CLASSIFICATION AND MECHANISM OF FRACTURES OF THE LEG BONES INVOLVING THE ANKLE

BASED ON A STUDY OF THREE HUNDRED CASES FROM THE EPISCOPAL HOSPITAL *

ASTLEY P. C. ASHHURST, M.D., AND RALPH S. BROMER, M.D.
PHILADELPHIA

ANATOMIC AND SURGICAL STUDY

By Dr. Ashhurst

Pott, Dupuytren, Cooper, Maisonneuve, Tillaux, Hönigschmied, Stimson, Destot, Chaput, Quénu—and shall I not add Scudder, Cotton, Roberts and Speed? What can any one say more, at this late day? And yet the fact remains that there is no entirely satisfactory classification of ankle fractures in existence, and that many points of the mechanism of their production still are in dispute. I say there is no entirely satisfactory classification of these fractures in existence, because that which is the best, being the most scientific and complete, namely that of Quénu, is less a classification than a catalog; and because his strict adherence to an anatomopathologic classification, and his stern rejection of the historical pathogenetic classification, compel him to place side by side lesions in no sense related, except that the fracture lines happen to be similar, and to separate widely other lesions which, though presenting very dissimilar lines of fracture, nevertheless represent only different degrees or stages, or merely variants, of one and the same lesion.

It is perhaps unnecessary to argue the desirability of classification; for without classification, the relation of one lesion to another can be neither remembered nor understood in any department of knowledge; and comprehension is a prerequisite for intelligent memory and for rational diagnosis and treatment.

HISTORICAL

Si chirurgien experimenté que vous soyez, ne sautez pas ces premières pages. Elles sont indispensables, mais fatigantes à lire; mieux vaut remettre à un autre jour cette besogne ardue que de l'entreprendre mal disposé.—Farabeuf.

Pott [1] (1769) described a fracture which doesn't exist, and Dupuytren [2] (1819) commended him for his acute observation and fidelity

* Read before the American Surgical Association, June 14, 1921.

1. Pott: Some Few General Remarks on Fractures and Dislocations, London, 1769, p. 57.

2. Dupuytren: Ann. méd.-chir. d. hôp. et hosp. civ. de Paris, 1819, p. 1.

to nature. Cooper[3] (1822), more sensible than either, merely recounted what he had seen, avoided speculation about what he had not seen, and was silent on subjects about which he had no knowledge. Maisonneuve[4] (1840) and Tillaux[5] (1872) studied the mechanism by experiments on the cadaver, and though they were both correct, they came to different conclusions; and Tillaux thought his work had entirely invalidated that of Maisonneuve. Hönigschmied's[6] (1877) experiments on cavaders (125 in all) may be said to have carried this means of investigation to its limit; and though subsequent students, including myself, have repeated such experiments, it is evident that this method of investigation has many limitations, as it is impossible to reproduce in the cadaver the falls which living patients suffer and the muscular tension to which their limbs are constantly subjected.

Stimson's[7] study, in 1892, was the last one of importance before the advent of the roentgen ray; and it was Destot[8] (1911) who first of all published extensive observations of ankle fractures illustrated by, and based on, roentgenographic studies. It is strange that no English writer since Cooper has made a special study of fractures at the ankle, and that with the exception of Stimson, already mentioned, no American surgeon has made a particular study of the subject, though Scudder, Cotton, Roberts and Kelly, and Speed have discussed it at greater or less length in their textbooks on fractures. It is evident, however, to any attentive student of the subject that most of the recent writers, if not, indeed, all, demonstrate by their statements that they have not themselves read, or at any rate have not read with understanding, the works of their predecessors—especially of Dupuytren, Cooper, Maisonneuve and Tillaux. Most surgeons think they know what they mean by a "Pott's fracture," but as I said before, there is little use in knowing much, or anything, about a type of fracture which does not exist.

What is Pott's fracture? Let Mr. Percivall Pott tell in his own words (1769).[9]

---

3. Cooper: Treatise on Dislocations and Fractures of the Joints, London, 1822.

4. Maisonneuve: Arch. gén. de méd. **1**:165, 433, 1840.

5. Tillaux, cited by Gosselin: Bull. de l'Acad. de méd., Paris, Series 2 **1**: 817, 1872.

6. Hönigschmied: Deutsch. Ztschr. f. Chir. **8**:239, 1877.

7. Stimson: New York M. J. **55**:701, 1892.

8. Destot: Traumatismes du pied et rayons-x, Paris, 1911.

9. It should be borne in mind that Pott is discussing the importance of treating fractures of the leg bones in the flexed position (the limb resting on its outer surface with the knee bent), and hence that he speaks of fractures of the fibula only incidentally.

"The limb most commonly preserves its figure and length . . . if the fibula only be broken, in all that part of it which is superior to letter *A* in the annexed figure" (Fig. 1), "or in any part of it between its upper extremity, and within two or three inches of its lower one. . . . I have already said . . . that the support of the body and the due and proper use . . . of the joint of the ancle depend almost entirely on the perpendicular bearing of the tibia upon the astragalus, and on its firm connection with the fibula. If either of these be perverted or prevented, so that the former bone is forced from its just and perpendicular position on the astragalus, or if it be separated by violence from its connection with the latter, the joint of the ancle will suffer a partial dislo-

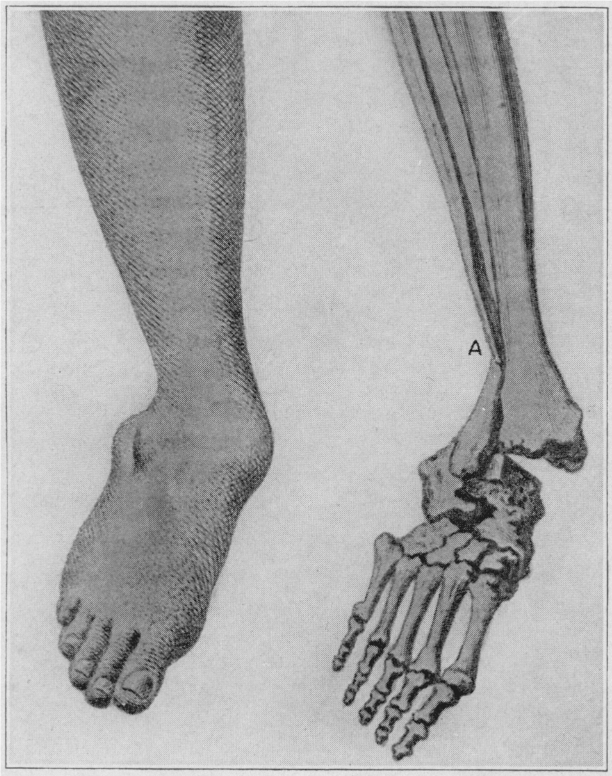

Fig. 1.—Illustration from Pott's work, "Some Few General Remarks on Fractures and Dislocations," London, 1769, facing p. 69.

cation internally; which partial dislocation cannot happen without not only a considerable extension or perhaps laceration of the bursal ligament of the joint, which is lax and weak, but a laceration of those strong tendinous ligaments which connect the lower end of the tibia with the astragalus and os calcis, and which constitute in great measure the ligamentous strength of the joint of the ancle.

"This is the case when, by leaping or jumping, the fibula breaks in the weak part already mentioned, that is, within 2 or 3 inches of its lower extremity. When this happens, the inferior fractured end of the fibula falls inward, toward

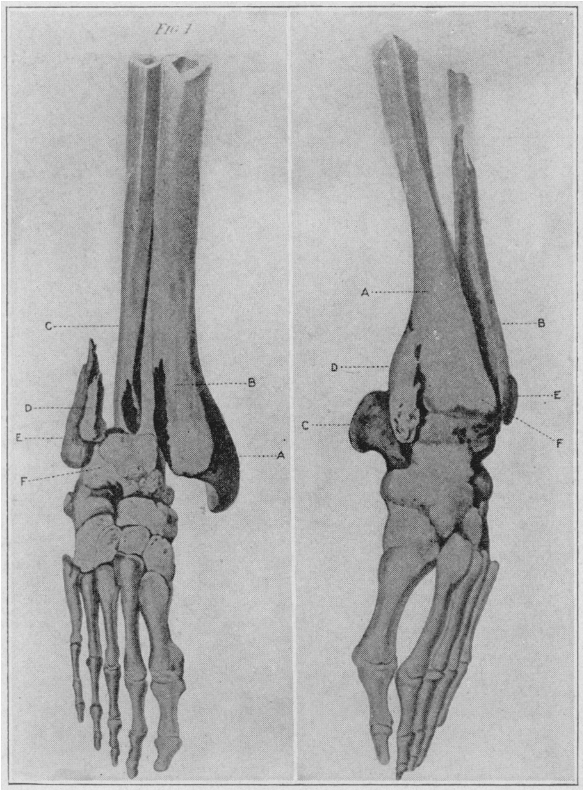

Fig. 2.—Illustrations from Cooper's "Treatise on Dislocations and Fractures of the Joints," London, 1822, Plate XVI, Figs. 1 and 2. "Fig. 1 shows the dislocation of the tibia inwards at the ankle-joint: *A,* the malleolus internus of the tibia thrown on the inner side of the astragalus; *B,* a portion of the tibia split off; *C,* fibula broken; *D,* the broken portion of the tibia adhering by ligament to the fibula; *E,* the malleolus externus of the fibula, with the broken portion of the tibia adhering to it, and *F,* astragalus thrown outwards. Fig. 2 shows the dislocation of the tibia outwards, at the ankle-joint: *A,* the tibia; *B,* the fibula; *C,* the os calcis; *D,* fracture of the tibia at the malleolus internus, which has become reunited; *E,* extremity of the fibula broken, and, *F,* tibia thrown on the outer side of the articulatory surface of the astragalus, to which it is anchylosed."

the tibia, that extremity of the bone which forms the outer ancle is turned somewhat outward and upward, and the tibia, having lost its proper support and not being of itself capable of steadily preserving its true perpendicular bearing, is forced off from the astragalus inward [Evidently, he means by the weight of the body, after primary fracture of the fibula produced by the first impact of the foot with the ground.] by which means weak bursal, or common

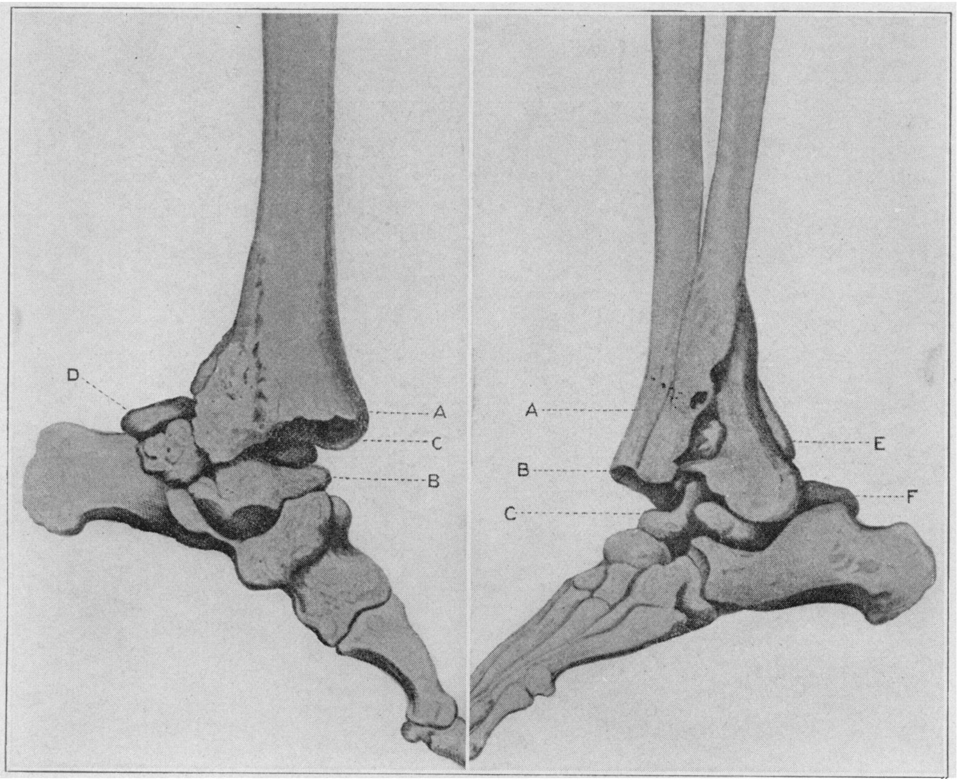

Fig. 3.—Cooper's Plate XVII, Figs. 1 and 2, "Partial dislocation of the tibia forwards, at the ankle-joint: Fig. 1: *A*, the tibia thrown forward over the os naviculare; *B*, the astragalus; *C*, new articulatory surface of the tibia, and, *D*, the portion of the astragalus behind the tibia. Fig. 2: opposite view of Fig. 1: *A*, the tibia thrown forwards; *B*, new articulatory surface of the tibia; *C*, astragalus; *D*, fibula broken and reunited; *E*, malleolus externus of the fibula, and *F*, astragalus behind the tibia."

ligament of the joint is violently stretched, if not torn, and the strong ones, which fasten the tibia to the astragalus and os calcis, are always lacerated, thus producing at the same time a perfect fracture and a partial dislocation, to which is sometimes added a wound in the integuments, made by the bone at the inner ancle. By this means, and indeed as a necessary consequence, all the tendons which pass behind or under, or are attached to the extremities of the tibia and fibula, or os calcis, have their natural direction and disposition so altered, that instead of performing their appointed actions, they all contribute to the distortion of the foot, and that by turning it outward and upward." (Note that there is not a word of posterior displacement, and that this is not shown in the plate, here reproduced as Figure 1.)

