseal plate of the head of the femur is damaged, there develops gradually during growth a typical coxa vara formation with associated malformation of the head and shortness of the neck of the femur (Edgren 1965). Similar malformations and growth disturbances may also arise as a result of trauma or infection of the hip joint suffered in childhood. Such malformations have also been observed in animals (Compere et al. 1940, Langenskiöld et al. 1957, 1962). If, on the other hand, the epiphyseal plate of the greater trochanter is damaged, a coxa valga can be observed as a result (Laurent 1959, Langenskiöld & Salenius 1967).

Since Milch et al. (1957) published their study showing the binding of tetracyclines on the bone, tetracycline has become increasingly popular for studying the metabolism and biology of bone tissue. Tetracycline allows the development of a growing bone to be followed, because a connection has been observed between tetracycline and calcification of the matrix of bone (Milch et al. 1957, 1958). The purpose of the present work is to study experimentally induced growth disturbances in the proximal end of the femur with the aid of tetracycline.

MATERIAL AND METHODS

The material comprises 20 pigs, 4-8 weeks old, and 20 rabbits, a few weeks old. In the first stage epiphyseodesis of the greater trochanter was performed on the



Figure 1. Epiphyseodesis of the greater trochanter with resulting coxa valga formation. The contra lateral hip on the left.

rabbits by emptying the epiphyseal plate under local anaesthetic, and epiphyseodesis of the capital epiphysis was performed on other animals likewise by destroying the epiphyseal plate. Before operation these rabbits were given tetracycline (50 mg per kilogram), and the same dosis after operation at 4-week intervals. It was found that rabbit femurs were too small for the purpose of this investigation so the same tests were transferred to pigs. Under general anaesthesia epiphyseodesis of the greater trochanter was performed in some pigs and of the capital epiphysis in others. The animals were given tetracycline before operation and again afterwards. The animals were killed 2-4 months after operation and results recorded both by X-ray and by photographing a longitudinal section of the proximal end of the femur in ultraviolet light.

RESULTS

Epiphyseodesis of the Greater Trochanter

After epiphyseodesis of the greater trochanter, coxa valga formation developed in all operated animals (Figure 1). In the longitudinal tetracycline section, growth was found to be totally lacking in the region of the greater trochanter (Figures 2, 3, 4). The capital epiphysis had



Figure 2. In a longitudinal section in ultraviolet light the deposition of tetracycline is seen in the metaphysis as well as lines in the diaphysis. The capital epiphyseal plate has grown new bone between it and the tetracycline deposit. This is not seen on the side of the trochanteric epiphyseal plate. Both the capital epiphysis and the trochanter have grown new bone also from the periosteum, but this is more marked on the side of the trochanter.

