Classification of the callus in limb lengthening

Radiographic study of 35 limbs

Chiaki Hamanishi[1], Yosiyuki Yasuwaki[1], Hiraku Kikuchi[1], Seisuke Tanaka[1] and Kiyosi Tamura[2]

35 calluses formed during limb lengthening were classified radiographically into 6 types: external, straight, attenuated, opposite, pillar, and agenetic. The healing indexes correlated well to the intrinsic periosteal and endosteal conditions of each type. This classification enabled us to estimate the intrinsic conditions, predict the healing index, control the daily lengthening speed, and decide to apply early augmentation of the callus.

Departments of Orthopedics, [1]Kinki University School of Medicine, and [2]Kobe City General Hospital, Japan
Correspondence: Dr. Chiaki Hamanishi, Department of Orthopedics, Kinki University School of Medicine, Oono-Higashi, Osaka-Sayama, Osaka 589, Japan. Tel +81-723 66 0221. Fax +81-723 66 0206
Submitted 91-12-29. Accepted 92-03-22

Leg-lengthening has become a less invasive and less troublesome technique since the concept of callus distracton was introduced (DeBastiani et al. 1987, Ilizarov 1969a) thanks to more simple and strong lengthening devices. The callus formation, however, has often been very poor, and prolonged application of the method increases the risk of serious complications, such as pin tract infection. Many factors affect callus formation; the lengthening speed and strategy should be chosen in each case according to the radiographic findings. We have classified the radiographic appearance of the distraction callus into 6 types.

Patients and methods

Since 1985, limb-lengthening has been performed using the Dynamic Axial Fixator (Orthofix, Italy; DeBastiani et al. 1979). Callus distraction was performed in 17 femora, 7 tibiae, 2 radius, 1 ulna, 1 humerus, and 1 metatarsus. Physeal distraction was carried out at the distal femoral growth plate in 6 cases. The classification of the callus was based on these 35 limbs in 29 patients. The etiology of the shortening was deformed femoral head (14 cases) due to congenital dislocation of the hip (11) and coxitis (2 tuberculous and 1 septic), congenital (3), fracture (3), physeal damage (3), tumor (3), short stature (2), and Perthes' disease (1).

The radiographic appearance of the lengthened callus was classified into 6 types (Figure 1).

1. *External:* barrel-like fusiform callus wider than the original bone (Figure 2).

2. *Straight:* homogeneous callus just as wide as the original bone (Figure 3).

3. *Attenuated:* callus narrower than the original bone with attenuated mid portion (Figure 4).

4. *Opposite:* callus formation or maturation mainly at the opposite side of the lengthener (Figure 5).

5. *Pillar:* poor callus only in the central portion and looking like a central pillar (Figure 6).

6. *Agenetic:* only sparse calcification in the lengthened gap (Figure 7).

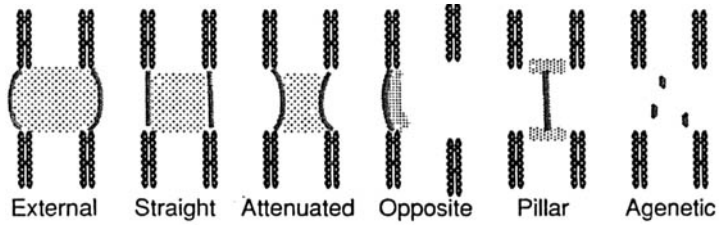
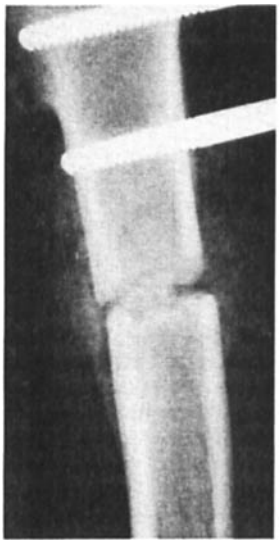


Figure 1. Classification of the distraction callus.



Massive calcification in the hematoma during a waiting period occurred.

Callus formation and maturation was so rapid that 1.5 mm of daily lengthening was possible.

Figure 2. *External type.* A 9-year-old boy had suffered from physeal trauma on the distal femur when he was 3 years old. Shortening was 5 cm. The eventual healing index was 0.8.

Figure 3. *Straight type.* A 12-year-old girl had a congenital humerus varus. The shortening of 7 cm was equalized rapidly, and the healing index was 0.8.