This description, and the accompanying illustration, call for several remarks. It is to be noted, first, that Pott's fracture, as described and pictured by himself, is a primary, nearly transverse, fracture of the fibula, attended by a subsequently produced "partial dislocation" of the

Fig. 4.—Transverse section of leg through inferior tibiofibular joint, showing fibula lodged in its groove formed by the anterior and posterior tubercles of the tibia. Note the obliquity of the intermalleolar axis, forming an angle of 30 degrees with the axis of motion of the ankle joint, which is nearly transverse. Note that the anterior tubercle projects laterally much farther than the posterior, so that in anteroposterior roentgenograms its shadow much overlaps that of the fibula. (From a preparation in the laboratory of operative surgery, University of Pennsylvania.)

ankle joint internally. Second, the fracture of the fibula occurs at, or below, the point marked *A* in the illustration ("within 2 or 3 inches of its lower extremity"); and the upper end of the lower fragment is described as falling in against the tibia, while the external malleolus is turned outward. Third, there then is supposed to occur rupture of the ligaments below the internal malleolus, with a partial dislocation of the tibia inward, off the trochlea of the astragalus, as the latter bone turns outward, around a more or less anteroposterior axis. Now, such a fracture of the fibula does not occur as a type, as may be readily verified by the examination of any series of roentgenograms or postmortem specimens; and if it did occur, it would be impossible for the upper end of the lower fragment to fall in against the tibia, for the

Fig. 5.—Posterior view of the ankle joint, all structures removed except the bandlike ligaments. Note the interosseous membrane, its fibers passing downward from the tibia to the fibula, the similarly directed fibers of the posterior inferior tibiofibular ligament; the middle band of the external lateral (fibulocalcanean) ligament; the posterior band of the external lateral ligament (fibuloastragalar ligament) attached to the lateral tubercle of the astragalus; the posterior fibers of the internal lateral ligament, and the posterior surface of the internal malleolus grooved for the tendon of the tibialis posticus. (From a preparation in the laboratory of operative surgery, University of Pennsylvania.)

reason that the fibula is already closely applied to the tibia at the point described. There is barely room to insert the blade of a scalpel between the bones at a point 3 inches (7.5 cm.), or less, above the tip of the fibula.

It was the particular merit of Dupuytren to systematize the teaching of various pioneers, such as Pott (1769), Bazille [10] (1771), Bromfeild [11] (1773) and Pouteau [12] (1783), who had recognized, as fractures, lesions which had been regarded by former generations as dislocations; and it is to Dupuytren's memoir on "The Fracture of the Lower End of the Fibula"[13] that surgery is principally indebted for its understanding of all these ankle fractures. It is true that Gosselin (1872) reproached Dupuytren with having propounded his theories of mechanism merely by means of his reasoning, and not on a basis of clinical observations or cadaveric experiments (though Dupuytren made a number of the latter, and presented records of 207 patients with ankle fractures). But there is much justification for Dupuytren's [14] statement that the mechanism detailed by patients cannot be relied on, since it is well known that in dislocations of the shoulder, for instance, they all will say the injury resulted from a fall on the point of the shoulder (because that is where they feel the pain), whereas the state of their elbow or hand proves quite the contrary. Similarly, I have known a patient with an ankle fracture badly united in abduction (fibular flexion) to assert that it was produced by adduction (tibial flexion), because her heel was prominent beneath the internal malleolus just after the accident; not realizing that the heel had been brought into that position by outward displacement of the point of the foot, the astragalus turning around the long axis of the leg.

Now it is to be noted that Dupuytren, who commended Pott for his accurate delineation of the typical fracture of the lower end of the fibula, was evidently of the belief that the typical fracture which he himself was describing was the same as that of Pott; and that this is still the opinion of the French is manifest from a footnote of

---

10. Bazille: Mém. sur les sujets proposés pour le prix de l'Acad. Roy. de Chir., Paris **4**:563, 1778.

11. Bromfeild: Chirurgical Observations and Cases, London **2**:78, 1773.

12. Pouteau: Oeuvres posthumes, Paris **2**:267, 1783.

13. This memoir was said by Nélaton (Eléments de path. chir., Paris **1**:810, 1844) to have been read by Dupuytren in 1813 before the Académie de sciences. However, I have searched the "Procès-verbaux des séances de l'Académie des sciences" (Paris **5**:1812-1815) and find no reference to such an event; and Quénu (Rev. de Chir. **45**:5 (Footnote 2) 1912) states that he has had the original records of the Academy searched page by page, without finding any trace of Dupuytren's Memoir; and says that "until further information" he will consider as "mémoire princeps" the appearance of the essay in the "Annuaire medico-chirurgicale des hôpitaux et hospices civiles de Paris," 1819, p. 1. The essay is most easily accessible where first reprinted, in the second edition of Dupuytren's "Leçons orales" (Paris **1**:275, 1839).

14. Dupuytren: Leçons orales de clinique chir., Ed. 2, Paris **1**:328, 1839.

Quénu,[15] in which he says that the French mean by Dupuytren's fracture precisely what the English mean by Pott's. So that it is somewhat confusing to have J. Hutchinson, Jr.,[16] and some recent writers name and illustrate as Dupuytren's fracture a lesion which Dupuytren[17] encountered only once in more than 200 cases, and which consisted in a fracture of the fibula, rupture of the tibiofibular ligaments, and displacement upward of the astragalus along the fibular side of the tibia. As it is a fact that the fracture at the ankle most

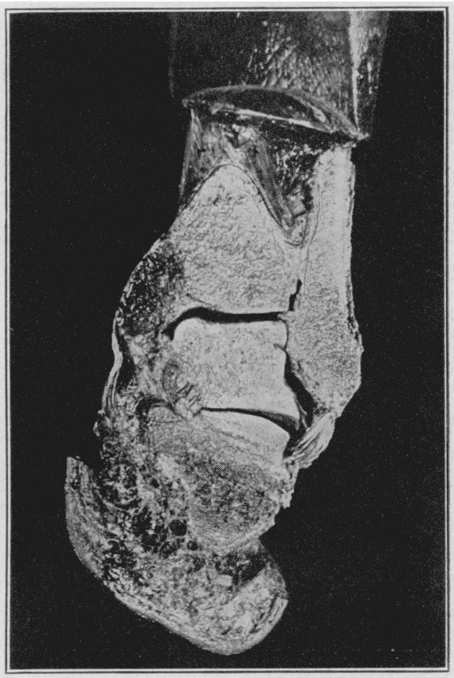

Fig. 6.—Frontal section of the ankle joint. Adduction causes tension on external lateral ligament and if forced will tear off the external malleolus.

often seen, and therefore the most typical fracture, is that first described accurately by Maisonneuve (1840),[18] it is safe to assume that both

15. Quénu: Rev. de chir. **46**:367 (Footnote 2) 1912.

16. Hutchinson: Tr. Path. Soc., London **39**:238, 1887-1888.

17. Dupuytren: Footnote 14, p. 368.

18. Though, unfortunately, it is not known by his name, which is attached to a fracture produced experimentally by him on the cadaver, but which he never saw clinically. The most frequent and most typical fracture the French now call the "low Dupuytren" to distinguish it from the true Dupuytren or Pott fracture, which they name "Dupuytren type."

Pott's and Dupuytren's descriptions applied to this fracture and not to the rather hypothetic type they thought they were describing.

However, there is a typical, though rare, fracture at the ankle which corresponds closely enough to the original illustration of Pott to make it worthy of being called by his name; it is a typical "flexion fracture" (Biegungsbruch) of the fibula, usually 8 cm. (3¼ inches) or *higher* above the tip of the external malleous, accompanied by fracture of the internal malleolus and almost invariably by rupture of the inferior

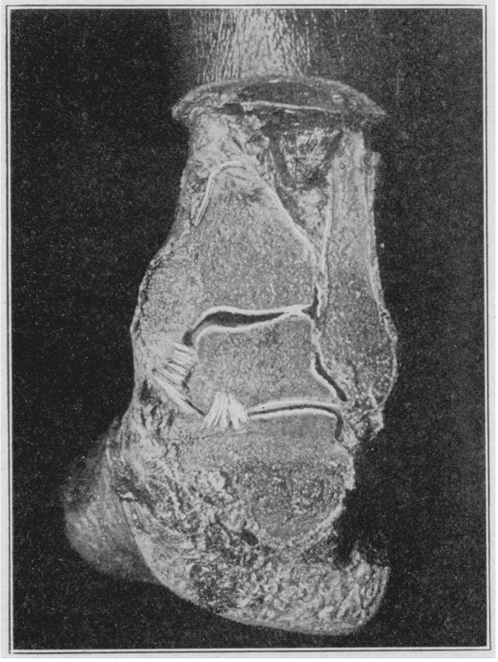

Fig. 7.—Frontal section of the ankle joint. Abduction causes tension on internal lateral ligament and will rupture this or fracture the internal malleolus before outward pressure on the external malleolus will fracture the latter or cause diastasis between tibia and fibula. (This specimen and that shown in Figure 6 are from a preparation in the laboratory of operative surgery, University of Pennsylvania.)

tibiofibular ligaments, permitting a diastasis between tibia and fibula. It is such a fracture as is illustrated in Fgure 26; and may well be called Pott's fracture, even though Pott in his own description placed the seat of the fibular fracture too low, and ignored the fracture of the internal malleolus and the tibiofibular diastasis.

Cooper [3] (1822) did not get away from the idea of the paramount importance of the dislocation of the tibia in these lesions (nor, it may be remarked, did Malgaigne, Hamilton, Treves, or Stimson, many years later); and he described the fractures as mere incidents. But any modern surgeon will find it difficult to bring forth as extensive a list of severe ankle lesions as that recorded by Cooper, though he can easily excel Cooper in the number of lesions which (owing to the absence of deformity) can be certainly recognized only with the aid of the roentgen ray.

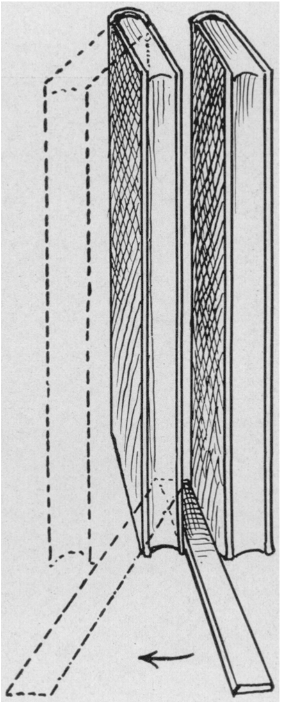

Fig. 8.—An illustration of Maisonneuve's explanation of fracture of the external malleolus by outward rotation of the foot around the axis of the leg. The books represent the malleoli and the ruler represents the foot. See page 100.

Cooper describes succinctly, but accurately, the following main groups of lesions; and scarcely one additional type has been discovered since, even with the aid of roentgenography:

1. *Simple Dislocation of the Tibia Inward.*—In this case there is a fracture of the fibula, two inches above its tip, carrying with it an attached fragment of the tibia;[19] the lower end of the upper fragment of the fibula rests on top of the

19. This is the "intermediate fragment" known to the French as the "third fragment of Tillaux," who produced it frequently in his cadaveric experiments.

astragalus,[20] and the tibia with the internal malleolus intact descends on the median surface of the astragalus. (This is illustrated in Figure 1 of Plate 16 of Cooper's monograph, first edition, 1822, and is reproduced here as Figure 2. The figure was copied by Vidal de Cassis[21] in his second edition [1846] as Figure 53 and the lesion was for many years known in France by his name; until Quénu recently called attention to the fact, quite clearly stated by Vidal, that the illustration was copied from Cooper.) This, says Cooper, is the most frequent of the dislocations of the ankle. It corresponds probably to the form now known to the French as the "low Dupuytren" fracture, though in the latter type, which is very frequent, there is very seldom any intermediate fragment detached from the tibia.

