A Longitudinal Test of Angular Remodeling in the Tibia

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ABSTRACT After superimposing earlier and later tibial radiographs on the same proximal and distal lines of increased density in boys and girls 1.0 through 18.0 years, it was possible to show that angular axial remodeling is an uncommon feature at most.

Tubular bone remodeling is a complicated process involving shifting rates of subperiosteal apposition and resorption relative to endosteal apposition and resorption such that the outer bone surface at one age may become the inner bone surface at a later age and vice versa. Moreover, remodeling dynamics of tubular bones include sideways movement (i.e. osseous or "cortical" drifts as described by Enlow, '62, '63) as well as axial changes. Using natural bone markers (cf. Garn, Hempy and Schwager, '68) and superimposition of serial, anteroposterior radiographs, and by measuring rates of lateral movement of the marker lines, we have been able to document the phenomenon of cortical drift in the human tibia (Garn, Silverman, Hertzog and Rohmann, '68). In the present report, we have extended the longitudinal superimposition technique to test the possibility of angular remodeling in the human tibia from infancy through adolescence.

To do this we first examined serial, longitudinal radiographs of hundreds of children and selected a small pilot group characterized by well-marked "transverse" lines at both the proximal and distal ends of the tibia. This pilot group, numbering seven (5 males and 2 females) was remarkable in that the same persistent lines at both the proximal and distal aspects of the tibia could be followed for a minimum of three years and a maximum of ten. By superimposing the "earliest" and "latest" radiographs in which the pair of lines could be verified, and with due corrections for increased radiographic enlargement, it was then possible to ascertain whether the long axis of the tibia had shifted or whether the bone axis remained the same. This approach is shown diagramatically for subject 353, employing radiographs

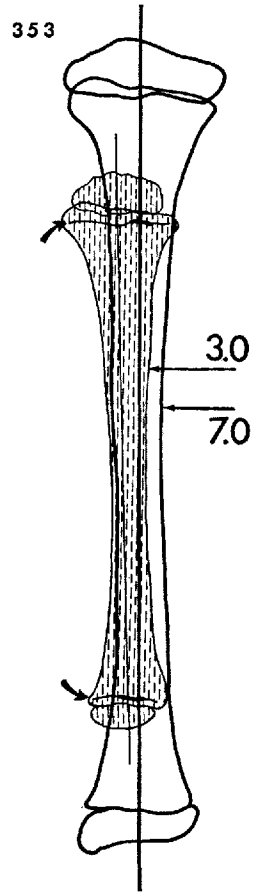

Fig. 1 Tracing of an earlier radiograph (indicated by light lines and shaded) and a later radiograph (indicated by heavier lines) superimposed on common proximal and distal transverse lines of increased density (denoted by arrows). In this example, subject 353, the tibial axis, determined by bisecting the metaphyses, has shown no demonstrable angular change over a 4-year period, though axial drift is evident.

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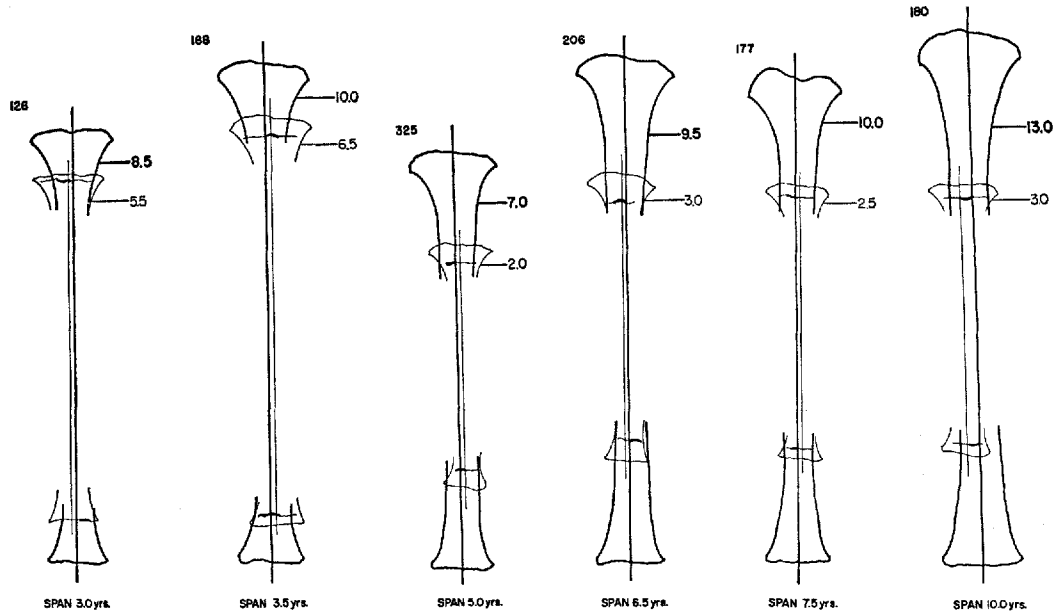

Fig. 2 Tracings of earlier radiographs (light lines) and later radiographs (heavy lines) of six subjects similarly superimposed on common proximal and distal transverse lines of increased density. As shown, over intervals of as long as ten years, there is no evidence of angular tibial remodeling since the bone axes remain parallel (cf. Garn et al., '68 — fig. 36).

