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The Time of the Fracture Union and the Influence of Growth upon Angular Deformity of Rat's Tibia

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Introduction

Spontaneous correction of angular deformity of the growing long bone is well-known phenomenon in clinical practice (Blount 1955, Sharrard 1971, Ryöppy 1972). It is obvious that the anteroposterior angulations are more easily corrected than the lateral angulations. Coxa vara deformity, after hip fracture remains as a permanent deformity and there is no change in the neck angle as result of growth, but if subtrochanteric pelvic support osteotomy was performed to stabilize a dislocated hip, then its effectiveness gradually diminishes and the angulation osteotomy must be repeated (Blount 1955).

The mechanism of this process and the factors influencing it are still not known clearly. It is generally accepted that the straightening of the deformity caused by a malunited fracture is due mainly to apposition and resorption at the fracture site (Frost 1964). The bone is normally exposed to the action of gravity, acceleration and deceleration forces, and forces due to the action of muscles. Aegerter and Kirkpatrick (1968) have reported that the spontaneous correction of angular deformity has been noted as piezoelectric phenomenon that a curved of deformed cylindrical bone is electronegative on the concave side and positive on the convex; so the osteoblastic activity is accentuated in concave side due to the osteoblastic drift and osteoclastic activity in convex side due to the osteoclastic drift.

The purpose of this study was to find out to what extent and speed of the spontaneous correction of the artificially made deformity of rat tibia may occur, and what influence it has to bony growth. Also the time of clinical and radiological union was determined.

Material and Methods

Under general anesthesia with ether, a closed fracture was made manually in the left hind leg of Sprague-Dawley rats aged 3 weeks and left them alone without immobilization. After the fractures had stabilized, one week after fracture, the animals were examined radiologically at regular intervals and 15 were chosen for the study. X-ray pictures were taken in prone position of the animals under general anesthesia with 40 inches distance, 300 mA, and 47 K.V.P. of irradiation at one, three, five and eight weeks after fracture. Such method of X-ray projections was the same result of lateral

Table 1. Growth of proximal, distal fragments and total length of tibia

Length / Wks.	Prox. frag.		Dist. frag.		Total length	
	Average daily growth	% of growth	Average daily growth	% of growth	Average daily growth	% of growth
4— 6	0.15mm	41.2	0.05mm	41.5	0.20mm	41.3
6— 8	0.11mm	30.2	0.03mm	25.8	0.14mm	28.0
8—11	0.07mm	28.6	0.02mm	32.7	0.09mm	30.7

wks: weeks Dist.: distal Prox.: proximal frag.: fragment

Table 2. Angle and % of correction of each cases

Case	1 wk. after fx.	3 wks. after fx.		5 wks. after fx.		8 wks. after fx.		Total % of
	angle	angle	% of correction	angle	% of correction	angle	% of correction	correction
1	50′	34′	80	31′	15	30′	5	40.0
2	31′	18′	81	16′	13	15′	6	51.6
3	50′	34′	76	31′	14	29′	10	42.0
4	28′	21′	58	16′	25	16′	17	42.9
5	46′	42′	21	35′	37	27′	42	41.3
6	39′	25′	63	20′	23	17′	14	56.3
7	54′	48′	50	45′	25	42′	25	22.2
8	25′	20′	50	18′	20	15′	30	40.0
9	27′	19′	62	17′	15	14′	23	48.2
10	41′	34′	33	21′	62	20′	5	51.2
11	36′	27′	82	25′	18	25′	0	30.6
12	−12′	−7′	63	−5′	25	−4′	12	66.7
13	38′	28′	77	26′	15	25′	8	34.2
14	−18′	−10′	67	−9′	8	−6′	25	66.7
15	42′	30′	70	27′	18	25′	12	40.5

Fx.: fracture wk.: week —: posterior angulation

projection of the rat's tibia, so we could measure only the anterior and posterior angulations. The degree of angulation and the longitudinal growth of the tibia were registered on the radiographs. The length of proximal and distal fragments of fractured tibia was measured with calipers permitting an accuracy to 0.1mm, from the center of the fracture sites to the proximal and distal epiphyseal plates, and then compared it to the normal side of each right tibia. The degree of angulations was represented by the angle between the long axis of the proximal and distal fragments. Before taking the radiographs, authors examined the fracture sites clinically to confirm the presence of local swelling and pseudomotion, and also by X-ray determined the time of radiological union of the fractures.