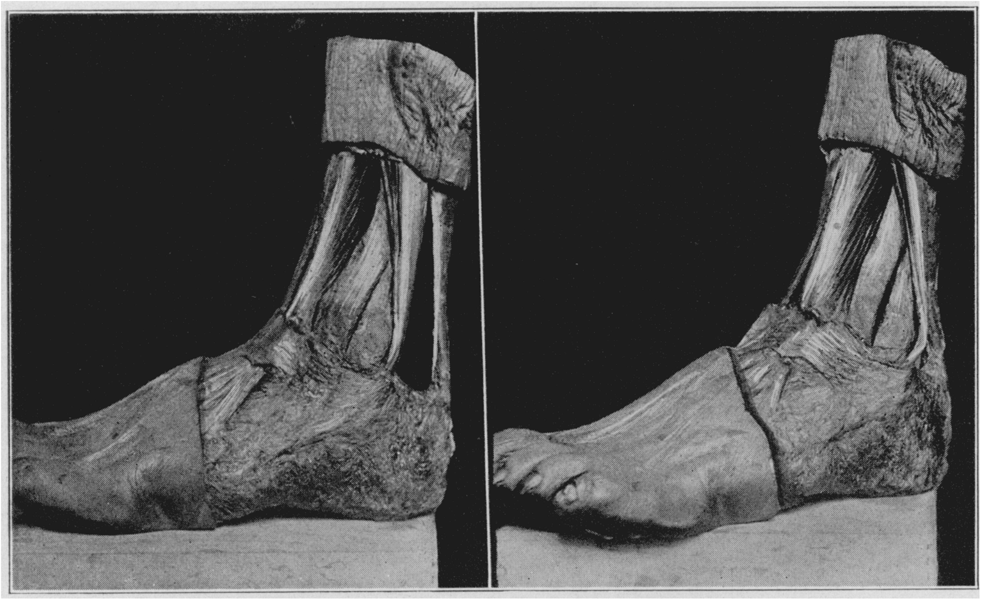

Fig. 9.—Oblique fracture of the fibula through the inferior tibiofibular joint, produced by an osteotome: in the first figure the foot is in the anatomic position; in the second it has been rotated outward around the axis of the leg, which is the only motion that will cause separation of the fragments. See page 101.

2. *Simple Dislocation of the Tibia Forward.*—In this case there is a fracture of the fibula, three inches above its tip; the internal lateral ligament is partly lacerated; the tibia and upper fragment of the fibula advance forward, and the tibia rests on the upper surface of the scaphoid and internal cuneiform. In

20. Richet (Unión méd. **20**:142, 1875) described such a case in which the astragalus was penetrated by the upper fragment of the fibula. Roentgenograms in anteroposterior view often show such an appearance, but the lateral views I have seen have always demonstrated that the fibula was behind, or very rarely in front of, the astragalus. Richet's lesion was demonstrated at necropsy.

21. Vidal de Cassis: Traité de pathologie externe, Ed. 2, Paris **2**:394, 1846.

partial dislocation of the tibia forward, the articular surface of the tibia is divided in two: the anterior part rests on the scaphoid and the posterior on the astragalus. The fracture of the fibula (as shown in Plate 17, Figs. 1 and 2, of Cooper's monograph, reproduced here as Figure 3) runs obliquely up and back, through the inferior tibiofibular joint. Thus there is here accurately described the posterior marginal fragment of the tibia, which many recent writers think they were themselves the first to discover after the introduction of roentgenography (Destot, Chaput, Cotton, Sear, etc.).

3. *Simple Dislocation of the Tibia Outward.*—This, says Cooper, is the most dangerous of the three, for it is produced by greater violence, etc. The internal

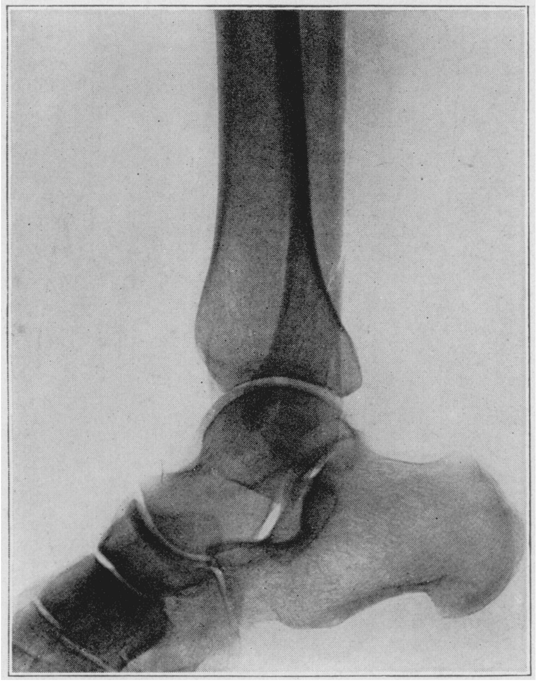

Fig. 10.—Mixed oblique fracture of the lower end of the fibula: the first lesion resulting from external rotation (A, I); occurs as isolated lesion in 25 per cent. of all cases of fracture of the ankle; as combined lesion, in 61 per cent. Usually invisible in anteroposterior views.

malleolus is obliquely fractured and separated from the shaft of the bone; the fractured portion sometimes consists only of the malleolus; at other times, the fracture passes obliquely through the articular surface of the tibia, which is thrown forward and outward on the astragalus before the external malleolus. The astragalus is sometimes fractured, and the lower extremity of the fibula is broken into several splinters. The internal and external lateral ligaments are usually intact; but if the fibula is not broken, the external lateral ligaments are ruptured. (Note that there is here described the "fracture by adduction" with a splitting off of a greater or less portion of the medial surface of the tibia—illustrated in Figure 2, from Cooper—a lesion which Tillaux thought had not before his time been observed by any surgeon).

Under the heading "Fractures of the Tibia and Fibula Near the Ankle Joint" (p. 353), Cooper describes a fracture of the fibula from two to three inches above the ankle joint (that is, not at a point from two to three inches above the tip of the external malleolus, but at the point where occurs the fracture called by Pott's name), produced by falling laterally while the foot is confined in a deep cleft; and a fracture of the tibia, in which the fracture line runs either obliquely down and in, toward the internal malleolus (i. e., the

Fig. 11.—Mixed oblique fracture of the fibula, with great obliquity. In these fractures, the obliquity may be great or slight; but the line of fracture is always higher on the posterior than on the anterior border of the fibula, and in 84 per cent. of the cases, the anterior end of the fracture line is between the tip of the malleolus below and the level of the articular surface of the tibia above. In 8 per cent. of the cases, the anterior end of the fracture line passes through the fibula at the level of the anterior tubercle of the tibia, and in 8 per cent. its anterior end is above this level (in which circumstances the tubercle is detached or there is diastasis). All tracings here reproduced were made directly from the roentgenograms.

ordinary spiral fracture of the shaft low down) or obliquely from 1 or 2 inches above the internal malleolus down and out into the ankle joint (i. e., the ordinary splitting fracture of the median part of the articular surface, usually dependent on a primary fracture of the fibula, and forming a less advanced degree of the fracture by adduction already described by Cooper as an outward dislocation of the tibia).

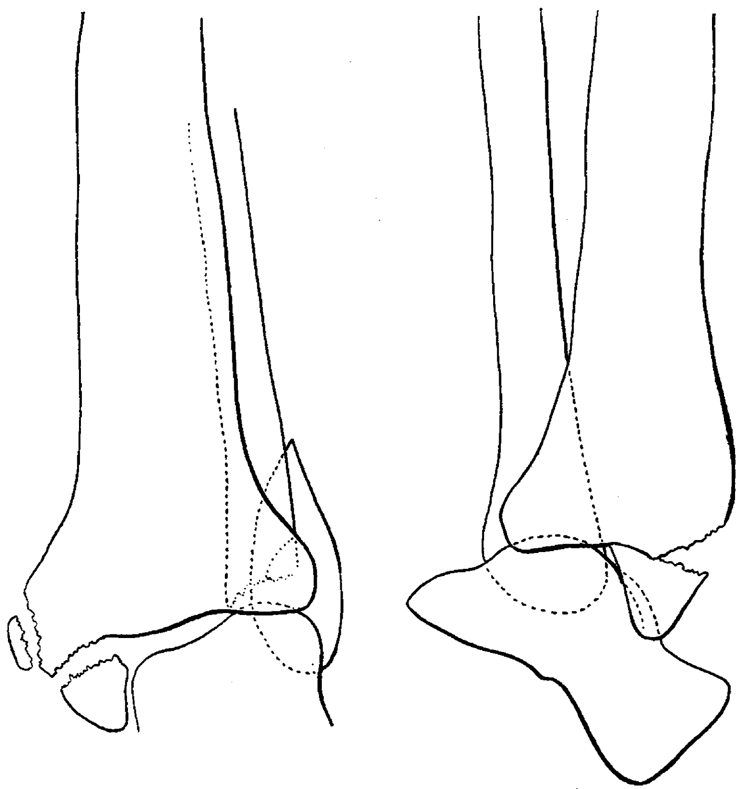

Fig. 12.—Mixed oblique fracture of fibula, with fracture of internal malleolus (A, II, b). The fibular fracture is visible only in the anteroposterior view (rare). Note that there is considerable lateral displacement of the astragalus, but that the posterior displacement is only apparent, not real, being due to the external rotation of the foot.

After Cooper, Maisonneuve [4] (1840). In a most remarkable essay, which has been ignored by most subsequent writers, Maisonneuve threw more light on the subject of ankle fractures than has any one since.

Up to that time, as he says, two theories prevailed to explain the mechanism of fractures of the lower end of the fibula: (1) by adduction, by which means the tip of the external malleolus was torn off; this was thought by Dupuytren to be the most frequent variety,[22] and (2) by abduction, when, from pressure upward and laterally by the astragalus on the external malleolus, the latter was forced outward until the fibula broke at its weakest point, namely, entirely above the malleolus, that is, in the region described by Pott; this fracture being usually accompanied by a secondarily produced fracture of the internal malleolus or rupture of the internal lateral ligament. The second variety was thought by everybody, except Dupuytren, to be the most frequent.

Now Maisonneuve proposed another mechanism, which he believed explained the production of the most common type of fracture: this was simple deviation of the point of the foot outward, that is, external rotation of the foot in the

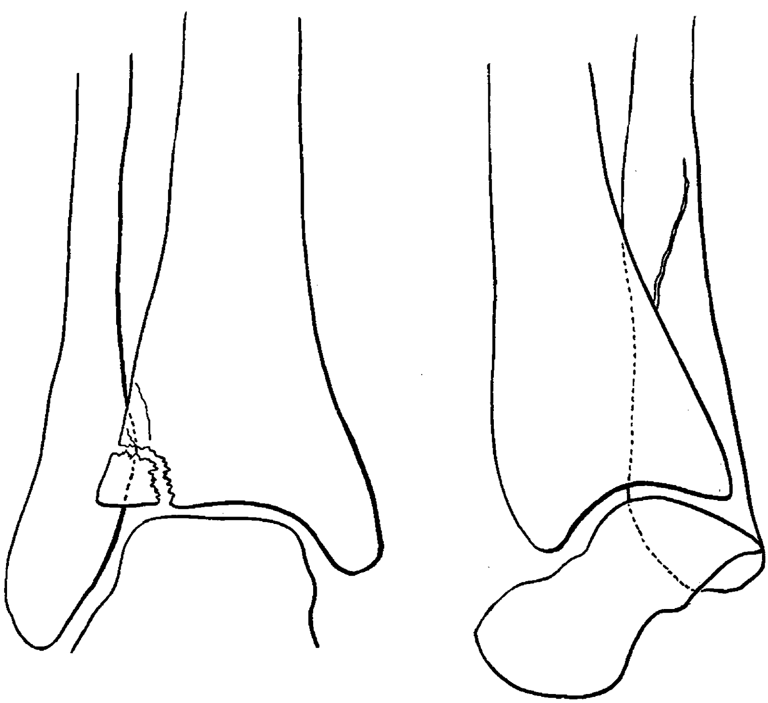

Fig. 13.—Mixed oblique (incomplete) fracture of fibula, complicated by, and subsequent to, avulsion of the anterior tubercle of tibia.

22. Dupuytren contended that the usual fracture which he described (and which he thought corresponded to that shown in Pott's illustration) was produced by a primary tearing off of the external malleolus when the foot turned so that the patient stepped on the outer edge of the sole; and that the rupture of the internal lateral ligament or fracture of the internal malleolus was produced secondarily by the patient's attempts to walk: whereupon, the external malleolus being already broken, the foot was forced into valgus; but he stated that when fracture of the fibula followed a turning outward of the foot, the internal malleolus broke first and the fibula only secondarily (Footnote 14, p. 327).

tibiofibular mortise around a vertical axis. In one recent necropsy, he had found an oblique fracture of the fibula, the line of fracture beginning on the anterior surface of the external malleolus 4 cm. above its tip and extending upward and backward to a point on the posterior surface of the fibula 8 cm. above the tip of the external malleolus. And he found that precisely this fracture was readily produced in the cadaver by the mechanism of outward rotation as above mentioned, whenever the tibiofibular ligaments held firm.