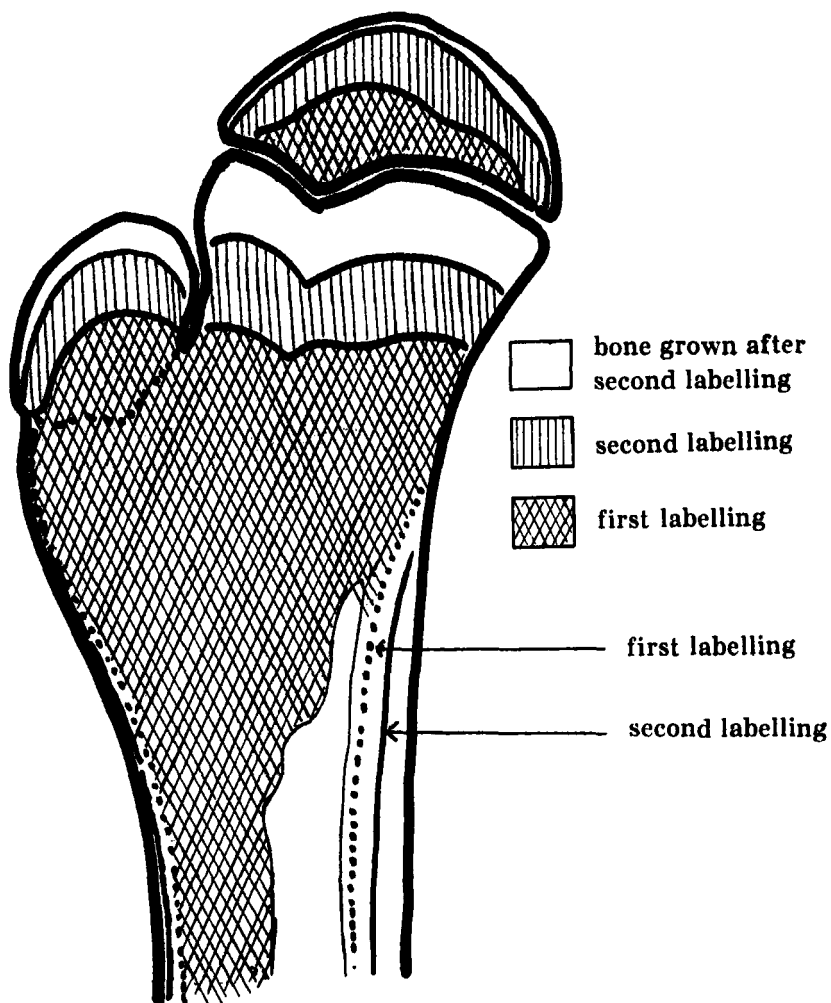


Figure 3. A schematic drawing of the changes in Figure 2.

grown new bone between the epiphyseal plate and the bone marked by tetracycline (Figures 2 and 4). It was then found that both capital epiphysis and trochanter had also grown from the periosteum but the trochanter considerably more than the head (Figures 2-7).

In comparison of tetracycline cross-sections from a normal hip and from the specimen in which epiphyseodesis of the greater trochanter was performed, the lines of tetracycline along the diaphysis indicate that epiphyseodesis of the trochanter not only stopped growth at the trochanter but also stopped the process of remodelling resorption (Fig-

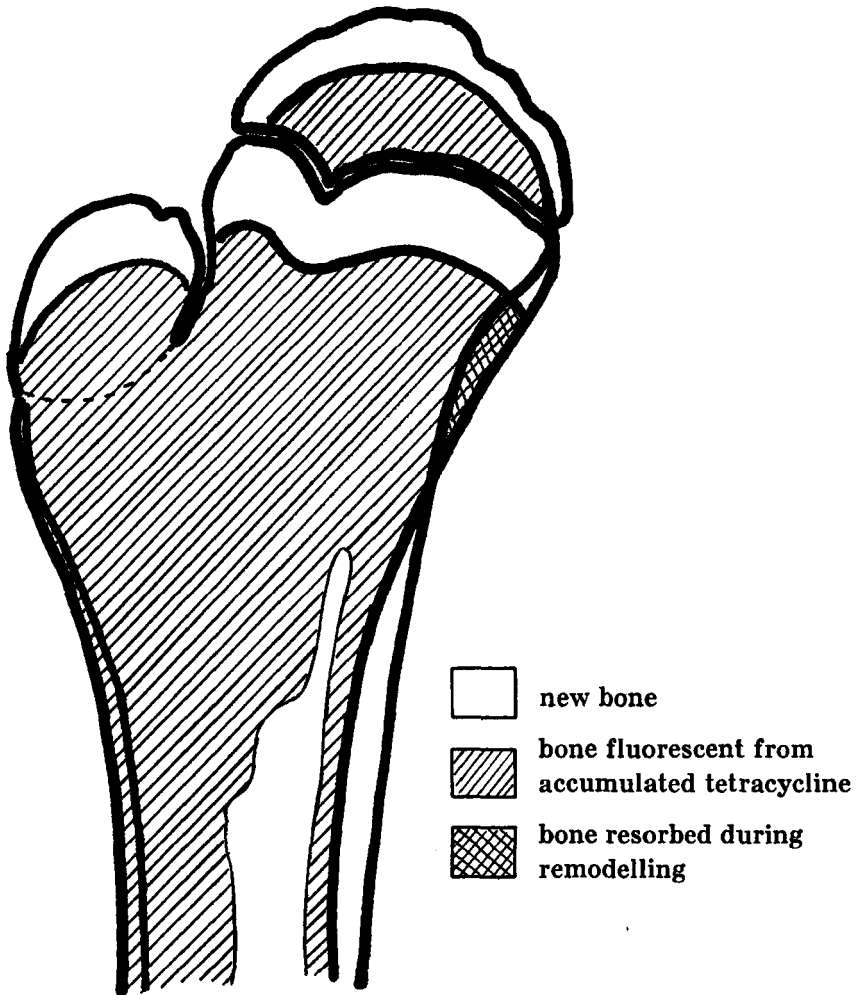


Figure 4. A schematic drawing of the changes in remodelling.

ures 2, 3, 4, and 5). This is shown by the fact that in the epiphyseodesis specimen the tetracycline line from the diaphysis at the side of the greater trochanter continues uninterrupted upwards to the epiphyseal line, whereas in a normal specimen it breaks below the trochanter (Figures 2 and 5). The same is seen in the other specimens.