Results

A) The rate of growth in length;

Closure of the proximal and distal growth plates of the fractured left tibia and normal right tibia was noted in the radiographs of

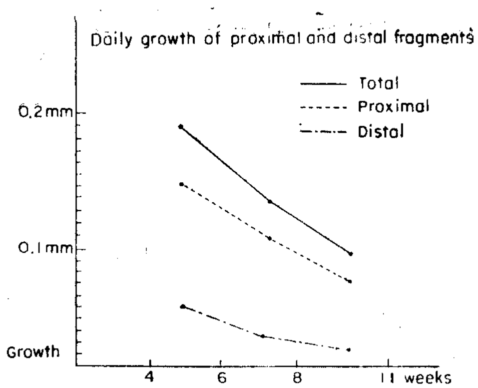

Fig. 1

eleven weeks of age. The longitudinal growth from the proximal epiphyseal plate was average 5.16 mm during four to eleven weeks of age and 1.50 mm from the distal epiphyseal plate during same periods; Therefore, 77.5% of longitudinal growth of thetibia occurred in the proximal epiphyseal plate. The rate of longitudinal growth of the tibia was maximum between the fourth and sixth week during which period the daily growth of the tibial length was 0.20 mm. The daily average growth was 0.14 mm during the age of six to eight weeks, and 0.09 mm during the age of eight to eleven weeks. The average actual length of the fractured tibia was 31.3 mm at the age of eleven weeks and it was 0.9 mm longer than the average length of normal tibia.

The average length of the fractured tibia at the certain ages, and the daily growth of proximal and distal fragments of tibia are shown in Table 1, and Fig. 1.

B) The spontaneous correctability of angulation;

The animals were divided into two groups; one with mild angulation (0°-30°) and the other with moderate to severe angulation (31°-60°). In fifteen rats, two had posterior angulation and the others anterior one. The angle and percentage of correction of each case are shown in Table 2. The maximum correction occurred in two cases of posterior angular deformity and the magnitude of correction was 66.7% of total angulations. The percentage of spontaneous correction was 53% of total angulations in group Ⅰ and 41% in group Ⅱ. But in group Ⅰ, two cases of posterior angulation were included, therefore the difference in percentages of both groups is not statistically significant. During one to eight weeks after fracture, the angular deformity was spontaneously corrected about 45% of its total deformity. Correction was quite rapid between one to three weeks after fracture, then slowed down and became more even. During this periods, 62.3% of total correction was obtained. The posterior angulation was better corrected than anterior one. The rate of correction in cases with severe angulation was more rapid during the initial phase than in cases with mild angulation.

Percentage of spontaneous correction of

Teble 3. Percentage of spontaneous correction of angular deformities

Number		Average initial angle	Average terminal angle	% of correction			
				4—6 wks.	6—8 wks.	8—11 wks.	Total
Group Ⅰ (0'—30')	5	22'	11'	59.8	18.6	21.6	53
Group Ⅱ (31'—60')	10	43,	26'	63.5	24.0	12.5	41
Total	15	36'	21'	62.3	22.0	15.6	45

wks.: weeks

angular deformities in two groups are shown in Table 3.

C) The time of fracture union;

Three weeks after fracture, the fracture sites were stable, and no local soft tissue swelling or pseudomotion were present. Good and solid callus formed around the fracture sites which was verified by radiographs. Radiographs of 5 weeks after fracture disclosed no increasement of angulation since previous survey, while the more correction obtained. Those observations definitely explained the fracture union at three weeks after fracture.

