

AN ATTEMPT TO EXPLAIN FRACTURE TYPES

Experimental studies on rabbit bones.

By

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INTRODUCTION

Clinically, certain types of fracture are considered to be due to specifically described forces. This is most common in fractures close to the joints. In the lower part of the human tibia supination and pronation traumas are often spoken of without there being sufficient experimental background to support the statements. Still less is known about the origin of diaphysial cracks, whether they are of a transverse, spiral or comminuted type. From a theoretical point of view a correlation might be expected between the impinging forces and the type of fracture. If so, the X-ray should reveal something about the accident behind the trauma.

In recent years attempts have been made in various centres to study fracture types in certain bones by experiments on autopsy material. (*Evans, Lebow 1952, Smith 1953*).

PLAN OF INVESTIGATION

Our intention has been to study the reasons for the different localities and types of fractures in the tibia and femur in rabbits. In order to make this possible special mechanical conditions have been created. Simple combinations of stress, static as well as dynamic, have been used. Although these arrangements were artificial, they afforded us an opportunity of making comparable experiments.

MATERIAL AND METHODS

Fresh bones from young rabbits, 53 tibias and 46 femurs were tested, X-rayed and registered. In 90 experiments all soft tissues were

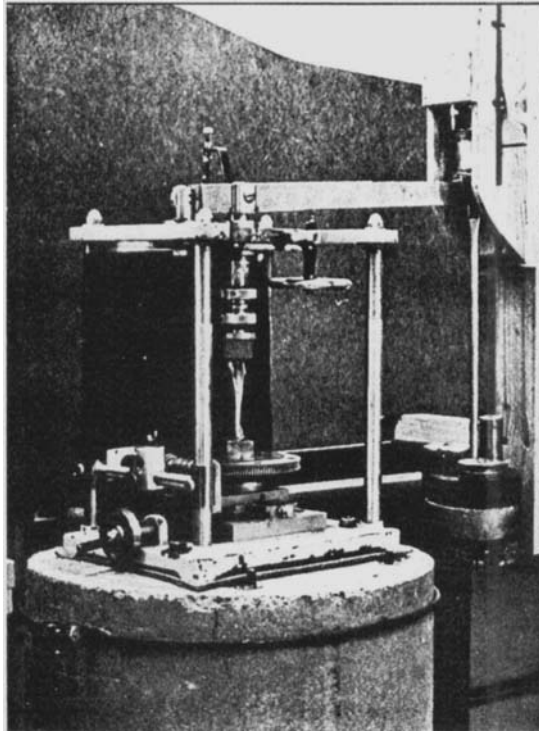


Fig. 1.

Total view of the experimental devices.

removed. In 9 of them ligaments, tendons and muscles were left, but they did not alter the results.

The fractures were produced in a compression apparatus according to Fig. 1. The devices allowed a firm fixation in various positions. The bones have been subjected to forces acting:

1. In a vertical direction.
2. In an oblique direction (15°).
3. By twisting 5° – 15° in a vertical as well as in an oblique position.

The fractures were produced by:

1. Slowly increasing weights.
2. A falling standard weight.

RESULTS

*Tibia.**Loading in a vertical position.*

Metaphysial fractures occurred at below 100 kg loading. Out of these, 4 were in the upper metaphysis, and 2 in the lower. Diaphysial fractures occurred upon a loading above 100 kg. 3 were in the lower third of the diaphysis and 1 in the upper third (Table 1 and Fig. 2).

TABLE 1
Tibia. Loading in a vertical position.

Case no.	Fract. weight kg	Type of fracture
1	64	Upper metaphysis
2	91	Upper metaphysis
3	85	Upper metaphysis
4	55	Upper metaphysis
5	76	Lower metaphysis
6	85	Lower metaphysis
7	140	Lower third of diaphysis
8	106	Lower third of diaphysis
9	130	Lower third of diaphysis
10	145	Upper third of diaphysis

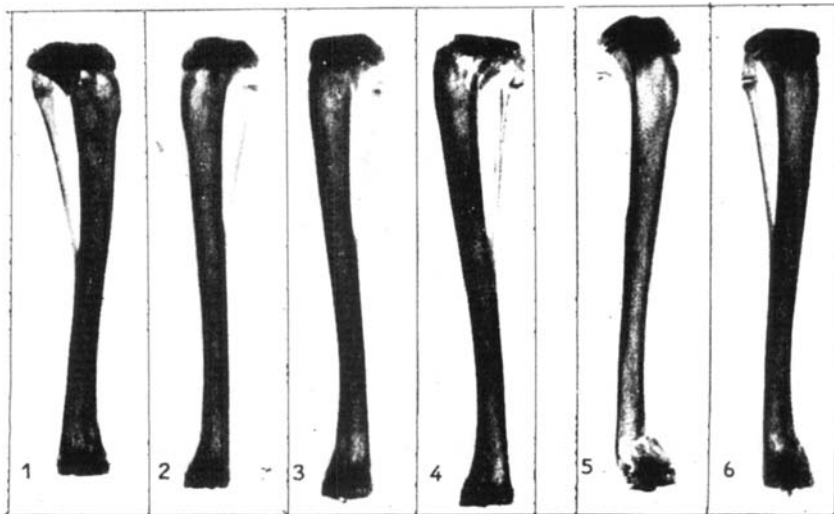


Fig. 2.