Callus of the attenuated type in the tibia.

The callus matured rapidly with resultant attenuated shape of the tibia.

Figure 4. *Attenuated type.* A 12-year-old girl with multiple enchondromatosis of the right tibia and femur.The healing index was 1 in both of them.

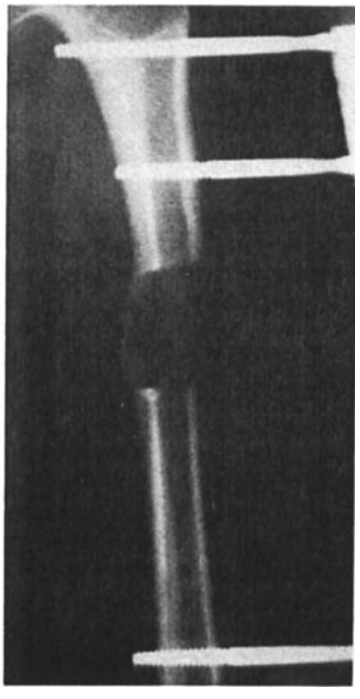


Figure 5. *Opposite type.* A 16-year-old girl with 3 cm of shortening after CDH. The callus tissue matured mainly on the opposite side of the lengthener. A slight varus deformity was observed. The healing index was 1.9.

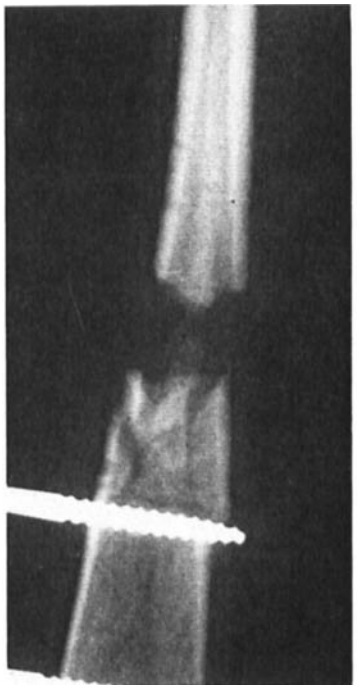


Figure 6. *Pillar type.* A 51-year-old woman had a cup arthroplasty due to coxarthrosis. Distal diaphyseal lengthening was performed to prepare for a total hip replacement. Lengthening was concluded at 2 cm due to aggravated coxalgia. Although the lengthening speed was restricted to 0.25–0.5 mm per day, the callus was produced poorly, mainly at the center.

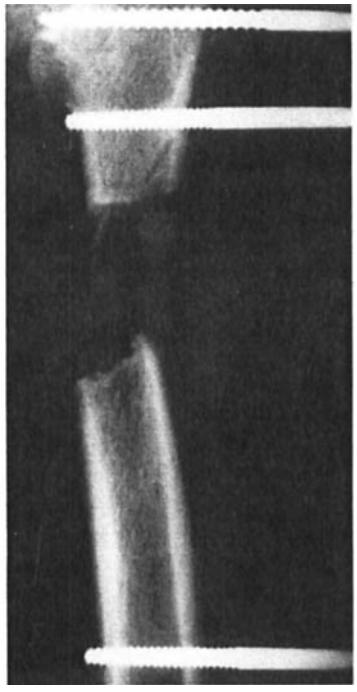


Figure 7. *Agenetic type.* A 27-year-old man with short stature due to metaphyseal chondrodysplasia. The right femur and left tibia were lengthened initially. The proximal fragment of the femur was fixed in valgus position to correct the initial varus deformity. The callus formation was good in the tibia (attenuated type), but was so poor in the femur that autogenous bone grafting was indicated.

Table 1. Types of distraction callus and healing index

	Femur	Tibia	Forearm bone	Humerus	Metatarsus	Total	Healing	
							Index	*SD*
External	8					8	1.1	*0.3*
Straight	9	4		1		14	1.3	*0.3*
Attenuated	1	3	2			6	1.5	*0.4*
Opposite	3					3	2.1	*0.2*
Pillar	1					1	4	
Agenetic	1		1		1	3	3.7	*1.1*
Total	23	7	3	1	1	35	1.7	*0.9*

The callus types and their mean healing indexes (HI, no. of months per 1 cm lengthening) are listed in Table 1.