Discussion

It is the generally recognized fact that spontaneous correction of the artificially produced certain deformities of growing long bone can occur (Pauwel 1950, Blount 1955, Sharrad 1971, Ryöppy 1972), and that correction is caused by the bone remodelling mechanism. Ryöppy and Karaharju (1974) reported that the corrective mechanism possibly acting in the remodelling of the growing long bone are local remodelling of diaphyseal deformity by the absorption and resorption, and asymmetric growth of physis.

In this experiment authors also could observe remodelling in the deformed shaft, but could not clarify which one of these two mechanisms played key role in corrective process yet. Authors are now doing the further investigation to solve this mechanisms by injuring the physis of the affected bone, and periosteum around the fracture site.

It is the known fact that younger the animal more correction is obtainable, and more correction is expected when deformity is located nearer to the physis. To equalize the local factors, authors produced fracture in midshaft of tibia. The rate and amount of correction is influenced by many factors; That is the site of fracture, age, and the presence of associated epiphyseal injury etc. In this experiment 62.3% of total correction was obtained within one to three weeks after fracture (four to six weeks of age), and 67 % of correction in the two cases of posterior angulation. These data are in accordance with Ryöppy's report. Growth contribution by the proximal tibial physis is known to be 55-57% of total growth of human tibia (Salter & Harris, 1963) and remaining growtn by the distal one, while 27% of growth increment by proximal epiphysel plate of rabbit was obtained when distal plate was destroyed (Hall-Craggs, 1969). Tapp (1966) reported that growth from proximal plate of mouse tibia was the most active between three to five weeks of age and daily average growth was 0.15-0.23 mm, and only 0.07 mm between twelve to thirteen weeks of age. Total average growth per day was 0.18-0.50 mm between three to five weeks of age. In this experiment daily average growth from the proximal epiphyseal plate was 0.15 mm between age of four to six weeks, and average daily tibial growth was 0.20 mm. All those data are also similar to other reports.

Ryöppy and Karaharju, also reported daily average growth of mouse tibia was 0.18 mm between age of three to five weeks. Thereafter growth slows down and average daily growth is 0.10 mm at age of nine weeks. He found no growth difference between fractured tibia and unfractured one. But it is generally accepted view that a diaphyseal fracture stimulates growth of the affected bone. In human femur, overgrowth is expected to develop by 9-12 months after injury (Blount, 1955). Authors in this experiment found 0.9

mm overgrowth of fractured tibia when they measured length of both tibiae, but functional length of deformed tibia with mild angulation was 1 mm shorter than the normal one. These are practically negligible leg length discrepancy. In Greiff's experiment (1975) fractured tibia which was immobilized by intramedullary Kirschner wire fixation united within three to four weeks. In our series, all fractured tibiae united in three weeks after fracture. This fact suggests that certain local factor plays role in fracture healing, and the immobilization is not ssential element for fracture healing.

Summary

The artificially produced angular deformity of tibia of fifteen rats were followed up by regular X-ray studies with two to three weeks intervals to estimate the spontaneous correctability of the deformity by growth. Also growth contribution of proximal and distal tibial growth plates and the time of union after fracture were estimated.

The result obtained were as follows;

1. The longitudinal growth of tubular bones of rat ceased at about eleven weeks of age by the spontaneous closure of the epiphyseal plate.

2. The experimentally produced angular deformity was spontaneously corrected about 45% of its total deformity during four to eleven weeks of age, and maximum correction was obtained during one to three weeks after fracture. During this periods, 62.3% of total correction was obtained.

3. The posterior angulation was better corrected than anterior one.

4. The maximum tibial growth occured in four to six weeks of age and about 77.5% of total tibial length was due to the growth of the proximal epiphyseal plate.

5. The daily growth of tibia during four to six weeks of age was 0.20 mm/day, 0.14 mm/day in six to eight weeks and 0.09 mm/day in eight to eleven weeks.