Capital Epiphyseodesis

After capital epiphyseodesis a typical coxa vara formation appears in the hip during growth (Figure 8). In the longitudinal sections



Figure 5. The tetracycline deposition in a normal hip. If compared to Figure 9, it can be seen that the lines in the diaphysis break on both sides, whereas in Figure 9 the line continues until the epiphyseal plate on the side of the epiphyseodesis.

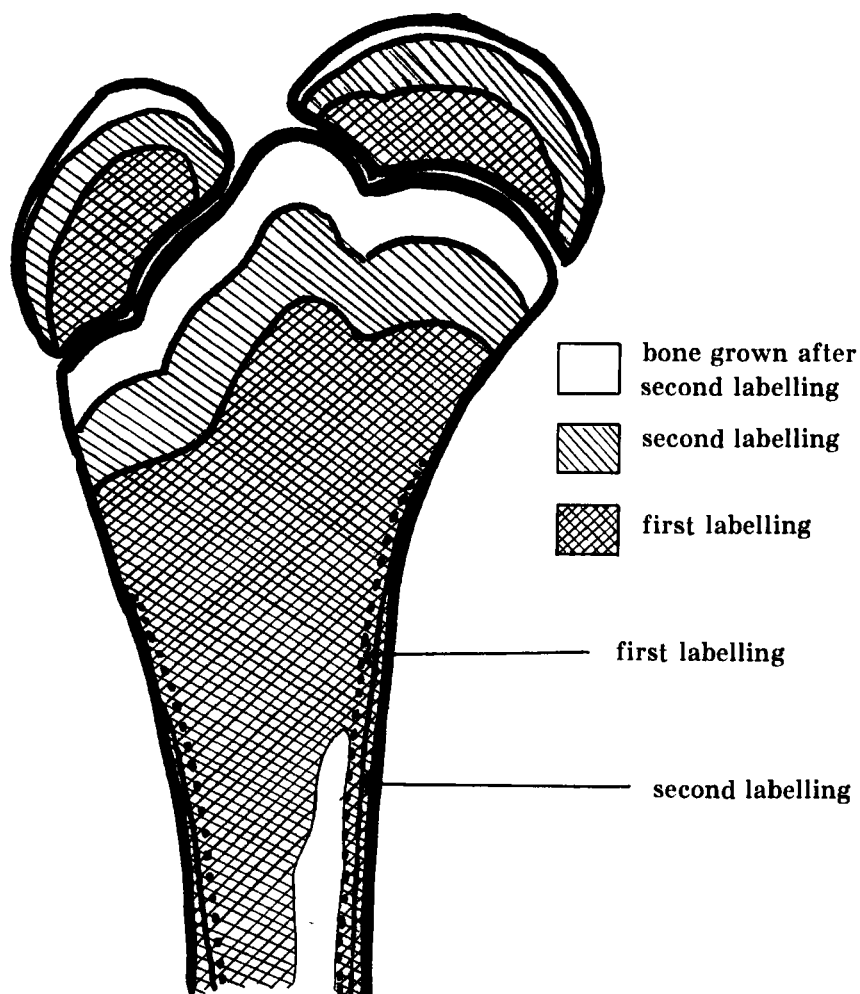


Figure 6. A schematic drawing of the changes in Figure 5.

marked by tetracycline it is observed that the trochanteric epiphyseal plate causes growth on the side of the trochanter in the normal manner, whereas the destroyed capital epiphyseal plate has not caused growth (Figures 9–11). Comparison with the normal hip shows that resorption remodelling has also been disturbed in addition to growth. Further, the neck of the femur has clearly shortened and the trochanter grown far above the head. The head has become irregular and broad.