Results

In the tibia, only straight or attenuated types were observed. Physeal distraction of the distal femur was

usually followed by a good callus of the straight type. All 6 cases of the attenuated type were observed either in tumor conditions (multiple enchondromatosis in a tibia and a femur and 2 forearm bones with osteochondromas) or in skeletal dysplasia (both tibiae of metaphyseal chondrodysplasia). The 3 cases of opposite type of callus developed only in femora, and their HI were 2.3, 2.0 and 1.9; this type resulted in varus deformity during lengthening in 2 cases and after removal of the fixator in one. The pillar type of callus was observed only in a case of distal diaphyseal femoral lengthening in a 51-year-old woman. The agenetic type of callus was observed in a radius with an HI of 3.3, in a femur of a metaphyseal chondrodysplastic patient, and in a normal metatarsus; both needed autogenous bone grafting and, when the lengthener was removed, the HI were 2.5 and 5.2, respectively.

Discussion

The distraction callus is histologically organized and longitudinally oriented in the direction of the distraction (Ilizarov et al. 1969b, Kojimoto et al. 1988, Ilizarov 1990). The volume of the initial unorganized callus depends on periosteal and endosteal conditions, and is affected by intrinsic factors such as age, nutrition, systemic disease, pathological skeletal conditions, bone diameter, cortico-medullary ratio, site of the osteotomy, previous injuries or operation, tumors, and vascularity of the surrounding tissues. Technical factors such as lengthening speed and rigidity of the fixator also affect the maturation and corticalization of the callus. Cases of defective callus formation have seldom been mentioned or reported, possibly because they are so few, but also because they have been considered as intraoperative or postoperative technical failures (Catagni 1991) rather than the expression of poor intrinsic conditions. However, each of our 6 grades appeared to reflect intrinsic periosteal conditions and correlated well with the healing index. The external and straight types of callus represent the sound periosteum-dominant callus formation in contrast with the very defective pillar type in which only the endosteum seemed to participate in the callus formation as found in experiments (Kojimoto 1988). Poor intrinsic factors such as tumors and systemic skeletal conditions may cause the attenuated type, as our 6 cases indicated. The opposite type calluses may be caused by stress protection from the rigid fixator with angulation deformity as a result. Valgus deformity in the tibia occurred less often because the distance from the lengthener to the bone was shorter and bending of the screws was less likely. The agenetic type of the callus in two cases was suspected to be a result of so poor intrinsic conditions that autogenous bone grafting was needed.

The classification of the callus enabled us to judge the intrinsic conditions, to predict the healing index, and to control the daily lengthening speed. If the callus is opposite, pillar or agenetic, the lengthening speed should be lowered to 0.25 mm per day or stopped temporarily, and augmentation by autogenous bone grafting, bone marrow transplantation (Ohgusi et al. 1989) or early controlled dynamization should be considered.

References

Catagni M. The radiographic classification of bone regenerate during distraction. In: Operative Principles of Ilizarov (Ed. Maiocchi, A. B, Aronson, J.) Williams & Wilkinson, London 1991; 5: 53–7.

DeBastiani G, Aldegheri R, Renzi Brivio L. Fissatore esterno assiale. Chir Organi Mov 1979; 65 (3): 287–93.

DeBastiani G, Aldegheri R, Renzi Brivio L, Trivella G. Limb lengthening by callus distraction (callotasis). J Pediatr Orthop 1987; 7 (2): 129–34.

Ilizarov G A. Clinical application of the tension stress effect for limb lengthening. Clin Orthop 1990; 250: 8–26.

Ilizarov G A, Deviatov A A. Operative elongation of the leg with simultaneous correction of the deformities. Ortop Travmatol Protez 1969a; 30: 32–7.

Ilizarov G A, Lediaev V I, Shitin V P. The course of compact bone reparative regeneration in distraction osteosynthesis under different conditions of bone fragment fixation (experimental study). Eksp Khir Anesteziol 1969b; 14 (6): 3–12.

Kojimoto H, Yasui N, Goto T, Matsuda S, Shimomura Y. Bone lengthening in rabbits by callus distraction. The role of periosteum and endosteum. J Bone Joint Surg (Br) 1988; 70 (4): 543–9.

Ohgushi H, Goldberg V M, Caplan A I. Repair of bone defects with marrow cells and porous ceramic. Experiments in rats. Acta Orthop Scand 1989; 60 (3): 334–9.