6. Three weeks after fracture, the fracture united solidly clinically and radiologically.

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—국문 초록—

성장이 골절후 발생한 경골의 굴변곡형에 미치는 영향 및 골절부 골유합의 시기

가톨릭의과대학 정형외과학교실

우 영 균·문 병 상

저자들은 성장기 흰쥐의 경골에 인위적인 골절을 일으킨 후 합병한 굴곡변형의 자연교정 과정과 골절이 경골근위 및 원위부 성장판에 의한 경골성장에 미치는 영향을 X-선상으로 관찰하였으며 또한 골절부의 골유합의 시기를 X-선 및 임상적으로 관찰하여 다음과 같은 결론을 얻었다.

1) 흰쥐의 선상골성장은 X-선상 성장판이 생후 11주에 폐쇄되는 것으로 보아 이 시기를 전후로 하여 성장이 끝남을 알았다.

2) 성장기 흰쥐의 경골에서 유발된 굴곡변형은 평균 45% 자연교정이 가능하며 골절후 1~3주 즉 생후 4~6주 사이에 가장 많이 교정되며 이 시기에 일어나는 자연교정은 전체 자연교정의 62.4%를 차지하였다.

3) 후방굴곡변형이 전방굴곡변형보다 자연교정이 더 잘 되었다.

4) 경골의 성장은 생후 4~6주 사이가 가장 활발하였으며 근위부 골성장판에서의 성장은 경골 전체 성장의 77.5%를 차지하였다.

5) 경골의 평균성장은 생후 4~6주 사이에는 일평균 0.20 mm, 생후 6~8주에는 일평균 0.14 mm, 8~11주에는 일평균 0.09 mm의 속도로 성장함을 알았다.

6) X-선 및 임상적으로 골절부 골유합은 골절 3주후에 충분히 일어남을 알았다.

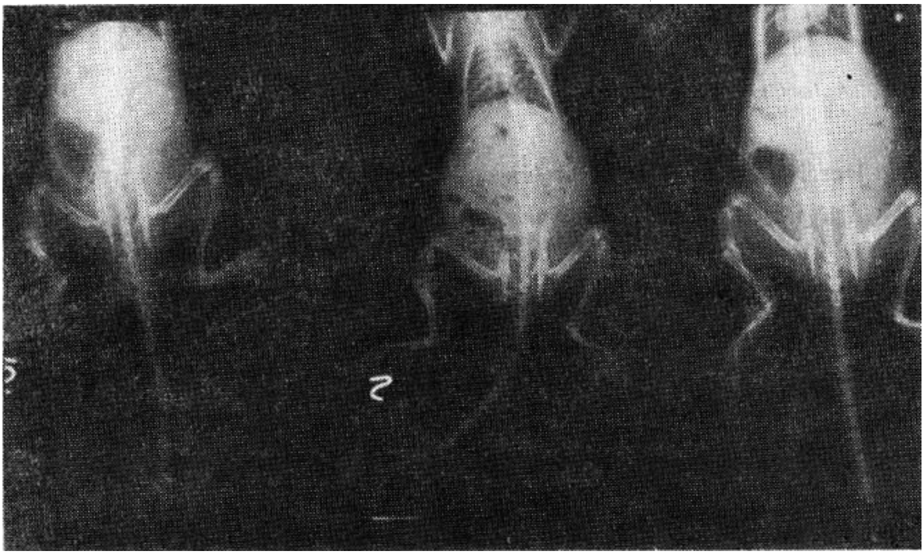

Fig. 1-1. One week after fracture; There are much callus around the fracture site with anterior angulation.