So far as I can ascertain, Maisonneuve was the first, and I might say almost the only, writer up to the present day to appreciate properly

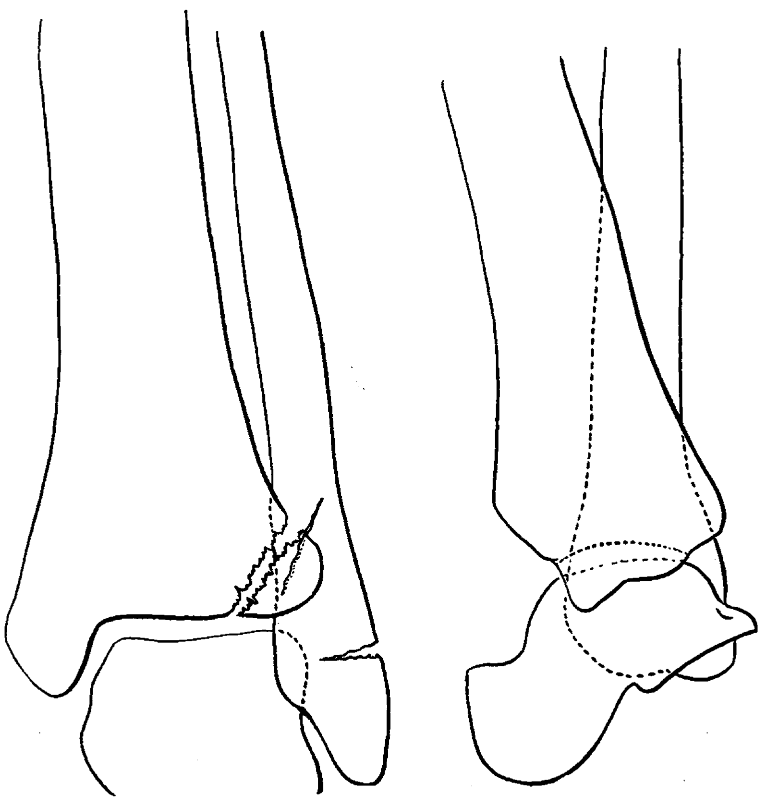

Fig. 14.—Mixed oblique (incomplete) fracture of fibula complicated by, and subsequent to, avulsion of anterior tubercle of tibia.

the importance of the inferior tibiofibular ligaments in the mechanism and classification of ankle fractures; and to recognize the great frequency of the oblique fracture of the fibula. This fracture, he found, was always the first lesion following external rotation of the foot, and occurred without any ligamentous injury. If the external rotation of the foot were continued far enough, the internal lateral ligament would rupture, or often the internal malleolus would be pulled off.

The resulting deformity, he found, was precisely the picture drawn by Dupuytren (*"coup de hache,"* etc.); and all of these phenomena disappeared when the position of the foot was corrected. If the inferior tibiofibular ligaments break, during this external rotation of the foot around the long axis of the leg, there occurs a greater or less diastasis of the inferior tibiofibular joint; and if the movement still continues, the fibula breaks not at the usual site, but in its upper third, or at least in its middle third. It is to this fracture of the fibula in its upper third, produced after diastasis of the inferior tibiofibular joint has occurred,

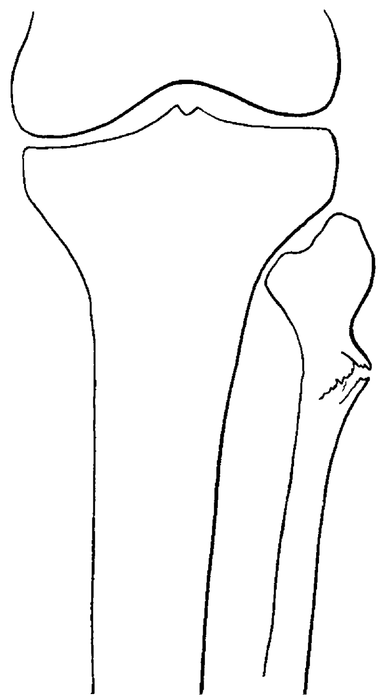

Fig. 15.—Incomplete fracture of fibula below its head (A, I, Variant), apparently from compression in its long axis (see pp. 103 and 107). No bone lesion at ankle. There was a history of a fall down three steps while carrying a load of 100 kilograms on the back. Injury occurred so quickly the patient did not know whether he turned his ankle or struck the side of his leg against the marble steps. Pain was so great that he had to be brought to the hospital by a patrol wagon. Examination showed fracture in the upper third of the left fibula (crepitus and deformity). The ankle was swollen over the external malleolus.

that the name of Maisonneuve's fracture has been attached; though he never encountered such a case clinically.

Maisonneuve's chief contribution was his recognition of the oblique fracture of the lower end of the fibula as the first stage of a lesion frequently including also a fracture of the internal malleolus or a rupture of the internal lateral ligament; and it is a pity that his name is not applied to this very frequent fracture rather than to one of the utmost rarity. Moreover, he was no doubt correct, as I have previously intimated, in believing that this was the lesion whose clinical signs were described by Dupuytren, and that the latter erroneously thought these

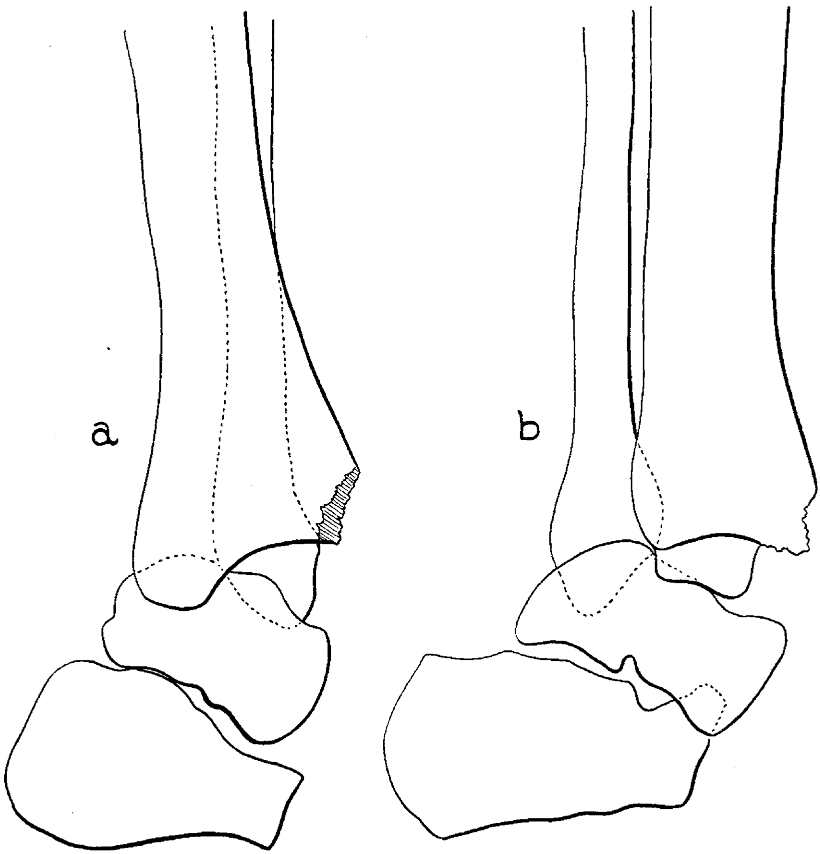

Fig. 16.—Diastasis with displacement of fibula behind tibia. The anterior tubercle of tibia has been torn off and accompanies the fibula, which is not fractured. Diastasis by external rotation (mechanism described by Huguier[49]): (*a*) anteroposterior view, and (*b*) lateral view before reduction. See also Figure 17 (A, I, complication) and page 103.

cases were such as had been depicted by Pott. Maisonneuve's chief, and almost his only, error, as it seems to me, was his failure to appreciate that a lesion did exist, consisting of a fracture well above the inferior tibiofibular joint, associated with fracture of the internal malleolus or rupture of the internal lateral ligament, and that this type of fracture, though rare, was yet much less rare than a fracture of the fibula in its upper third or even in its middle third.

After Maisonneuve, Tillaux [5] (1872). Tillaux did not distinguish in his cadaveric experiments between abduction (fibular flexion) of the foot and the same movement combined with slight outward rotation (i. e., around the long axis of the leg). Abduction, he found, caused (*a*) rupture of the internal lateral ligament or tearing off of the internal

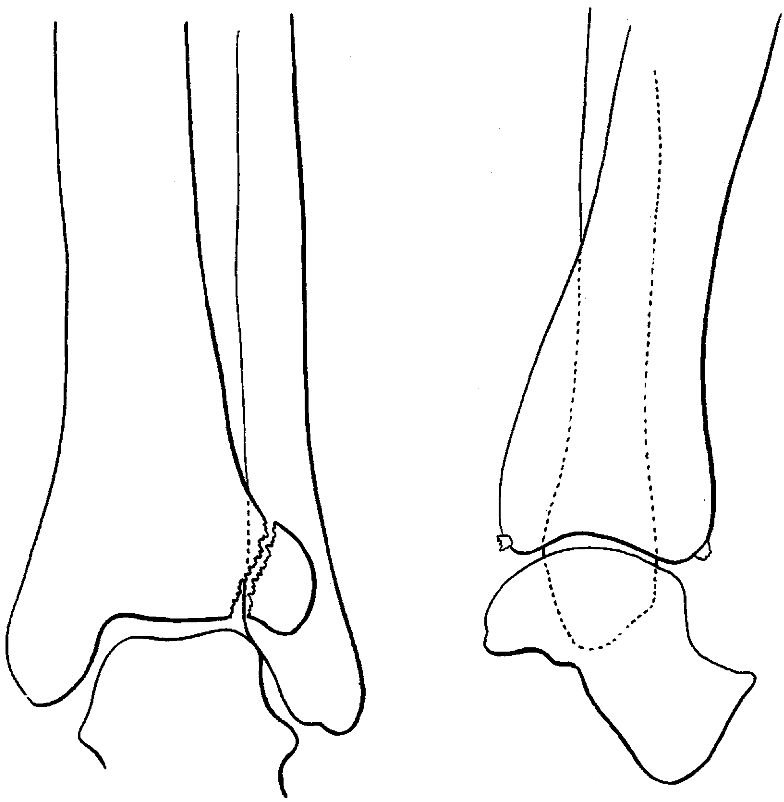

Fig. 17.—Same case as that shown in Figure 16, after reduction. Fracture of anterior tubercle of tibia clearly seen.

malleolus, or (*b*) the same lesions plus fracture of the fibula above the inferior tibiofibular ligaments, or 6 to 7 cm. above its tip; the tibiofibular ligaments may not rupture, but the degree of rupture of these ligaments determined the degree of the displacement; and he found the fibula could not be broken in abduction movements unless the internal malleolus or the internal lateral ligament had been previously broken. He also called particular attention to the great frequency of a fragment of bone torn off the lateral border of the tibia by the inferior tibiofibular ligaments; this fragment has since been known to the French as the "third fragment of Tillaux" (remember it had been described and illustrated by Cooper and by Vidal de Cassis).[23]

It is thus seen that while Maisonneuve minimized the mechanism of pure abduction, Tillaux magnified it out of all reason; for the fact remains that the vast majority of fractures are not of the type produced experimentally by Tillaux by abduction (and which correspond rather to the original type with which Pott and Dupuytren thought they had to deal), but are of the type produced experimentally by Maisonneuve by external rotation. In his description of the results of adduction (tibial flexion), Tillaux agreed with his predecessors and successors (the results are noted below under the account of Hönigschmeid's experiments); but he also describes a rare result of adduction which consists in a transverse supramalleolar fracture of the tibia sometimes occurring in those cases in which the fibula breaks above the inferior tibiofibular joint instead of below it (Fig. 43). This mechanism, he says, involves great strain on the superior tibiofibular joint until the fibula breaks above its malleolus; and he observed a case in life in which this transverse supramalleolar fracture (of the tibia only) was complicated by a diastasis of the *upper* tibiofibular joint. (In this connection, one of the specimens from the Mütter Museum [72] is of much interest.)