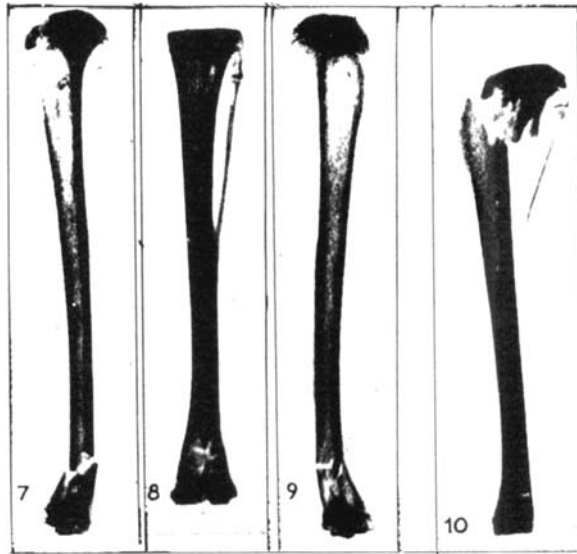


Fig. 2.

Loading in an oblique position.

5 metaphysal fractures, all caused by a greater force than those which occurred in vertical loading. 4 of the fractures were in the upper metaphysis, and 1 in the lower. 4 fractures were diaphysal in the lower third of the tibia (Table 2 and Fig. 3).

TABLE 2
Tibia. Loading in an oblique position.

Case no.	Angle of oblique position	Fract. weight kg	Type of fracture
11	e. 15°	94	Upper metaphysis
12	„ 15°	130	Upper metaphysis
13	„ 15°	135	Upper metaphysis
14	„ 15°	91	Upper metaphysis
15	„ 15°	115	Lower metaphysis
16	„ 15°	115	Lower third of diaphysis
17	„ 15°	155	Lower third of diaphysis
18	„ 15°	120	Lower third of diaphysis
19	„ 15°	130	Lower third of diaphysis

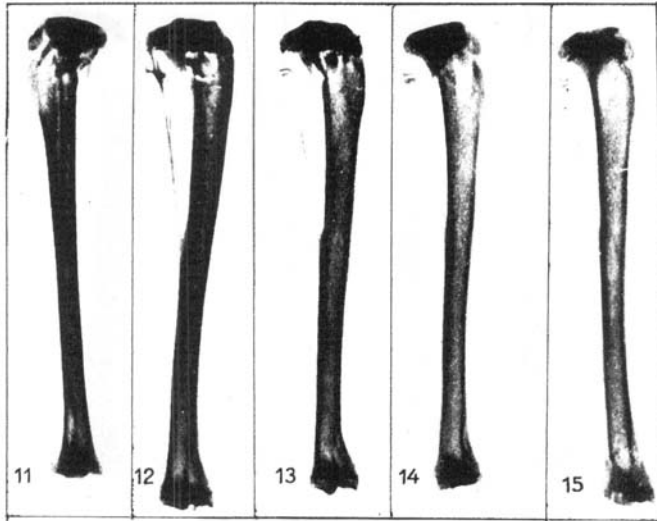


Fig. 3.

Both the metaphysial and the diaphysial fractures occurred upon a loading about or above 100 kg.

In oblique loading the metaphysis seems to escape the influence of the lower force, and the fracture then occurs at the same weight as used for the diaphysis fracture.

Hitting in a vertical position.

Out of 4 fractures 3 were metaphysial with epiphysial displacement (Table 3 and Fig. 4).

TABLE 3
Tibia. Hitting in a vertical position.

Case no.	Load kg	Blow kp	Type of fracture
20	25	27	Lower third of diaphysis
21	25	27	Displaced upper epiphysis with fracture
22	25	27	Displaced upper epiphysis with fracture
23	25	27	Displaced lower epiphysis with fracture

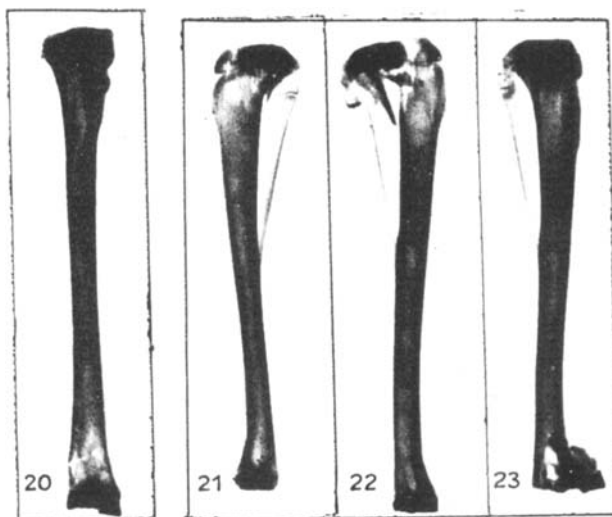


Fig. 4.