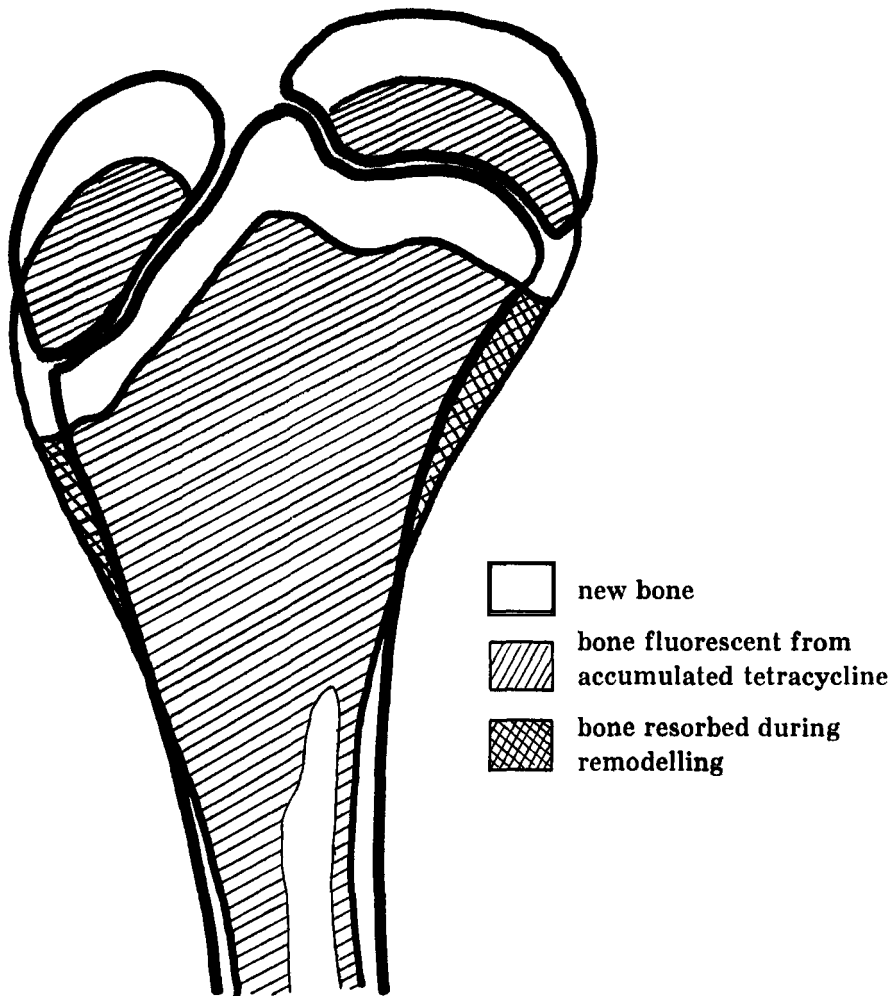


Figure 7. A schematic drawing of the changes in remodelling.

DISCUSSION

In the present study disturbance of the epiphyseal plate was caused artificially using the pig and rabbit as experimental animals. Both the epiphyseal plate of the greater trochanter and the capital epiphysis were destroyed in different animals. Thus the coxa vara and coxa valga formations previously observed in the series of Compere (1940) and Laurent (1959) were produced. After capital epiphyseodesis a typical coxa vara was then produced. This is often observed in clinical work in connection with Legg-Perthes-Calvé disease, congenital coxa vara,



Figure 8. In this animal epiphyseodesis of the capital epiphysis was performed which resulted in coxa vara formation. The normal hip on the left.

and CDH. In sections marked by tetracycline it was observed that as the epiphyseal plate of the greater trochanter continued its growth, producing an area of bone free from tetracycline below it, a similar area also developed at the tip of the trochanter, showing that the latter grows considerably from the periosteum also.

Capital epiphyseodesis caused formation of a short neck of the femur. A malformed femoral head appeared at the same time. In addition to cessation of the growth in the epiphyseal plate, it is apparent from tetracycline lines in the diaphysis that remodelling resorption in the peripheral part of the epiphysis has also ceased. This resorption is indispensable in the upward growth of the bone in order to preserve the normal form of the proximal end of the femur (Enlow 1963). It is thus evident that growth and resorption are interconnected in the function of the epiphyseal plate.