Hönigschmied [6] (1877), as already remarked, made 125 experiments on the cadaver, to determine the mechanism of ankle fractures, and

23. Souligoux (Bull. et mém. Soc. de chir. de Paris **38**:1103, 1912) described two unpublished diagrams made by Tillaux to illustrate this "third fragment:" the anterior view showed the anterior tubercle of the tibia torn off, while the posterior view showed the posterior tubercle torn off. Apparently, then, it was Tillaux's opinion that either tubercle could represent his third fragment. A larger fragment from the inferior lateral margin of the tibia may exist, known to the French as the "intermediate fragment of Verneuil," but it is quite rare. This seems to correspond to what Roberts and Kelly (the advance proof sheets of whose second edition, 1921, Dr. Roberts has very courteously sent me) describe as the "drunkard's fracture." Confusion is added to this matter by the statement of Thaon (Bull. Soc. anat. de Paris **45**:212, 1870), in presenting a necropsy specimen of a posterior marginal fracture, that he had often seen this posterior fragment in experiments made by Tillaux; and by the statements of Demoulin (Bull. et mém. Soc. de chir. de Paris **38**:1103, 1912), of Mauclaire (Bull. et mém. Soc. de chir. de Paris **38**:1141, 1912), and of Viallet (Rev. de chir. **46**: 690, 1912) that the third fragment of Tillaux may easily be mistaken in roentgenograms for a posterior marginal fragment. My own belief is that the third fragment of Tillaux is the anterior tibial tubercle and that the fragment composed of the posterior tubercle and that known as the posterior marginal fragment usually are indistinguishable.

a brief summary of them is given, as it will be necessary to refer to them frequently in the latter portions of this memoir.

1. *Plantar hyperflexion, twenty experiments.* In fourteen cases he got rupture of the internal lateral ligament and anterior fibers of the external lateral ligament; the rupture sometimes occurred from the tarsus, sometimes from the leg bones; sometimes a small fragment of bone was torn loose. In five cases (aged subjects), one or both of the malleoli were broken.

2. *Dorsal hyperflexion, twenty-one experiments,* always with previous division of the tendon of Achilles. In seventeen the internal malleolus was broken, by push of the tarsus against its tip. In two the internal lateral ligament was ruptured. In two the only lesion was in the tarsus.

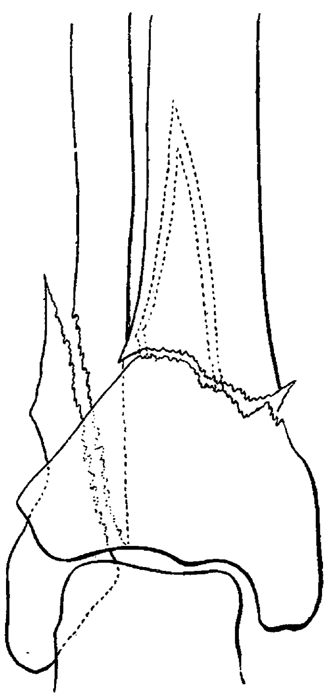

Fig. 18.—Mixed oblique fracture of fibula, internal malleolus represented by whole lower end of tibia (A, III).

3. *Tibial flexion (adduction or supination), seventeen experiments.* In all the external malleolus (five) or external lateral ligament (twelve) was broken. He never got fracture of the internal malleolus or of the tibia.

4. *Fibular flexion (abduction or pronation), twenty-two experiments.* In fifteen the internal lateral ligament or the internal malleolus broke. In seven the only lesions were in the tarsal (two) or subastragalar (five) ligaments. He never obtained a primary fracture of the external malleolus: in two cases only did it break, the lesion being a compression fracture at its tip. (If the inferior tibiofibular ligaments had previously ruptured, the weight of the patient's body, in a fall, would have fractured the fibula above these ligaments.)

5. *Inward rotation of foot around long axis of leg, twenty experiments.* In nineteen there were lesions of the ligaments (fifteen involved the tarsal ligaments, of which six involved also the external lateral ligament; while in four the external lateral ligament was alone involved). In one the anterior margin of the external malleolus was broken, evidently being torn off by the anterior fibers of the external lateral ligament. (Such a fracture had been described by Wagstaffe,[24] in 1875, and was later studied by L. LeFort[25] (1886) and by his pupil LeRoy[26] (1887).

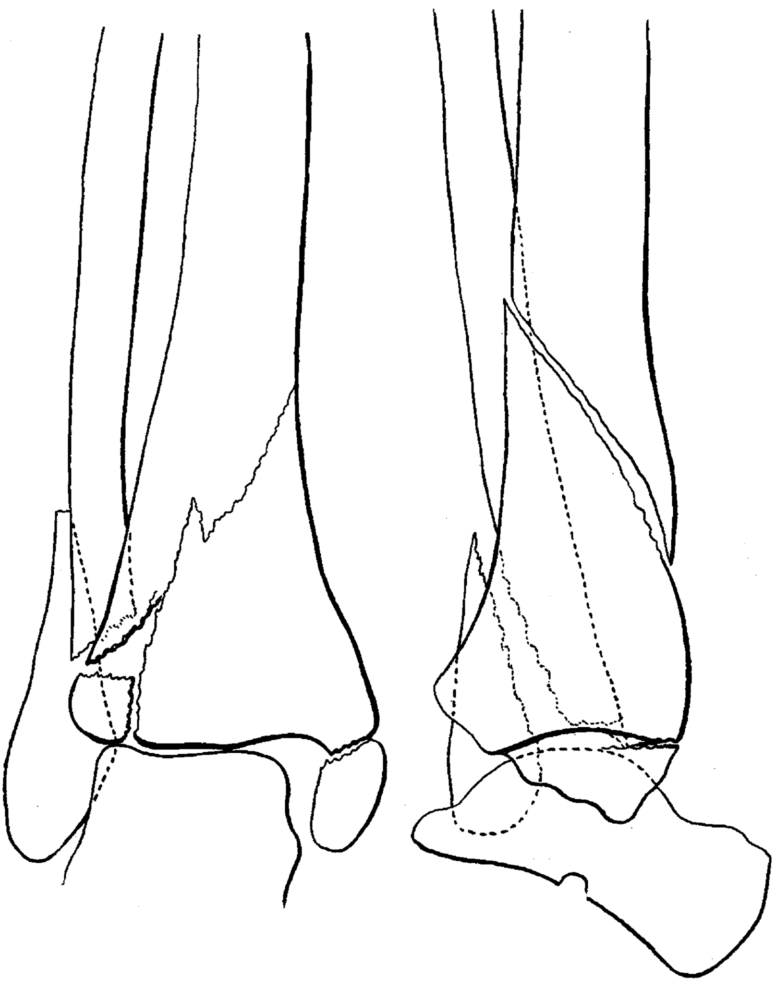

Fig. 19.—Mixed oblique fracture of fibula, with fracture of internal malleolus and of whole lower end of tibia. There is also a fracture of the anterior tubercle of the tibia (A, III).

24. Wagstaffe: Saint Thomas's Hospital Reports, London **6**:43, 1875.

25. LeFort: Bull. gén. de Thérap., Paris **110**:193, 1886.

26. LeRoy: De la fracture marginale antérieure de la malleole externe. Paris, 1887.

6. *Outward rotation of foot around long axis of leg, twenty-two experiments.*

(1) In twenty, fracture of the lower end of the fibula occurred: (*a*) in fourteen of these there was no diastasis of the inferior tibiofibular joint; in two there was rupture of the external lateral ligament with sprain fracture of the tip of the external malleolus. In seven there was only slight obliquity of the fracture line, upward and backward (four had no other lesion, three had also rupture of the internal lateral ligament). In five the line of fracture was distinctly oblique, involving more of the posterior surface of the fibula (two of these five had also rupture of the internal lateral ligament). (*b*) In six cases there was diastasis, usually detaching a small intermediate fragment from

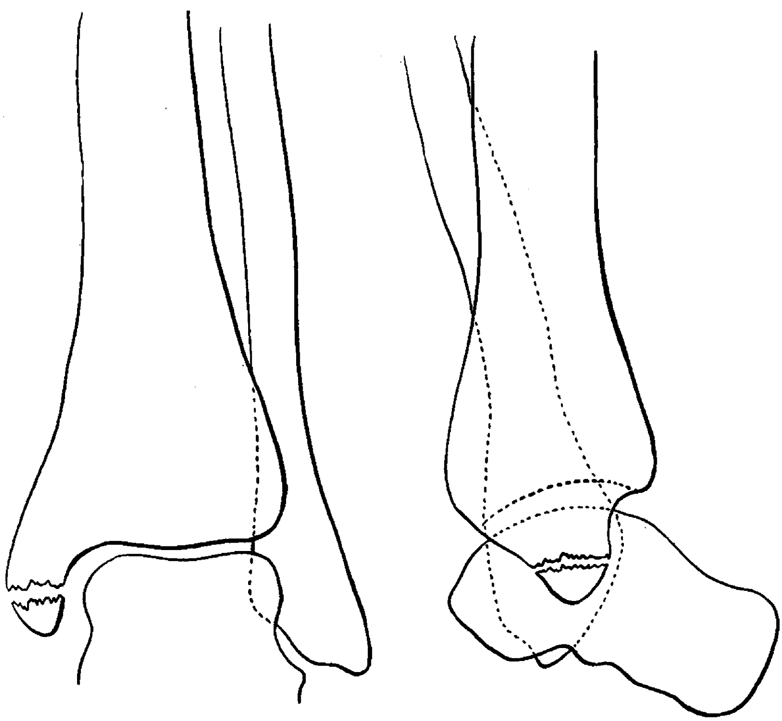

Fig. 20.—Abduction fracture, first degree (B, I): avulsion of internal malleolus. In this patient the internal malleolus extended abnormally low. This fracture occurs in 6.6 per cent. of all fractures at the ankle. All forms of the abduction type together comprise about 21 per cent. of the cases.

the tibia, and with rupture of the internal lateral ligament or fracture of the internal malleolus; in four of these six cases the fracture of the fibula was oblique upward and backward, and in the remaining two cases the fibula was broken obliquely in its upper third (i.e., Maisonneuve's fracture).

(2) In two cases diastasis occurred without fracture of the fibula.

Hönigschmied concluded that these oblique fractures of the lower end of the fibula produced during external rotation are not due, as Maisonneuve taught, to the outward pressure of the astragalus on the anterior border of the external malleolus, but to the pull exerted by the posterior band of the external lateral ligament, which tears off the posterior portion of the malleolus.

Destot, in the thesis of Bondet [27] (1899) and in his own monograph [8] (1911), attempted a physiologic classification, abandoning that based on the mechanism. He pointed out that the main function of the tibia was that of support, while the fibula acted merely as a splint along the outer side of the ankle joint to maintain the direction of the foot. Thus his classification embraces (1) those fractures which involve only the mortise, and disturb the equilibrium of the foot; and (2) those

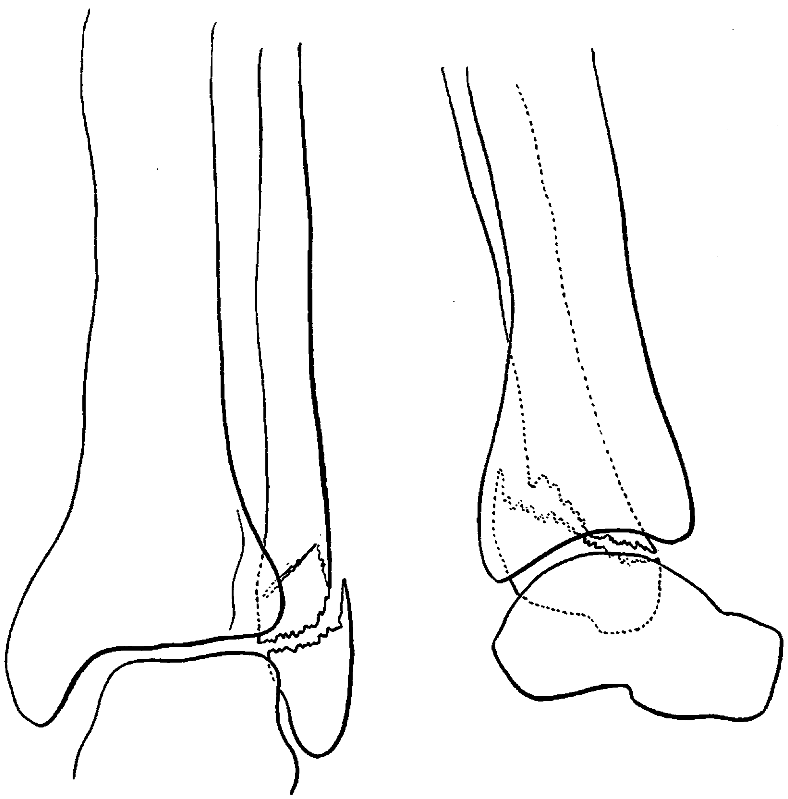

Fig. 21.—Fracture of fibula below inferior tibiofibular ligaments, with very slight obliquity, accompanied by rupture of the internal lateral ligament, as evidenced by lateral displacement of astragalus. This type of fracture is intermediate between the fracture by external rotation already discussed and the fracture by abduction. It is impossible from the roentgenogram alone to say to which of the two types such a fracture really belongs (A, I or B, I).

which involve the "pilon tibial" (the tibial "pestle") and hence compromise the support of the body. Quénu [28] (1912) addressed very severe criticisms against this classification, and, pointing out that the

27. Bondet: Thèse de Lyon, 1899.
28. Quénu: Rev. de chir. **45**:1, 211, 416, 560, 1912.

gravity of the lesions depends entirely on whether they are isolated (involving one bone only) or associated (involving both tibia and fibula), erected on this basis an elaborate scheme which, as I have already said, is less a classification than a catalog.