Hitting in an oblique position.

All the 5 fractures produced were extremely comminute, diaphysial fractures (Table 4 and Fig. 5).

TABLE 4
Tibia, Hitting in an oblique position.

Case no.	Load kg	Blow kp	Angle of oblique position	Type of fracture
24	25	27	c. 15°	Comminuted lower diaphysis
25	25	27	„ 15°	Comminuted lower diaphysis
26	25	27	„ 15°	Comminuted upper diaphysis
27	25	27	„ 15°	Comminuted middle diaphysis
28	25	27	„ 15°	Comminuted upper and middle diaphysis

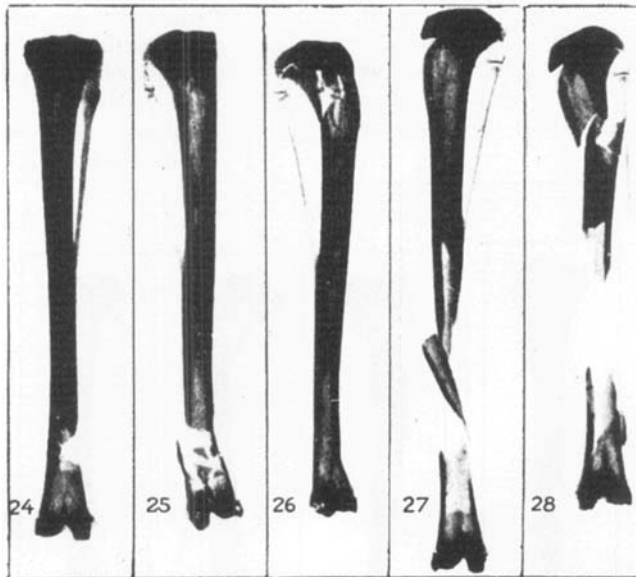


Fig. 5.

Fracturing by twisting in a vertical position.

The bone is loaded with 40 kg. This is not enough to break it. It is then twisted until it breaks. See Fig. 7.

A spiral diaphysial fracture is produced when the bone is twisted about 10°–15° (Table 5 and Fig. 6).

(In the devices used it was necessary to put on 40 kg in order to perform the twisting).

TABLE 5
Tibia. Fracturing by twisting in a vertical position.

Case no.	Load kg	Angle of twisting	Type of fracture
29	40	10°-15°	Spiral, upper third of diaphysis
30	40	10°-15°	Spiral, upper third of diaphysis
31	40	10°-15°	Spiral, upper third of diaphysis
32	40	10°-15°	Spiral, lower third of diaphysis
33	40	10°-15°	Spiral, lower third of diaphysis
34	40	10°-15°	Spiral, lower third of diaphysis

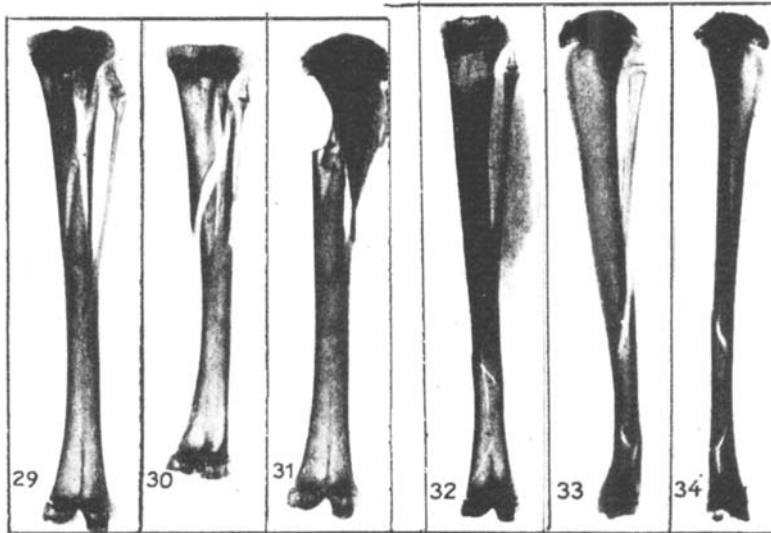


Fig. 6.

Twisting and loading in a vertical position.

6 tibiae were twisted 10° and then subjected to increasing loads. In all the bones fractures occurred at loads between 103 and 127 kg. 4 were close to the upper metaphysis, and 2 were middle diaphysis (Table 6).

Twisting and hitting in a vertical position.

The fractures were of the same type as those where no twisting was used: displaced fractures were close to the metaphysis (Table 7).