In connection with epiphyseodesis of the greater trochanter, typical coxa valga formation with corresponding cessation of resorption and growth on the side of the trochanter were observed, while on the side



Figure 9. In a longitudinal section of the hip seen in Figure 6 the deposition of tetracycline can be seen in ultraviolet light. On the side of the greater trochanter the line in the diaphysis indicates a resorption remodelling process while on the side of the capital epiphysis the line continues to the epiphyseal plate. No growth but also no resorption has taken place on this side.

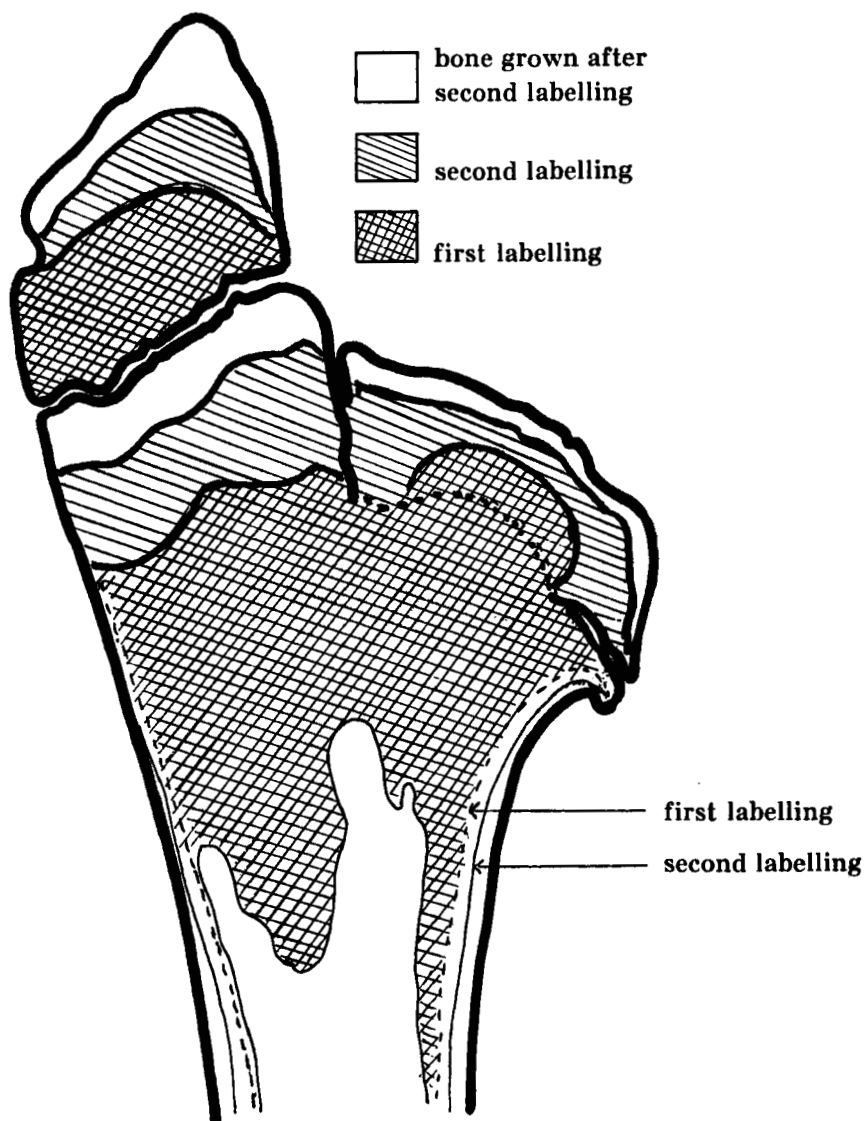


Figure 10. A schematic drawing of the changes seen in Figure 9.

of the head growth continued normally. Resorption, however, was clearly less prominent than increase of the growth. This is obviously necessary because the head and neck grow in all directions with the normal, growing animal. In normal specimens strong periosteal growth at the tip of the greater trochanter is also clearly in evidence. This ex-