Finally, Tanton[29] (1916) attempted to combine the merits of Destot's and of Quénu's classifications, with a reasonable degree of success. Indirect forced movements, he said, may involve (1) the malleolo-astragalar or tarsal ligaments (sprain); (2) the inferior tibiofibular ligaments (diastasis); (3) the malleoli (isolated fractures), very frequent; (4) the "pilon tibial" (isolated), very rare; (5) the malleoli and tibial *pilon* (frequent). Thus he tabulated the lesions as follows (omitting sprains and simple diastases):

I. Fractures of Malleoli—
- 1. Isolated:
  - (*a*) External malleolus.
  - (*b*) Internal malleolus.
- 2. Associated:
  - (*a*) Low bimalleolar.
  - (*b*) Low Dupuytren.
  - (*c*) Typical Dupuytren (Pott's).
  - (*d*) Maisonneuve.

II. Fractures of Pilon—

A. Partial.
- 1. Isolated:
  - (*a*) Anterior or posterior tubercles of tibia.
  - (*b*) Marginal: anterior, external, posterior.
  - (*c*) Wedge-shaped internal fractures.
- 2. Associated:
  - (*a*) Anterior margin with a malleolar fracture.
  - (*b*) External margin with a malleolar fracture.
  - (*c*) Posterior margin with a malleolar fracture.

B. Total (Eclatements).

Stimson,[7] both in his lecture of 1892, and in the last edition[30] (1917) of his book on "Fractures and Dislocations," makes a distinction between fractures in which the mechanism of fibular flexion (abduction) predominates and those in which outward deviation of the point of the foot (outward rotation) predominates.

In the former, he says, the internal malleolus is broken, followed by rupture of the inferior tibiofibular ligaments (or sometimes detachment of a piece of the tibia), and then occurs a fracture of the fibula "close above the malleolus;" while in the latter there occurs rupture first of the anterior inferior tibiofibular ligament, then of the anterior fibers of the internal lateral ligament,

29. Tanton: Fractures du membre inférieur, Paris, 1916.

30. Stimson: Fractures and Dislocations, Ed. 8, Philadelphia, 1917, p. 450.

and almost coincidentally the fibula breaks by the twisting of its lower end, the line of fracture being very oblique.

But in spite of all this comparatively explicit and positive teaching for so many generations, the fact is undeniable that the average surgeon knows little or nothing about ankle fractures; and that most teachers of surgery either leave their students with but a confused notion of the subject, or else teach them positively what is certainly not correct.

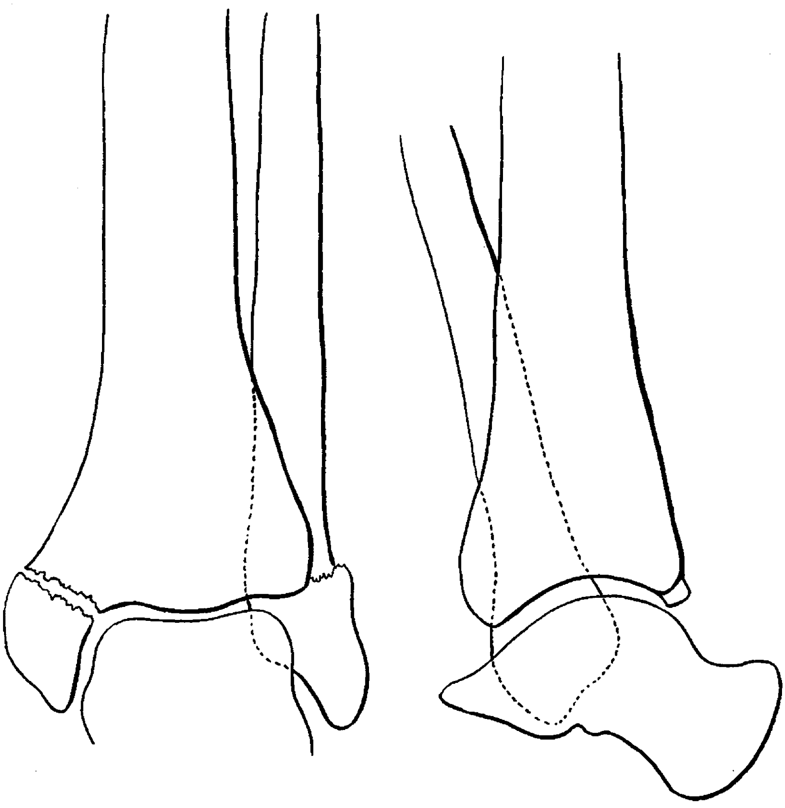

Fig. 22 (B, II, a).—Fracture of both malleoli by abduction. A heavy steel I-beam, lying on the ground beside the patient while he was standing at work was tipped over and struck the lateral surface of his leg, causing sudden abduction of the foot. He was not knocked down, but he felt a sudden pain in the ankle. He was able to walk on the leg. In the lateral view, the fracture of the external malleolus (which occurred subsequent to that of the internal malleolus, and was incomplete and subperiosteal) is not visible at all, while even that of the internal malleolus can hardly be seen.

These examples may be cited:

"Fracture of the lower end of the fibula is a very frequent injury, resulting from indirect violence, the foot, as a rule, being turned violently outward (abduction fracture); as the astragalus forces the external malleolus outward, the tibiofibular ligaments act as a fulcrum, so that the fibula is bent in against the tibia above the attachment of these ligaments, and finally breaks at this point from five to eight cm. above the ankle joint; the internal malleolus often is avulsed from the tibia, at the same time; and to this combined lesion the name of Pott's fracture is given." (Ashhurst: Surgery, Philadelphia, 1914. p. 380.)

"What is a Pott's fracture? . . . It is a fracture of the lower end of the fibula that is produced by the foot turning outward when the injury is sustained. What happens when the foot turns outward? The external surface of the astragalus presses against the tip of the external malleolus, and the fibula

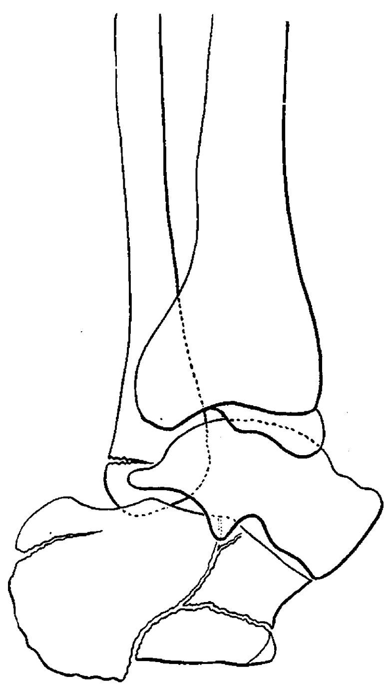

Fig. 23.—Crush fracture of calcaneum permitting fracture of external malleolus by compression. See page 99.

breaks primarily. If the interosseous ligament is strong, the fibula breaks within the first two and one-half inches above the tip of the external malleolus, otherwise only the tip of the fibula is broken off on a line with the tibio-astragaloid articulation, as in the case before us today. In a typical Pott's fracture the fibula fractures higher up.

"Next occurs a fracture of the internal malleolus, due to traction on the internal lateral ligament or rupture of the ligament. Then, as the pressure is continued with the foot everted and the weight of the patient's body is brought to bear on the foot, what happens? The astragalus is crowded up against the tibiofibular articulation, and, acting as a wedge, forces apart the tibia and fibula and splits or tears the interosseous ligament."[31]

"The mechanism of Pott's fracture consists first in forcible eversion of the foot until the outer surface of the astragalus is driven against the fibular malleolus; secondly, in fracture of the shaft of the fibula, usually above the inferior tibiofibular joint, the unyielding interosseous ligament acting as a fulcrum; thirdly, by a continuation of the vulnerating force, the acute supero-external border of the astragalus develops as a wedge and is driven upward between the tibia and fibula until it springs the joint by lacerating the interosseous membrane."[32]

Cotton[33] (1910) describes all "eversion fractures" as Pott's fractures, and, though he points out the inaccuracy of this term, does not dwell particularly on their mechanism, merely quoting Stimson's account already given.

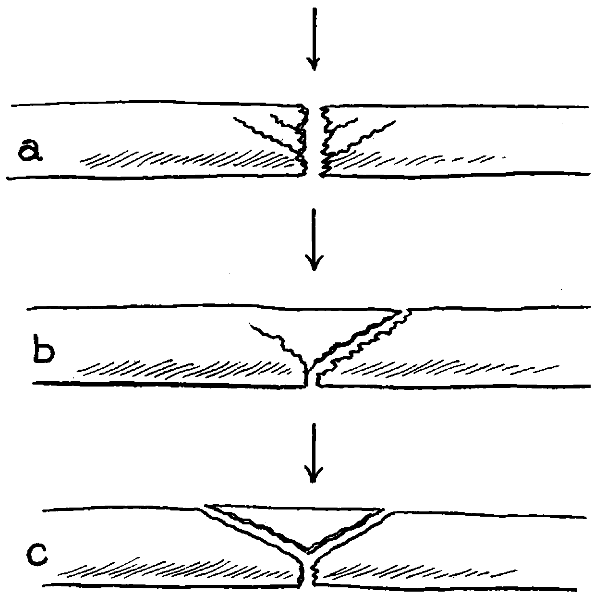

Fig. 24.—Messerer's diagram illustrating the mechanism of fracture by bending (Biegungsbruch) or flexion: (*a*) minute examination always shows in fractures apparently transverse delicate lines diverging from the main fracture and extending backward toward the surface of the bone which has been compressed or flexed, and away from the surface of extension; (*b*) an oblique fracture represents one of these diverging lines which has become a complete fracture; (*c*) very frequently a wedge-shaped fragment is detached, with its base on the compression (concave) surface and its apex toward that of extension (convex surface). See Figures 25, 26, 28, 29, 35, 36.

31. Murphy: Surgical Clinics, Philadelphia **3**:2, 1914.
32. Murphy: Surgical Clinics, Philadelphia **1**:620, 1916.
33. Cotton: Dislocations and Joint Fractures, Philadelphia, 1910, p. 545.

Roberts and Kelly[34] (1916), in describing "fracture by eversion and abduction," say the mechanism is first fracture of the internal malleolus or rupture of the internal lateral ligament; "as the force continues the astragalus is forced against the external malleolus, fixing the latter, at the same time the weight of the body falling outward carries with it the leg and the fibula; the fibula is checked by the astragalus [Do they mean that the external malleolus is kept from moving inward as the body of the fibula moves outward?] and kept attached to the tibia by the tibiofibular ligament; either the latter ruptures or a line of fracture occurs at the weakest point of the fibula just above the point of attachment of the tibiofibular ligament. It is here that the fixed portion

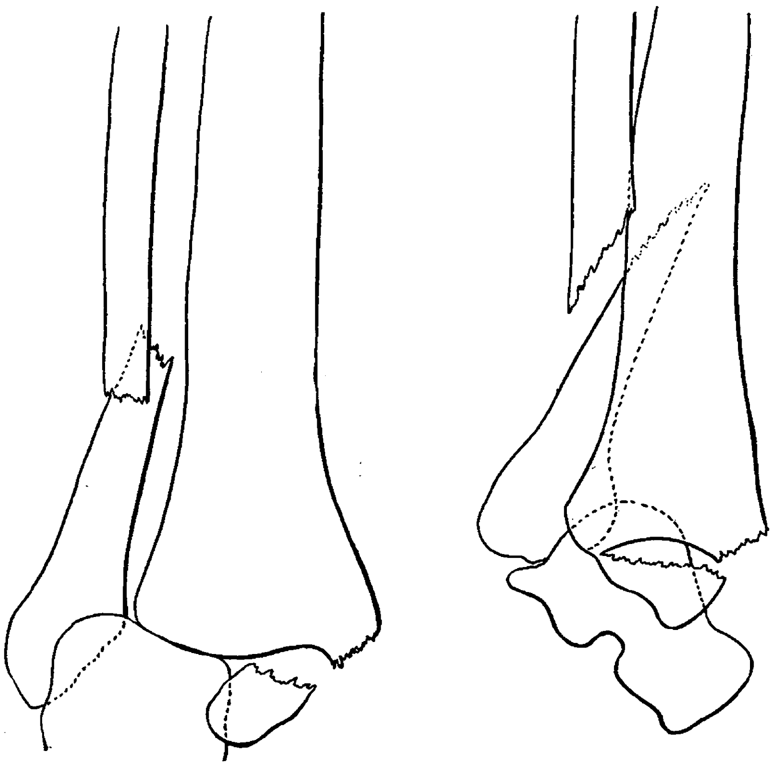

Fig. 25.—Fracture by abduction, second degree (B, II, b) (Pott's fracture, Dupuytren type): a primary fracture of the internal malleolus or rupture of the internal lateral ligament, followed by diastasis (with or without an intermediate fragment), finally succeeded by fracture of the fibula above the inferior tibiofibular joint by bending (Biegungsbruch).

of the fibula meets the potential moving upper portion, and fracture occurs about 2 to 2¼ inches above the malleolus. The line of fracture of the fibula depends to a great extent on whether the fall is directly outward, or whether some torsion of the tibiotarsal joint occurs at the moment of fracture."