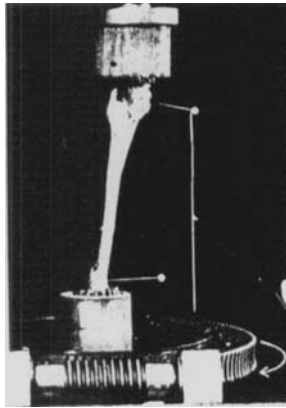


Fig. 7.

The method of measuring the degree of twisting.

TABLE 6
Tibia. Twisting and loading in a vertical position.

Case no.	Fract. weight kg	Angle of twisting	Type of fracture
35	103	8°-10°	Comminuted upper metaphysis
36	125	8°-10°	Comminuted upper metaphysis
37	110	8°-10°	Comminuted upper metaphysis
38	110	8°-10°	Comminuted upper metaphysis
39	127	8°-10°	Comminuted middle diaphysis
40	125	8°-10°	Comminuted middle diaphysis

TABLE 7
Tibia. Twisting and hitting in a vertical position.

Case no.	Load kg	Blow kp	Angle of twisting	Type of fracture
41	25	27	8°-10°	Comminuted upper diaphysis
42	25	27	8°-10°	Upper metaphysis
43	25	27	8°-10°	Lower diaphysis
44	25	27	8°-10°	Lower diaphysis

Twisting and loading in an oblique position.

All the fractures occurred at or above 100 kg. 2 were at the upper metaphysis and 3 were diaphysial. These fractures were of the same type as in oblique loading without twisting (Table 8).

TABLE 8
Tibia. Twisting and loading in an oblique position.

Case no.	Fract. weight kg	Angle of twisting	Angle of obli- que position	Type of fracture
45	100	8°-10°	c. 15°	Upper metaphysis
46	100	8°-10°	„ 15°	Upper metaphysis
47	130	8°-10°	„ 15°	Upper third of diaphysis
48	125	8°-10°	„ 15°	Lower third of diaphysis
49	110	8°-10°	„ 15°	Lower third of diaphysis

Twisting and hitting in an oblique position.

The same forces were used as in the non-twisted cases. All the fractures were comminuted, 2 in the upper metaphysis and 2 in the lower diaphysis (Table 9).

TABLE 9
Tibia. Twisting and hitting in an oblique position.

Case no.	Load kg	Blow kp	Angle of twisting	Angle of obli- que position	Type of fracture
50	25	27	8°-10°	c. 15°	Comminuted upper metaphysis
51	25	27	8°-10°	„ 15°	Comminuted upper metaphysis
52	25	27	8°-10°	„ 15°	Comminuted lower third of diaphysis
53	25	27	8°-10°	„ 15°	Comminuted lower third of diaphysis

Femur.

Loading in a vertical position.

All the bones fractured at between 40 and 70 kg., on an average 50-60 kg. The fractures were at the distal end of the bones, 6 in the metaphysis and 3 in the distal part of the diaphysis (Fig. 8 and Table 10).

Loading in an oblique position.

The femur is put in an oblique position in such a way that the gravity line from the greater trochanter cuts the anterior cortex somewhere in the middle of the bone (Fig. 10 a and b).

TABLE 10
Femur. Loading in a vertical position.

Case no.	Fraet. weight kg	Type of fracture
1	64	Lower metaphysis
2	76	Lower metaphysis
3	35	Lower metaphysis
4	49	Lower metaphysis
5	55	Lower metaphysis
6	50	Lower metaphysis
7	50	Lower third of diaphysis
8	40	Lower third of diaphysis
9	55	Comminuted lower third of diaphysis