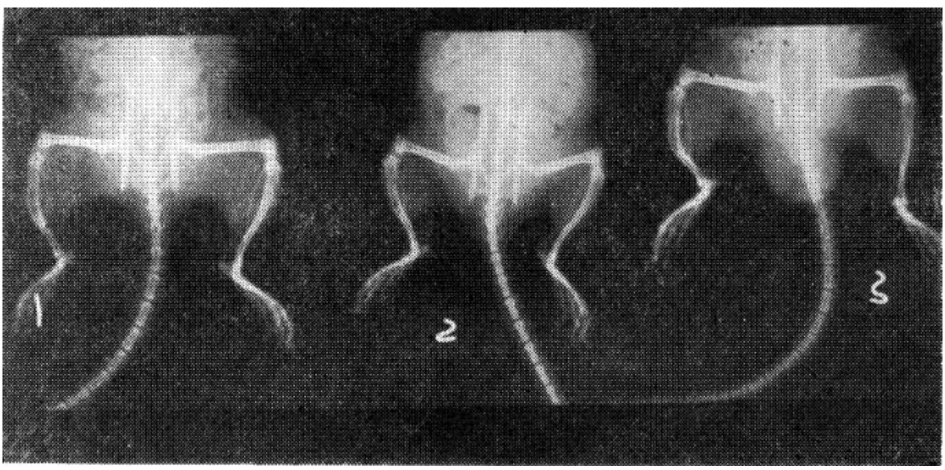

Fig. 1-2. Eight weeks after fracture; Angular deformities are more corrected than before and proximal fragments shows more growth than previous ones.

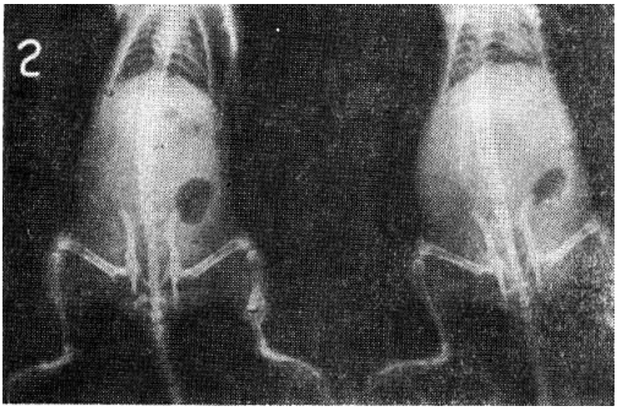

Fig. 2-1. One week after fracture; Rat on left side has posterior angulation of tibia with exuberant callus around the fracture, while rat on right side has anterior angulation of fractured tibia.

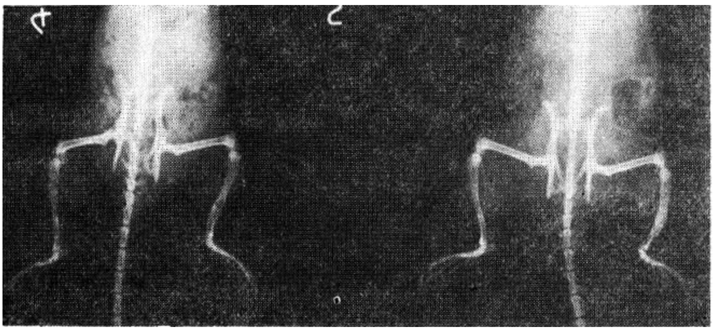

Fig. 2-2. Five weeks after fracture; Posterior angulation is well corrected than anterior ones.

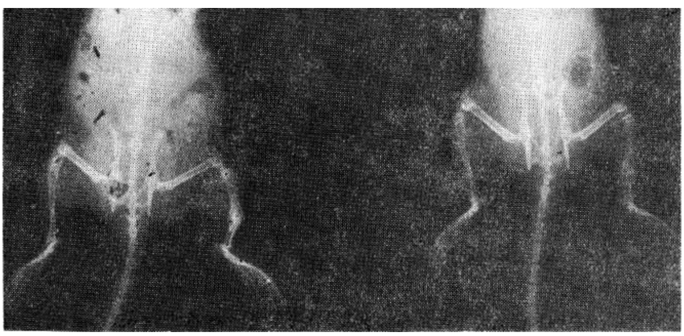

Fig. 2-3. Eight weeks after fracture; Posterior angulation tibia attained almost normal straight contour while anterior angulation is less corrected.