Acta Orthop Scand 1996; 67 (2): 158–160

Callus formation in femur and tibia during leg lengthening

7 patients examined with DXA

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We examined the callus formation during leg lengthening in 7 achondroplastic patients who underwent 3 bilateral femoral and 4 bilateral tibial lengthenings. Bone mineral content and bone mineral density (BMD) in the lengthened callus space were evaluated every 1 or 2 weeks for 10 weeks after the start of distraction using dual energy X-ray absorptiometry. The mean rate of callus mineralization in femurs (0.64 g/wk) was higher than in tibias (0.22 g/wk). The mean BMD at 10 weeks after the start was 0.35 g/cm^2 in the femur and 0.14 g/cm^2 in the tibia. Different rates of callus formation in different kinds of long tubular bones have not been reported previously.

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Submitted 95-06-17. Accepted 95-11-22

Many factors affect the rate of callus formation during leg lengthening, such as the age of the patient (Aldegheri et al. 1989, Paley 1990), the rate of distraction (Ilizarov 1989, Yasui et al. 1993), the osteotomy level (Ilizarov 1989, Steen and Fjeld 1989), and the degree of periosteal tissue preservation at the osteotomy site (Kojimoto et al. 1988, Ilizarov 1989).

We investigated whether the callus formation during the distraction period of leg lengthening proceeds at the same rate in both femur and tibia.

Patients and methods

We studied 7 achondroplastic patients, who underwent 3 bilateral femoral and 4 bilateral tibial lengthenings. The average age at the time of the operation was 14 (8–20) years. Patient age and the AP diameter of the bone at the corticotomy level were similar in the two groups (Table 1). Leg lengthening was performed after corticotomy in the proximal diaphysis, using a monolateral bone lengthener. Weight bearing was permitted from the first postoperative day. Bone lengthening at a rate of 0.5 mm twice a day was started after callus formation was recognized on a plain radiograph, between 10 and 14 days after the corticotomy (Table 1).

We measured bone mineral content (BMC) and bone mineral density (BMD) in the distracted callus space as an indicator of the amount of callus formation, using a dual energy X-ray absorptiometer (DXA), Norland XR-26 (Norland Inc., USA). Point and line resolution were 1 mm. Scan speed was 45 mm/sec (Horinaka et al. 1990, Kusaba et al. 1994). For the femur, the patients were placed in the supine position on the couch of the scanner and scanned by posteroanterior projection. For the tibia, in order to separate it from the fibula and to make positioning reproducible, the lower leg was placed on a raised pillow in a slightly internally rotated position. The angle of internal rotation was always kept the same for each patient, placing the lower leg so that external fixator half-pins were parallel to the scanner couch.

The distracted callus space was determined in the DXA image between the proximal and distal intact bones (Figure 1). Horizontal lines were intact bone ends and vertical lines were connected proximal and distal intact bone margins. The reproducibility of the results was evaluated by 3 consecutive measurements and was 2.4% and 2.5% for BMC and BMD, respectively.

The measurements were made every 1 or 2 weeks for 10 weeks after the start of distraction, because the final gain in length and the distraction periods were not the same, but 10 weeks was the minimum distraction period.

There were no premature unions, deep pin tract infections, or angulation during the first 10 weeks of distraction. The rate of lengthening had to be reduced in most cases, because of pain or joint contracture, so

Table 1. Determinations of callus formation in achondroplastic patients using DXA

A	B	C	D	E	F	G	H	I	J	K	L
Femur											
1	16	F	r	1	14	21	70	1.036 [b]	0.998	0.428	
			l	1	14	20	70	0.800	0.968	0.365	
2	8	F	r	1	14	16	60	0.662	0.989	0.433 [b]	1
			l	1	14	17	60	0.366 [a]	0.977	0.228 [a]	1
3	20	M	r	1	14	18	60	0.490	0.969	0.286	1
			l	1	14	19	60	0.504	0.991	0.338	1
Tibia											
4	10	F	r	1	14	17	67	0.134 [a]	0.974	0.100 [a]	
			l	1	14	17	64	0.185	0.953	0.124	1
5	17	F	r	1	10	18	65	0.194	0.881	0.113	1
			l	1	10	18	69	0.210	0.873	0.130	1
6	14	M	r	2	12	24	70	0.347 [b]	0.993	0.195 [b]	1
			l	2	12	20	70	0.267	0.961	0.125	1
7	12	F	r	2	12	21	64	0.242	0.987	0.151	1
			l	2	12	20	60	0.184	0.995	0.165	1