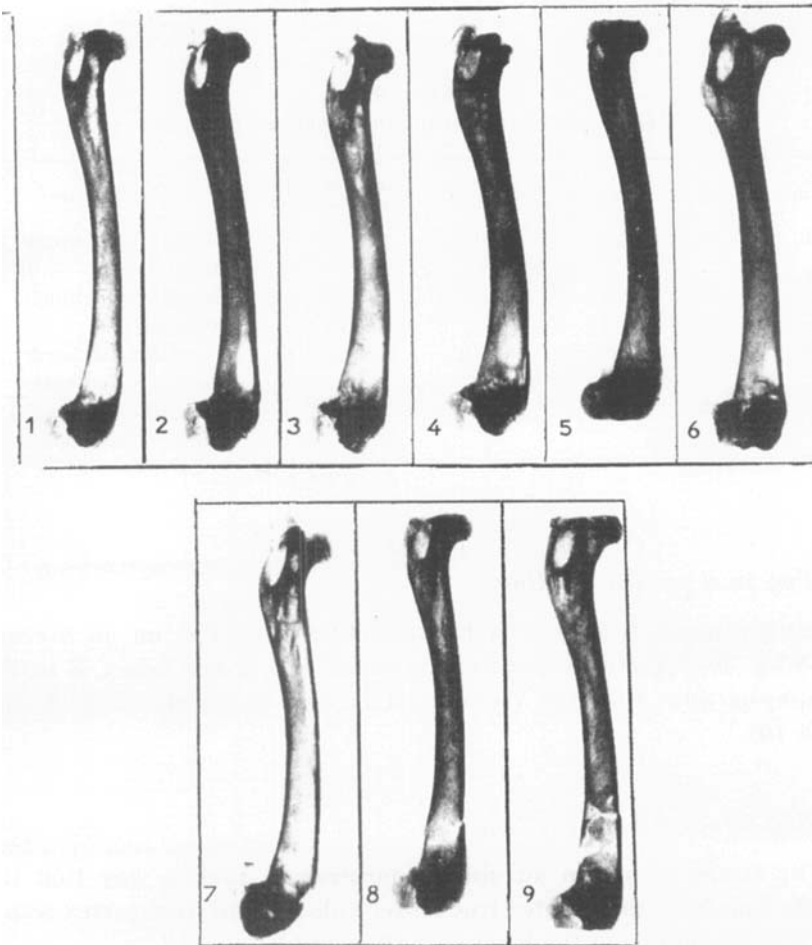


Fig. 8.

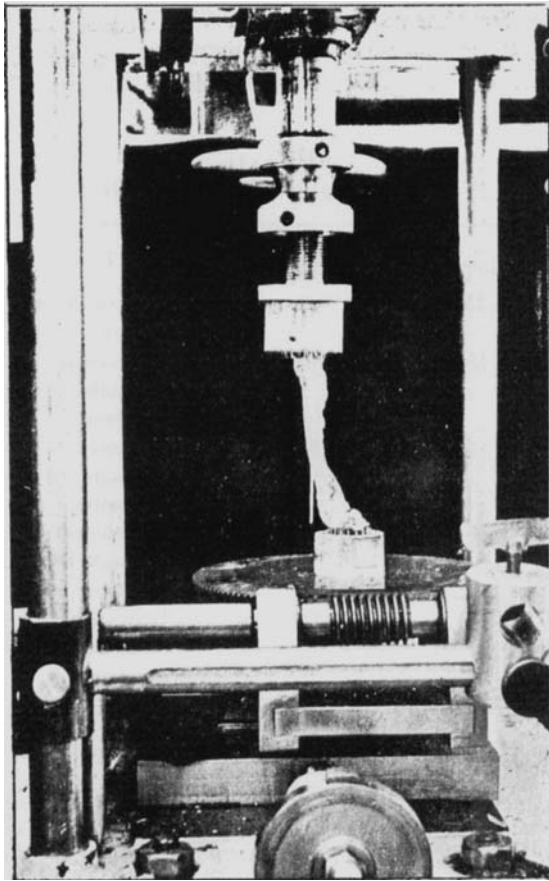


Fig. 10 a.

Loading a rabbit's femur in an oblique position.



Fig. 10 b.

Picture taken immediately after the bone was broken.

All the fractures were transverse comminuted, through the diaphysis (Table 11 and Fig. 9). They occurred at higher weights (85 - 115 kg). This is in conformity with the tibia.

TABLE 11
Femur. Loading in an oblique position.

Case no.	Angle of oblique position	Fract. weight kg	Type of fracture
14	c. 15°	85	Comminuted lower diaphysis-
15	„ 15°	103	Transverse comminuted, through the middle of the bone
16	„ 15°	85	Transverse comminuted, through the middle of the bone
17	„ 15°	115	Transverse comminuted, through the middle of the bone
18	„ 15°	95	Transverse comminuted, through the middle of the bone

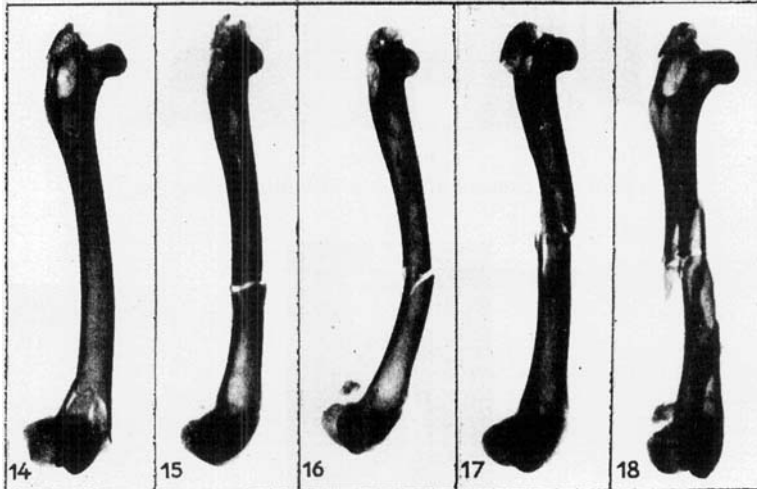


Fig. 9.

Hitting in a vertical position.

The fractures occurred in the lower part of the bones and were comminuted (Table 12 and Fig. 11).

TABLE 12
Femur. Hitting in a vertical position.