34. Roberts and Kelly: Treatise on Fractures, Philadelphia, 1916, p. 580.

On page 590, they describe another (?) mechanism: "In addition to the mechanism described under fibular fracture, there is the effect due to the weight of the body being applied simultaneously with the violence causing the supramalleolar fracture of the fibula; by this force the outer trochlear surface of the astragalus is carried sharply against the outer portion of the articular surface of the tibia, by external rotation and abduction of the foot, so that either the tibiofibular ligament must give way or the outer edge of the tibia be broken away from the shaft. Dislocation upward of the astragalus between the tibia and fibula may occur."

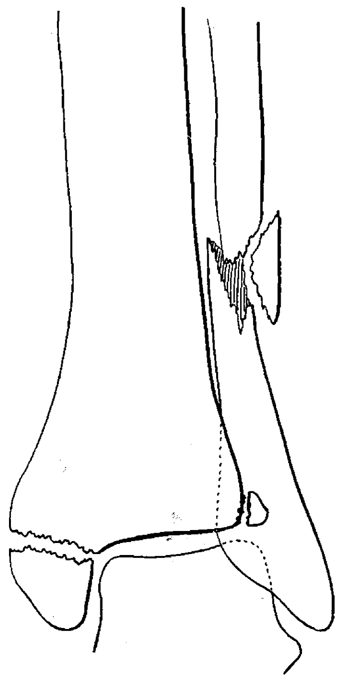

Fig. 26.—Fracture by abduction, second degree (B, II, b) (Pott's fracture, Dupuytren type): diastasis evidenced by detachment of fragment from anterior tubercle of tibia (intermediate fragment); fracture by bending clearly shown by detachment of wedge from concave side of fibula.

Rose and Carless[35] (1920) distinguish between Pott's fracture and Dupuytren's fracture thus:

"In Pott's fracture, sudden abduction, usually combined with eversion of the foot, results in severe strain on the internal lateral ligament, which gives way, or the base of the internal malleolus is torn off. The astragalus is at the same time driven outward against the external malleolus, and the force is thence transferred up the fibula, which bends and breaks at some weak spot. Generally, eversion is a large element in the force that produces the fracture which then runs obliquely from above downward and forward through the malleolus;

35. Rose and Carless: Manual of Surgery, Ed. 10, London, 1920, p. 632.

less frequently it is due to a pure abduction and may then be situated in the position originally described by Pott, viz., about three inches above the tip of the malleolus, and is transverse, the upper end of the lower fragment being displaced inward toward the tibia. The inferior interosseous ligament remains intact. . . .

"In Dupuytren's fracture a much more serious lesion is produced. The interosseous tibiofibular ligament yields more or less completely, or the flake of the tibia to which it is attached is torn off."

Speed[36] (1916) thus describes the mechanism of fractures about the ankle (p. 772): "When abduction and eversion of the foot are the cause of the fracture, the astragalus is pushed outward, and the fibula tends to break at a

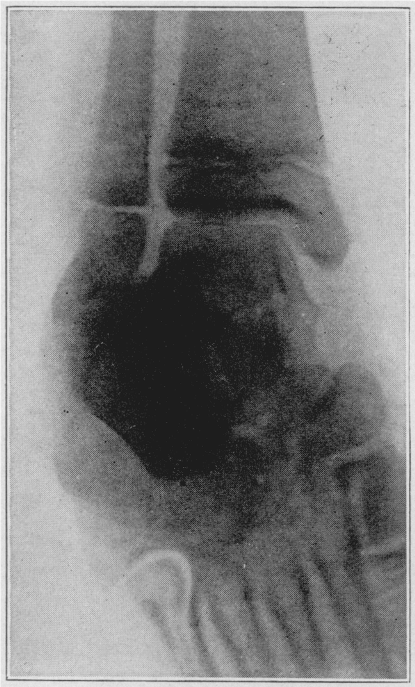

Fig. 27.—Diastasis of inferior tibiofibular joint, following rupture of internal lateral ligament, but not succeeded by fracture of fibula (B, II, b, 1, Variant).

point above the termination [presumably he means the *upper* termination] of the tibiofibular ligament in a transverse or oblique line from compressive force. Coincidently the internal lateral ligament either ruptures, or holding its insertion into the tibia, pulls off the internal malleolus squarely near its lower end (Fig. 566). [This figure represents a "low Dupuytren" fracture.] If this eversion continues strongly, the lower fibular fragment may be separated a little from the tibia by tearing of the tibiofibular ligament, and the internal malleolus is correspondingly dragged outward by the internal lateral ligament,

36 Speed: Textbook on Fracture and Dislocations, Philadelphia, 1916, p. 772.

and comes to lie under the joint surface (Fig. 567). [This figure shows a Pott's fracture, with wide diastasis; and the latter certainly preceded the fracture of the fibula and did not, as Speed contends, follow it.] Some torsion is present in all these cases. . . . If the torsion is a more predominating feature in conjunction with the eversion, we obtain the spiral fractures of the external malleolus, as this point projects lower down than the internal malleolus and meets with most of the force in external torsion and eversion. [The reason alleged is insufficient explanation.] These spirals, in a quickly acting force, are above the lower end of the tibiofibular ligament which by a slight elasticity holds while the rigid bone gives; but in slower acting force with more eversion or compressive violence from the body weight, the extreme end

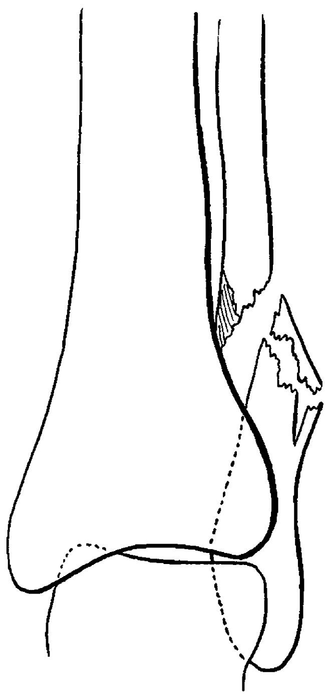

Fig. 28.—Fracture of lower fifth of fibula (surgical neck) by direct violence (kick of horse): there is no diastasis and under such circumstances the typical bending fracture (wedge detached from surface of flexion), which has been overcorrected by adduction of foot, could not have been produced by indirect violence (pressure of astragalus outward on external malleolus).

of the external malleolus is fractured and splintered up in a spiral manner. As a rule there is not much damage to the internal malleolus and the internal lateral ligament in this mechanism (see Fig. 568)."

This figure shows a low mixed oblique fracture of the fibula, unreduced, though the foot is in adduction and inward rotation. Speed says reduction has not been secured because of laceration of the external lateral ligament. But how could such a laceration occur in the mechanism he is discussing? Speed adds that "sometimes in eversion, in addition to fibular fracture, the tibiofibular ligament is torn, a condition permitting wide separation between the bone ends and possibly accompanied by a shell of bone pulled out from the tibia." Writing (p. 785) of "malleolar fractures caused by inversion of the foot," he says, "The mechanism of isolated fractures of the internal malleolus is that of fall or compression from body weight against the talus, which is tipped inward by the inverted foot. . . . For this result the inversion must not be great, because the pull of the external lateral ligament would also pull off the external malleolus." (Thus he regards fracture of the external malleolus as a secondary and not the primary lesion in adduction fracture. But the illustration he gives as an instance of isolated fracture of the internal malleolus is not happily chosen [Fig. 592], as it shows the astragalus displaced from the external malleolus,

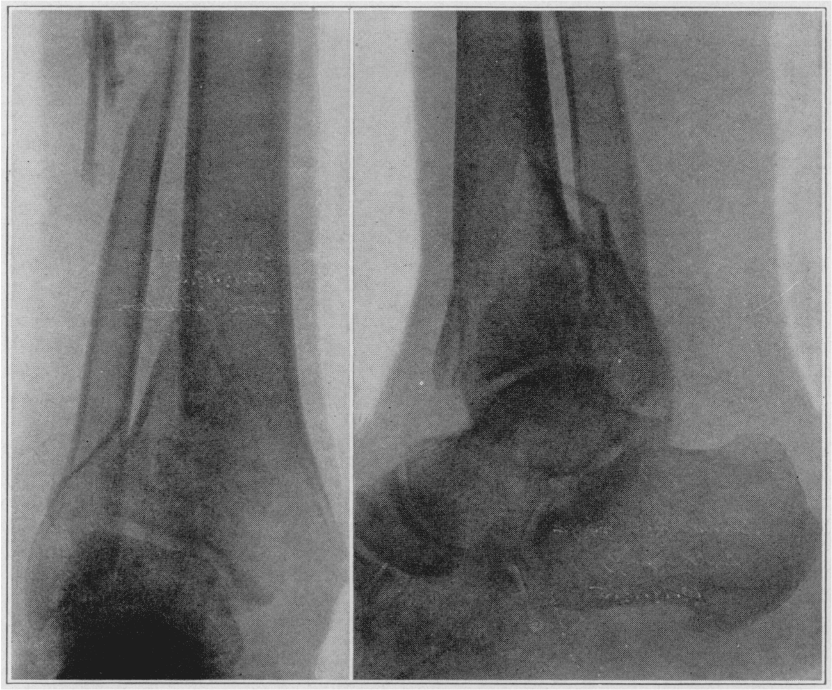

Fig. 29.—Fracture by abduction, third degree (B, III). The internal malleolus is represented by the whole lower end of the tibia; the fibula is broken by bending; there may or may not be an intermediate fragment. There were only two cases of this kind in our series of 300 cases.

an occurrence obviously permitted only by partial rupture of the anterior fibers of the external lateral ligament or sprain fracture of its tip.)

MECHANISM

Now, after the somewhat tedious historical review given above, it is worth while, before proceeding further in our inquiries, to pause a moment to refresh our knowledge concerning the structure and functions of the ankle. We have read of eversion, of abduction, of rotation, of torsion, compression and bending, of malleolus and fibula, of ligaments and tubercles, of sprains, displacements and diastases; but it is clear that few authors use any of these terms in the same senses, and

Fig. 30.—Fracture by abduction (B, II, b, 1): rupture of internal lateral ligament, followed by diastasis (note the intermediate fragment), and this succeeded by a bending fracture of fibula, in this case at an unusually high level.

that some of them probably do not know what they mean themselves. But what Nélaton[37] (1844) said of surgery in general may well be

37. Nélaton: Eléments de path. chir., Paris, 1844, vol. 1, Preface.

applied to this particular part of surgical knowledge: *"Rien en chirurgie n' est assez abstrait pour que l'obscurité s'excuse par le sujet même, et sur un grand nombre de points la science est assez avancée pour que la verité apparaisse au milieu des controverses à celui qui la cherche sans préoccupation."* And if what I succeed in explaining in the following pages appears to you to be nothing new, you will admit its truth; and I shall be satisfied. If on the other hand, you do not agree with my

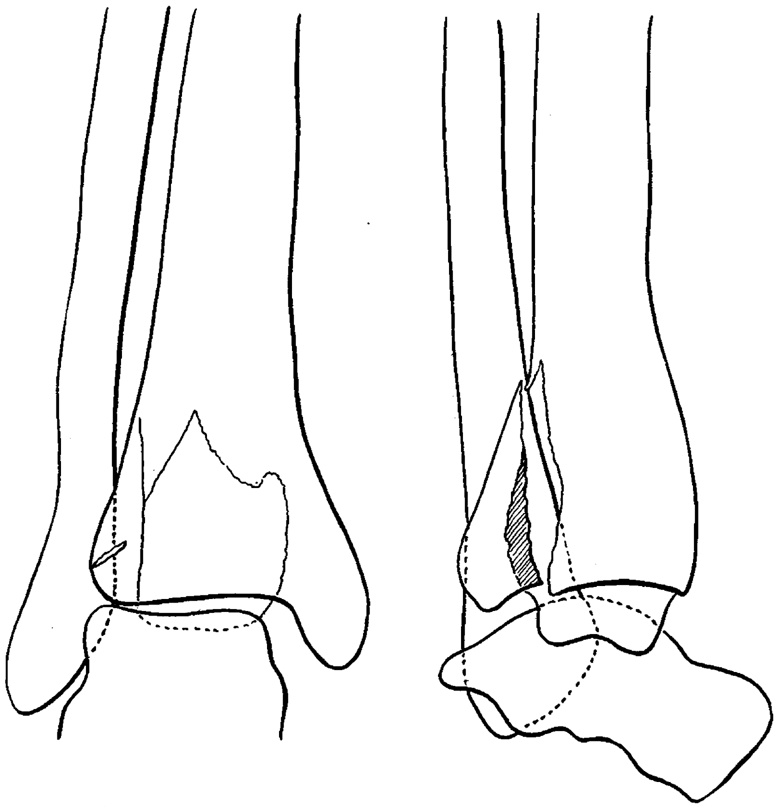

Fig. 31.—Fracture of posterior margin of tibia, associated with a tibiofibular diastasis, as evidenced by sprain fracture at this joint. The posterior marginal fragment which is unusually large is visible also in the anteroposterior view.

conclusions, that will not in the least disconcert me, for it will not impair their truth.