A Case
B Age
C Sex
D Side
E Type of fixator
  1 Orthofix
  2 Hifixator
F Delay before lengthening, days
G AP diameter of osteotomy level, mm
H Gain in length at 10 weeks after start of distraction, mm
I Rate of mineralization, BMC(g)/week
  a minimum
  b maximum
J Correlation coefficient of the regression line (R)
K BMD at 10 weeks after start of distraction, g/cm^2
  a minimum
  b maximum
L Complication
  1 joint contracture

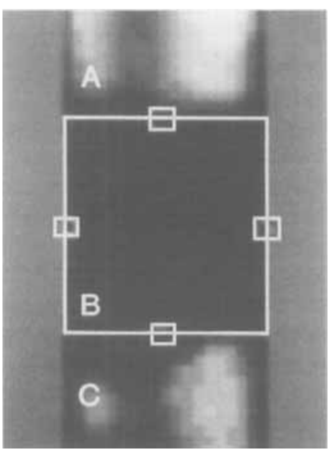

Figure 1. A representative DXA image. A. Proximal intact bone. B. Distracted callus space (demarcated by proximal and distal intact bone ends horizontally and vertically connected lines between proximal and distal intact bone margins). C. Distal intact bone.

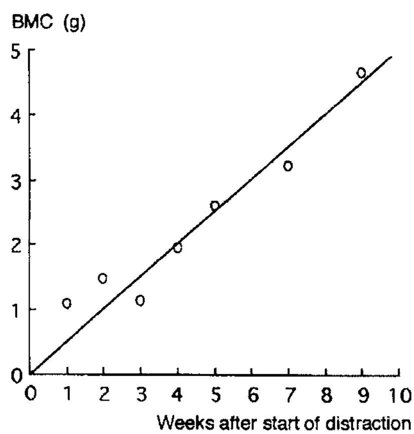

Figure 2. Case 3. Left femur: The rate of mineralization of this case is 0.50 g/week (r 0.99).

the gain in length during this period was 6.3 cm and 6.6 cm on average in the femur and the tibia, respectively.

For each patient, a single regression line was drawn on BMC data, plotted with the least squares method, and the rate of mineralization was evaluated by the inclination of this line (Figure 2).

Statistical differences were analyzed using the Mann-Whitney U-test. $P < 0.05$ was considered significant.

Results (Table 1)

The rate of mineralization (mean *SD*) in the distracted callus was 0.64 *0.24* g/week in the femur and 0.22 *0.06* g/week in the tibia. The BMD at 10 weeks was 0.35 *0.08* g/cm^2 in the femur and 0.14 *0.03* g/cm^2 in the tibia ($p < 0.01$).

Discussion

The rate of callus formation cannot be measured in vivo because the amount of distracted callus cannot be fully visualized by any practicable method. The mineralized part of the callus under distraction is the only part which can be quantitatively evaluated by measuring its mineral content. DXA entails less x-ray exposure than quantitative computed tomography (QCT), it is more reproducible and accurate than single-photon absorptiometry, dual-photon absorptiometry or QCT (Sartoris and Resnick 1989) and it can be used to measure any site on the distracted bone, without being affected by pins or leg lengthening devices (Horinaka et al. 1992). We therefore used DXA to measure callus mineralization.

The rate of mineralization was represented by the inclination of the regression line (g/week), because BMC data for each lengthened bone showed an almost linear increment each week. Most of the correlation coefficients of the single regression lines were above 0.95, and the lowest was 0.87.

Since the age of the patients and the AP bone diameter at the osteotomy levels were similar in the femoral and tibial lengthenings, we believe that the different rates of callus mineralization were caused by differences between the kinds of long tubular bones themselves. The cause of this difference is unknown.

Acknowledgements

The authors wish to thank Mr. Chikuma Hamada of the Department of Pharmacoepidemiology, Faculty of Medicine, University of Tokyo for his help with statistical analyses.

No benefits in any form have been received or will be received from any commercial party related directly or indirectly to the subject of this article.

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