Case no.	Load kg	Blow kp	Type of fracture
10	25	27	Comminuted lower third of diaphysis
11	25	27	Comminuted lower third of diaphysis
12	25	27	Comminuted lower third of diaphysis
13	25	27	Comminuted lower third of diaphysis

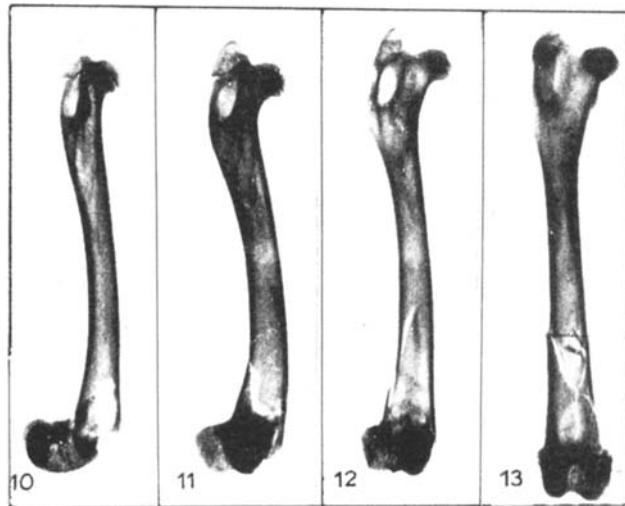


Fig. 11.

The Femur is an oblique bone in its lowest part, and therefore a comminuted fracture is to be expected, according to the observation made on the tibia.

Hitting in an oblique position.

All the fractures were in the middle of the diaphysis and 4 out of 5 were extensively comminuted (Table 13 and Fig. 12).

TABLE 13
Femur. Hitting in an oblique position.

Case no.	Load kg	Blow kp	Angle of oblique position	Type of fracture
19	25	27	c. 15°	Transverse middle diaphysis
20	25	27	„ 15°	Comminuted middle diaphysis
21	25	27	„ 15°	Comminuted middle diaphysis
22	25	27	„ 15°	Comminuted middle diaphysis
23	25	27	„ 15°	Comminuted middle diaphysis

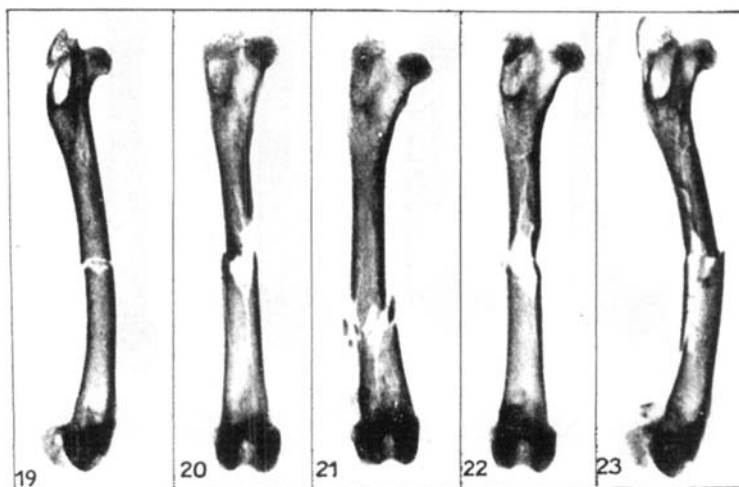


Fig. 12.

Fracturing by twisting in a vertical position.

All the fractures were spiral (Table 14 and Fig. 13).

TABLE 14
Femur. Fracturing by twisting in a vertical position.

Case no.	Load kg	Angle of twisting	Type of fracture
33	25	8°-10°	Spiral diaphysis
34	25	8°-10°	Spiral diaphysis
35	25	8°-10°	Spiral diaphysis
36	25	8°-10°	Spiral diaphysis
37	25	8°-10°	Spiral diaphysis

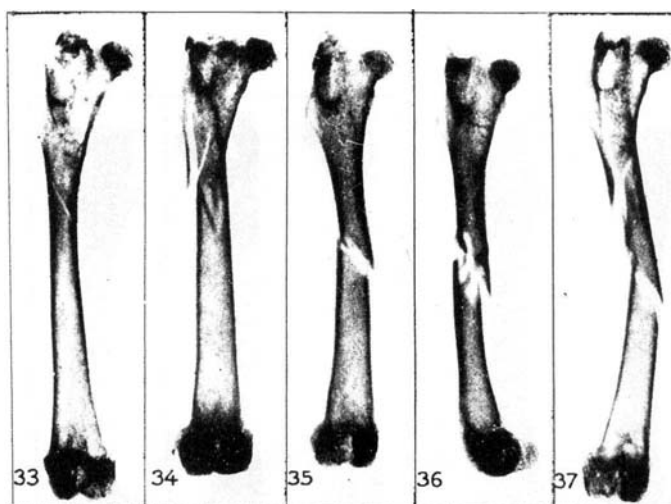


Fig. 13.

Twisting and loading in vertical position.