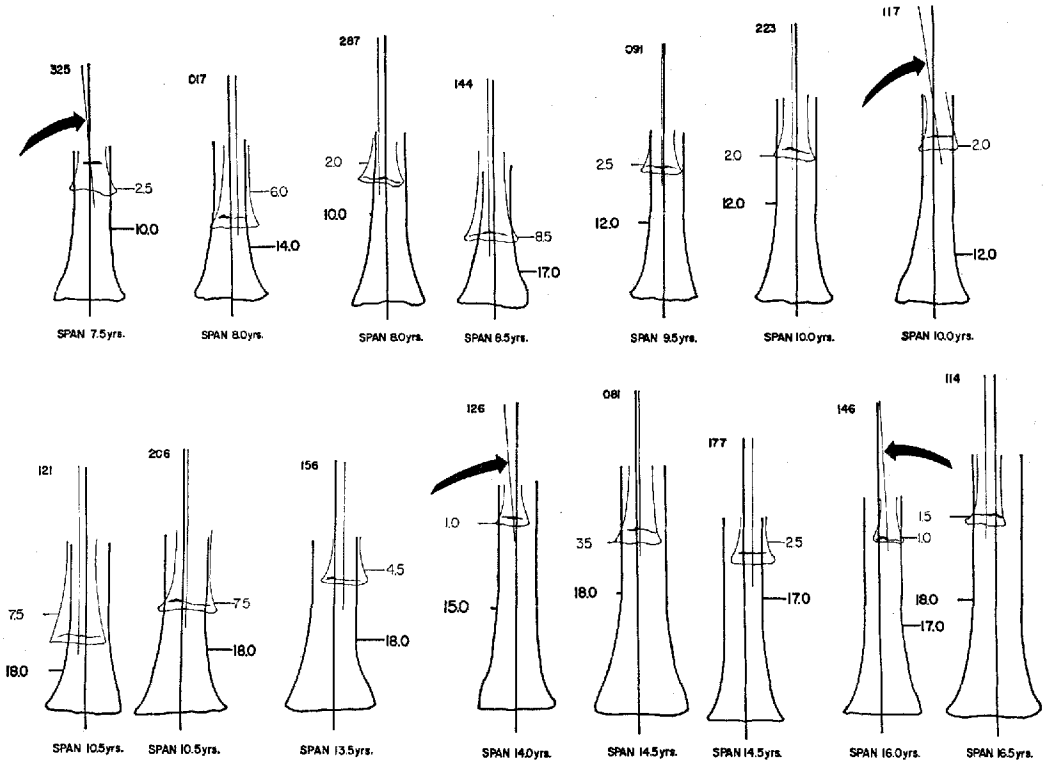

Fig. 3 Earlier and later radiographs of 15 subjects followed for periods of as long as 16.5 years and superimposed on common lines of increased density at the distal aspect of the tibia. This method of analysis similarly indicates that angular remodeling of the tibia is a relatively rare phenomenon and may not account for more than a few degrees of deviation in the axis of the tibia. As with the serial study of lines of increased density, serial superimpositions further show that isolated obliquely-placed tibial lines have developmental meaning and do not constitute evidence of successive angular remodeling (cf. Garn, Silverman, Hertzog and Rohmann, '68).

taken four years apart and superimposed — after correction for enlargement — on the same pair of proximal and distal transverse lines (fig. 1). It should be understood that the longitudinal superimposition technique cannot be easily applied where there are multiple but indistinguishable transverse lines of increased density (cf. Garn, Silverman, Hertzog and Rohmann, '68) or when the lines do not persist.

As shown in the example in figure 1 and in figure 2, these seven carefully selected subjects do not provide evidence of angular tibial remodeling over intervals of 3.0 to 10.0 years and covering the age range 2.0 to 13.0 years. Therefore, in order to extend the study, a second pilot series was developed, this time using paired and sequential radiographs superimposed on a common transverse line at the distal aspect of the tibia only. This latter series of 15 individuals, all with long-term persistent lines on the distal tibia, comprised eight boys and seven girls, it covered the age range 1.5 to 18.0 years and intervals (spans) of as much as 16.5 years.

After reviewing the serial, longitudinal radiographs of the 15 subjects with well-marked, long-persistent, distal tibial lines (excluding other subjects because of ambiguity) some degree of angular tibial remodeling was possible in 4, i.e. numbers 117, 126, 146 and 325. These four are shown in figure 3 and are specifically denoted by curved arrows. Only subject 117, however, showed unquestioned evidence of angular axial change of more than ten degrees over the entire 10-year period. For the remaining 14 subjects shown in figure 3, as with the seven depicted in figures 1 and 2, the long axis remained substantially parallel over long periods of time, as much as 16 years in some cases. Thus, angular (axial) tibial remodeling does not seem to be a regular or common feature of tibial remodeling and growth from infancy through adolescense.

Actually, angular tibial remodeling (i.e. angular axial change) must occur in some subjects, particularly those with wedge-shaped epiphyses, knock-knees or following paralytic poliomyelitis, necrosis of the femoral head, unequal extremities, etc. However, unlike transverse tibial remodeling involving simple osseous drift, which appears to be the rule in our serial, longitudinal studies (Garn, Silverman, Hertzog and Rohmann, '68) angular tibial remodeling is either relatively uncommon or of small magnitude after the age of walking. Under these circumstances, obliquely-placed lines of increased density, in the middle third of the tibia, need not be interpreted as evidence of early angular remodeling but rather may be regarded in connection with the developmental history of the bone, particularly in the first year of life.

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