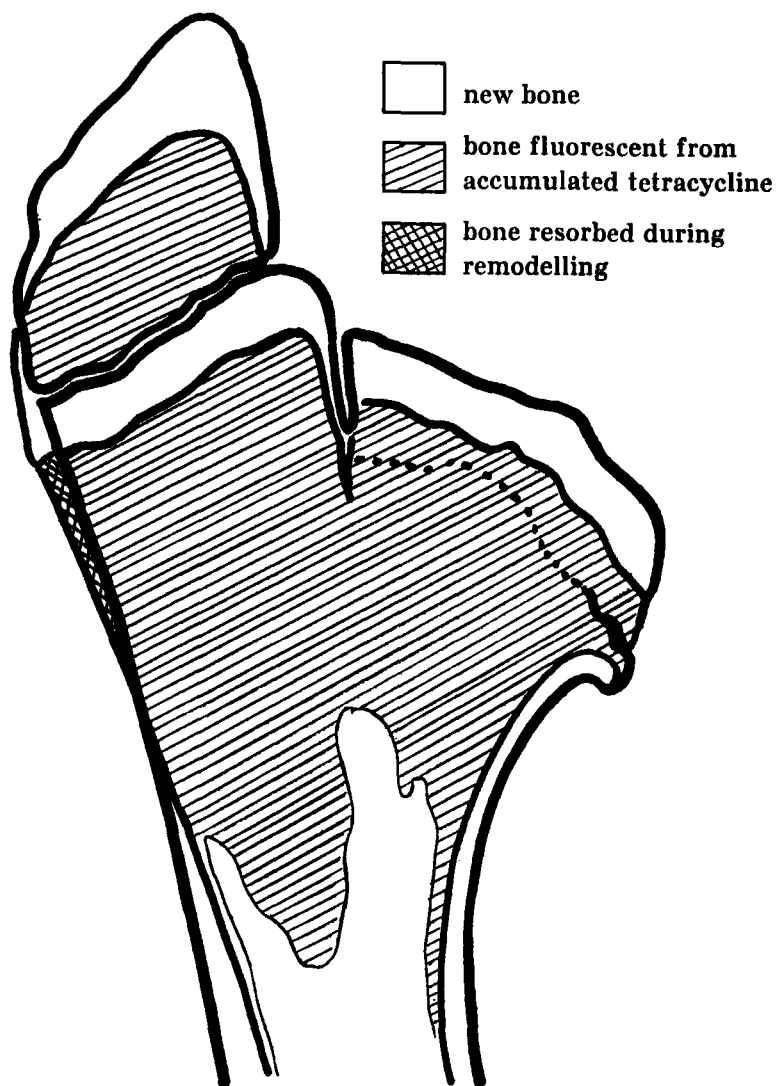


Figure 11. A schematic drawing of the changes in remodelling.

plains the fact that despite epiphyseodesis of the greater trochanter in certain cases of coxa vara, considerable growth still occurs, especially at the end of the growth period, at the tip of the greater trochanter (Langenskiöld & Salenius 1967).

Trochanteric epiphyseodesis has been used as a treatment and for prevention of coxa vara in children after Legg-Perthes-Calvé disease and in some other cases.

CONCLUSIONS

From the experiments performed on pigs, the following observations were made: (1) After epiphyseodesis of the greater trochanter, coxa valga formation developed. The growth continued on the side of the capital epiphysis. (2) The resorption ceased on the side of the epiphyseodesis whereas it continued on the side of the capital epiphysis. This was evident from the tetracycline lines in the diaphysis. (3) After epiphyseodesis of the capital epiphysis, coxa vara followed. The growth ceased on the side of the epiphyseodesis and continued on the side of the greater trochanter. (4) The resorption also ceased on the side of the epiphyseodesis but continued on the side of the greater trochanter. (5) The greater trochanter and the capital epiphyses also grow from the periosteum, but the greater trochanter more than the capital epiphysis.

SUMMARY

The authors performed experimental epiphyseodesis on the epiphyseal plates of the proximal end of the femur in rabbits and pigs. After trochanteric epiphyseodesis a typical coxa valga formation was observed, and after capital epiphyseodesis a coxa vara formation. The situation in the hip of the animal at the moment of epiphyseodesis was marked with tetracycline, and later the development of growth of the proximal end of the femur was followed by further doses of tetracycline. It was then observed that both the head and the greater trochanter grow to some extent from the epiphyseal plate and the periosteum but the trochanter considerably more from periosteum than the head. With the cessation of growth after epiphyseodesis the resorption remodelling also ceases near the particular epiphyseal plate. Resorption is evidently less prominent than was previously thought. The proximal end of the femur grows in all directions at the same time as it grows upward.

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