The twisting in a vertical position is very difficult, because when this is done the neck and greater trochanter are often fractured. Of the successful cases, 3 were spiral comminuted diaphysial fractures and 2 were intraarticular in the lower part of the femur with a tendency to a spiral pattern (Table 15 and Fig. 14).

TABLE 15
Femur. Twisting and loading in a vertical position.

Case no.	Fract. weight kg	Angle of twisting	Type of fracture
24	49	8°-10°	Distal intraarticular and spiral diaphysis
25	55	8°-10°	Distal intraarticular and spiral diaphysis
26	65	8°-10°	Comminuted spiral diaphysis
27	65	8°-10°	Comminuted spiral diaphysis
28	55	8°-10°	Comminuted spiral diaphysis

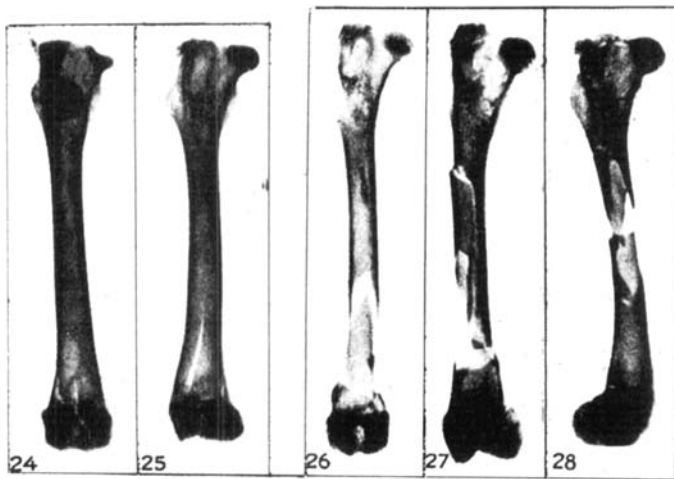


Fig. 14.

Twisting and hitting in a vertical position.

All the fractures were comminuted in the middle of the diaphysis, and more comminuted than if the femur had not been twisted (Table 16 and Fig. 15).

TABLE 16
Femur. Twisting and killing in a vertical position.

Case no.	Load kg	Blow kp	Angle of twisting	Type of fracture
29	25	27	8°-10°	Comminuted middle diaphysis
30	25	27	8°-10°	Comminuted middle diaphysis
31	25	27	8°-10°	Comminuted middle diaphysis
32	25	27	8°-10°	Comminuted middle diaphysis

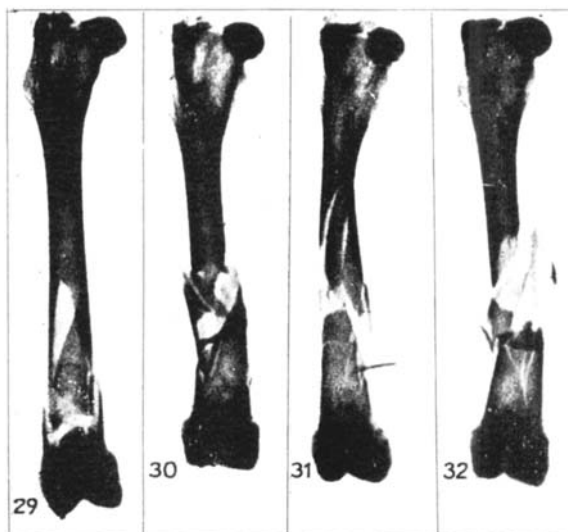


Fig. 15.

Twisting and loading in an oblique position.

All the fractures were diaphysial, more or less extensively comminuted (Table 17).

TABLE 17
Femur. Twisting and loading in an oblique position.

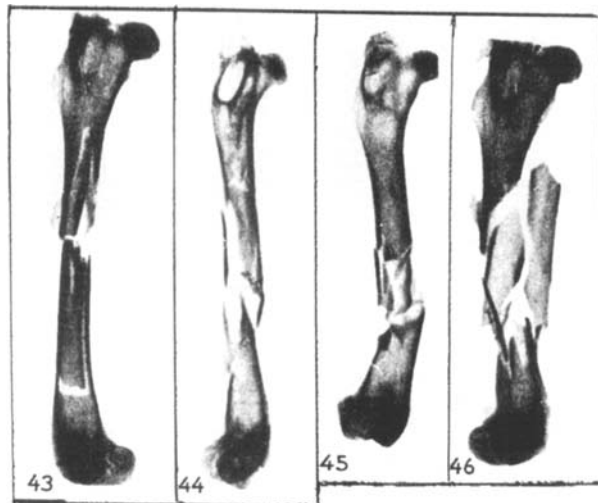
Case no.	Fract. weight kg	Angle of twisting	Angle of oblique position	Type of fracture
38	88	8°-10°	c. 15°	Transverse comminuted diaphysis
39	100	8°-10°	„ 15°	Transverse comminuted diaphysis
40	88	8°-10°	„ 15°	Spiral comminuted diaphysis
41	85	8°-10°	„ 15°	Comminuted diaphysis
42	88	8°-10°	„ 15°	Comminuted diaphysis

Twisting and hitting in an oblique position.

Extensively comminuted diaphysial fractures (Tab. 18 and Fig. 16).

TABLE 18
Femur. Twisting and hitting in an oblique position.

Case no.	Load kg	Blow kp	Angle of twisting	Angle of oblique position	Type of fracture
43	25	27	8°-10°	c. 15°	Extensively comminuted diaphysis
44	25	27	8°-10°	„ 15°	Extensively comminuted diaphysis
45	25	27	8°-10°	„ 15°	Extensively comminuted diaphysis
46	25	27	8°-10°	„ 15°	Extensively comminuted diaphysis

*Fig. 16.*

CONCLUSIONS

Tibia.

1. Vertical loading of the tibia mainly produces fractures close to the metaphysis.
2. Oblique loading produces more diaphysial fractures and, when the load is of short duration, comminuted fractures.

3. Twisting below 10° of the tibia does not change the amount of force necessary for a fracture, but breaks the bone closer to the ends.
4. Twisting above 10° tends to result in spiral fractures near the middle of the diaphysis.

Femur.

5. It is striking that the forces necessary to produce a fracture in a rabbit's femur are much less than in the case of a tibia. This may be due to the shape of the femur shaft.
6. Vertical loading mainly produces fractures close to the lower metaphysis.
7. Oblique loads result in more diaphysial fractures, and when the load is of short duration, comminuted fractures.
8. Twisting brings a spiral tendency into the fractures.
9. The fracture types are the same as those observed in the tibia.

CONCLUSION

Tibia.

1. Une charge verticale sur le tibia produit surtout des fractures près du *métaphysis*.
2. Une charge oblique produit des fractures plus *diaphysiales* et, quand la charge est de courte durée, des fractures *comminutives*.
3. Une torsion du tibia inférieure à 10° ne change pas la quantité de force nécessaire pour provoquer une fracture, mais rompt l'os plus près des extrémités.
4. Une torsion supérieure à 10° tend à donner des fractures spirales près du milieu du diaphysis.

Femur.

5. Pour produire une fracture du fémur d'un lapin il faut une force de beaucoup inférieure à celle qui provoque la fracture du tibia. Cela peut être dû à la forme du fémur.
6. Une charge verticale produit surtout des fractures près du *métaphysis* inférieur.
7. Des charges obliques donnent des fractures plus *diaphysiales* et, quand la charge est de courte durée, des fractures *comminutives*.
8. Une torsion donne une tendance spirale aux fractures.
9. Les types de fractures sont les mêmes que ceux observés pour le tibia.

ZUSAMMENFASSUNG

Schienbein.

1. Vertikale Belastung des Schienbeins ruft im wesentlichen Brüche nahe der Metaphyse hervor.
2. Schräge Belastung verursacht häufiger Diaphysenbrüche und bei schnelle, kurzzeitiger Belastung Brüche mit Fragmentierung.
3. Drehung des Schienbeins um weniger als 10° ändert die für einen Bruch erforderliche Kraft nicht, bricht jedoch den Knochen näher an den Enden.
4. Drehung von mehr als 10° führt zu Spiralbrüchen nahe an der Diaphysenmitte.

Oberschenkel.

5. Es ist überraschend, dass die zur Erzielung eines Bruchs in einem Kaninchenoberschenkel erforderlichen Kräfte bedeutend geringer sind als für einen Schienbeinbruch. Dies kann auf der Form des Oberschenkels beruhen.
6. Vertikale Belastung ruft im wesentlichen Brüche dicht an der unteren Metaphyse hervor.
7. Schräge Belastungen ergeben häufiger Diaphysenbrüche und bei schneller Belastung Brüche mit Fragmentierung.
8. Drehung bringt eine Spiraltendenz in die Brüche.
9. Die Bruchtypen sind die gleichen wie die beim Oberschenkel beobachteten.

RESUMEN

Tibia.

1. El peso vertical sobre la tibia produce principalmente fracturas en las proximidades de la metafisis.
2. El peso oblicuo produce más bien fracturas diafisarias, o fracturas conminutas cuando la carga es de corta duración.
3. Un torcimiento de la tibia inferior a 10° no altera la cantidad de fuerza necesaria para una fractura pero rompe el hueso más cerca de sus extremidades.
4. Torcimiento superior a 10° tiende a producir fracturas espirales cerca del centro del diáfisis.

Fémur.

5. Es interesante que la cantidad de fuerza necesaria para producir una fractura en el fémur de un conejo es mucho menor que en el caso de una tibia. Esto es tal vez debido a la forma del fémur.

6. La carga vertical produce principalmente fracturas junto al metáfisis inferior.
7. Las cargas oblicuas ocasionan fracturas diafisarias, o fracturas conminutas cuando la carga es de corta duración.
8. El torcimiento d una tendencia espiral a las fracturas.
9. Los tipos de fractura son las mismas que las observadas en la tibia.

L I T E R A T U R E

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