The ankle joint is formed above by the tibiofibular mortise, and below by the trochlea of the astragalus, which fits into the mortise as a tenon. This trochlear surface is one fourth wider in front than behind, conforming to the divergent direction of the internal surfaces of the malleoli. The inferior articular surface of the tibia may be described as the roof or ceiling (*plafond*) of the joint; and the articular surfaces of the malleoli have long been known as the "cheeks" of the mortise.[38] That portion of the fibula *which projects beyond the tibial plafond* is properly called the external malleolus; and the corresponding projection of the tibia is called the internal malleolus. The posterior lip of the tibial plafond projects so low as to have been called by Destot the posterior malleolus. This serves to reinforce the mortise posteriorly. It is further deepened by the transverse tibiofibular ligament which

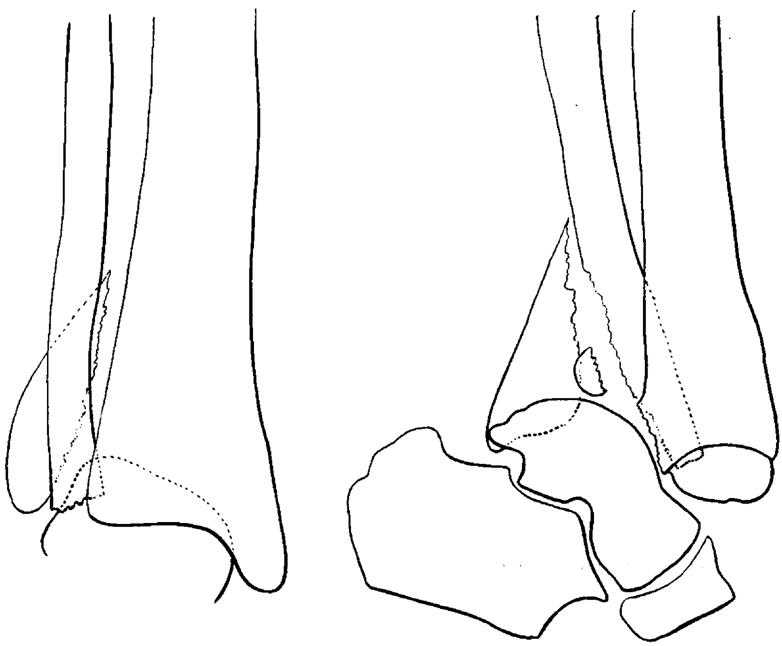

Fig. 32.—Small posterior marginal fragment in a case of fracture by external rotation. Notice the mixed oblique fracture of fibula; the intact internal malleolus (rupture of internal lateral ligament), and the complete posterior dislocation of the foot, the astragalus and the posterior marginal fragment accompanying the external malleolus.

extends from the external malleolus to the posterior lip of the tibia. Thus in walking, as the foot meets the ground in plantar flexion, the leg bones are checked in their tendency to slide forward on the astragalus by the wedge shape of the trochlea of the latter bone (broad anteriorly

38. From the Greek word for cheek, Quénu derives the adjective *génienne*, which he constantly employs in his classification and nomenclature of ankle fractures, inventing such terms as *bi-malleolaire géni-sus-genienne*, *géni-peronière* and *géni-supramalleolaires*.

and narrow posteriorly), by the corresponding divergence of the anteroposterior planes of the malleoli, and by the long posterior lip of the tibial plafond. In walking backward (always digitigrade, not plantigrade) the same mechanism is effective.

The fibula is attached firmly to the tibia, but a slight range of motion is permitted. The interosseous membrane extends throughout the length of the tibial and fibular shafts, the fibers running downward and laterally from tibia to fibula (as in the forearm from radius to ulna); and in addition, there are strong ligaments whose fibers run in the same direction, binding both ends of the fibula to the tibia, at which

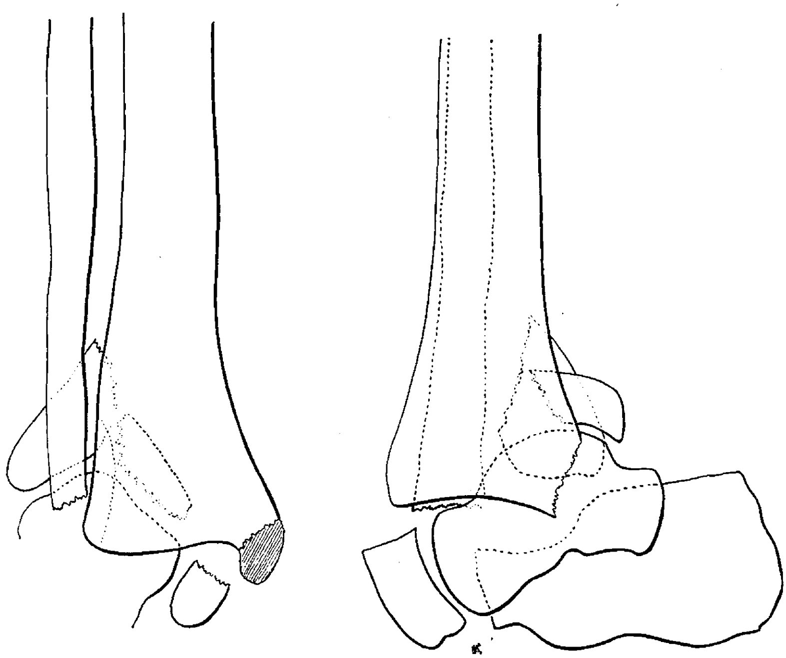

Fig. 33.—Medium-sized posterior marginal fragment in association with mixed oblique fracture of fibula and fracture of internal malleolus. The posterior marginal fragment, which is visible also in the anteroposterior view, accompanies the external malleolus and the astragalus in the very marked lateral displacement and in the incomplete posterior dislocation.

points only are the two bones in contact. At the upper end, where the head of the fibula butts against the overhanging external condyle of the tibia, there is a synovial cavity to the tibiofibular joint; but at the lower end, where the fibula is received into a longitudinal groove between the anterior and posterior tubercles on the lateral surface of the tibia (Fig. 4), no such joint cavity exists, union being effected by a dense feltlike interosseous ligament, reinforced anteriorly by the anterior inferior tibiofibular ligament, and posteriorly by the posterior ligament of the same name. The malleoli, of which the external is the longer and is situated more posteriorly, serve to keep the foot (which is appended to the astragalus) under the leg bones. The astragalus itself has no muscles attached to it, and serves only as a ball in a ball-bearing joint to facilitate movements of the leg bones above it and of the tarsal bones below and in front. The foot is attached to the leg bones by

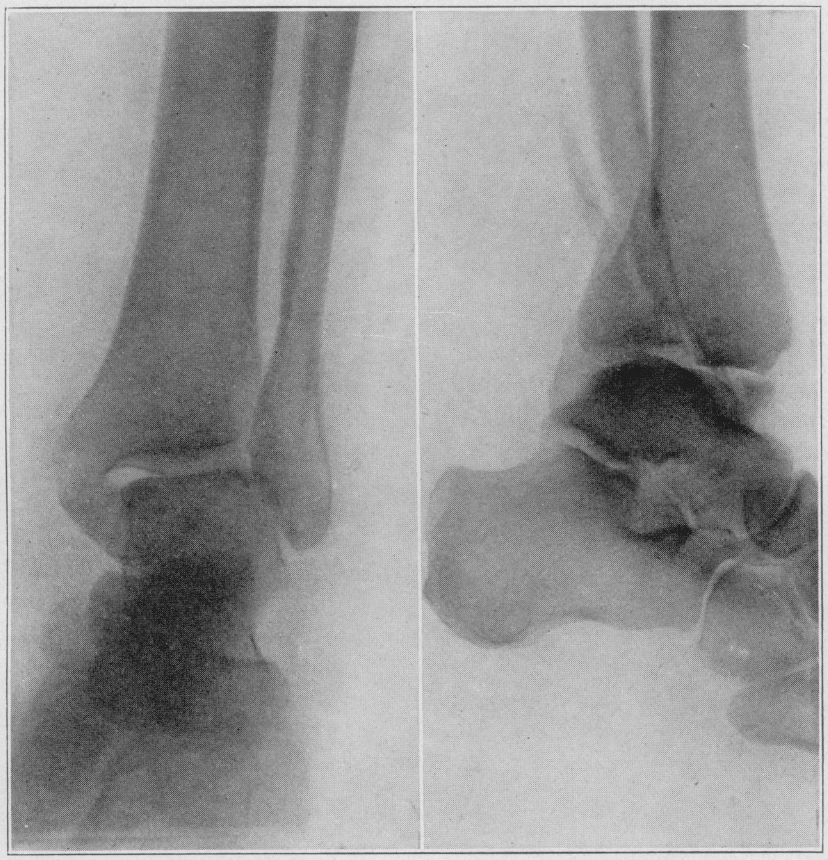

Fig. 34.—Large posterior marginal fragment in association with mixed oblique fracture of fibula and fracture of internal malleolus; only moderate displacement, chiefly due to the outward rotation.

ligaments, of which the lateral portions are best developed, constituting for the ankle, as in other hinge joints, lateral ligaments which hinder motion except in the anteroposterior plane. The internal lateral ligament passes from the internal malleolus in radiating direction (1) anteriorly to the scaphoid and median surface of the calcaneum (sustentaculum tali) and (2) posteriorly to the median tubercle on the posterior surface of the astragalus. The external lateral ligament has three distinct bands, passing from the external malleolus: one goes forward to the lateral border of the neck of the astragalus, just above the sinus of the tarsus; the middle band passes downward and slightly backward to the calcaneum; while the posterior, whose deep portion is extremely strong (Fig. 5), is attached to the lateral tubercle on the posterior surface of the astragalus (os trigonum), which, being from 5 to 7 mm. posterior to the median tubercle, is the portion of the

Fig. 35.—Small posterior marginal fragment in association with abduction fracture of fibula and fracture of internal malleolus. Note the diastasis, the typical wedge detached from the flexion surface of fibula and the posterior marginal fragment accompanying the external malleolus and astragalus in their marked lateral and posterior displacement.

astragalus which casts the farthest posterior shadow in lateral roentgenograms of the foot. This posterior band of the external lateral ligament is so exceedingly strong that it is very seldom ruptured; it holds the astragalus almost indissolubly attached to the external malleolus,[39] and

39. Chaput (Bull. et mém. Soc. de chir. de Paris **38**:1192, 1912.) says they are like Siamese twins.

in injuries of the ankle either one or other bone to which the ligament is attached is more easily broken than is the ligament ruptured. As will be shown subsequently, usually the fibula gives way when the strain comes; occasionally, however, the posterior tubercle of the astragalus is detached; and I have seen at least one case in which fracture occurred at both points simultaneously.[40]

The next question that arises is, what is the function of the fibula?

Fig. 36.—Posterior marginal fragment associated with diastasis and fracture of internal malleolus, and with fracture of fibula by bending backward (flexion surface posterior, extension surface anterior) as evidenced by wedge detached from posterior surface of fibula.

---

40. The posterior tubercle of the astragalus may sometimes be fractured by direct violence as it is crushed against the posterior lip of the tibia in forced plantar flexion of the foot.

Humphry[41] (1858) notes that the fibula is an inconstant bone in animals: in carnivora and pachydermata it extends from the upper end of the tibia to the ankle as in man. In most rodents it is united with the tibia at the lower part. In ruminants it altogether disappears. In birds its upper extremity enters into the knee joint and articulates with the external condyle of the femur; it lies close against the tibia and dwindles and disappears about the middle of the leg. In reptiles, it is large, in many extending to the knee joint above and

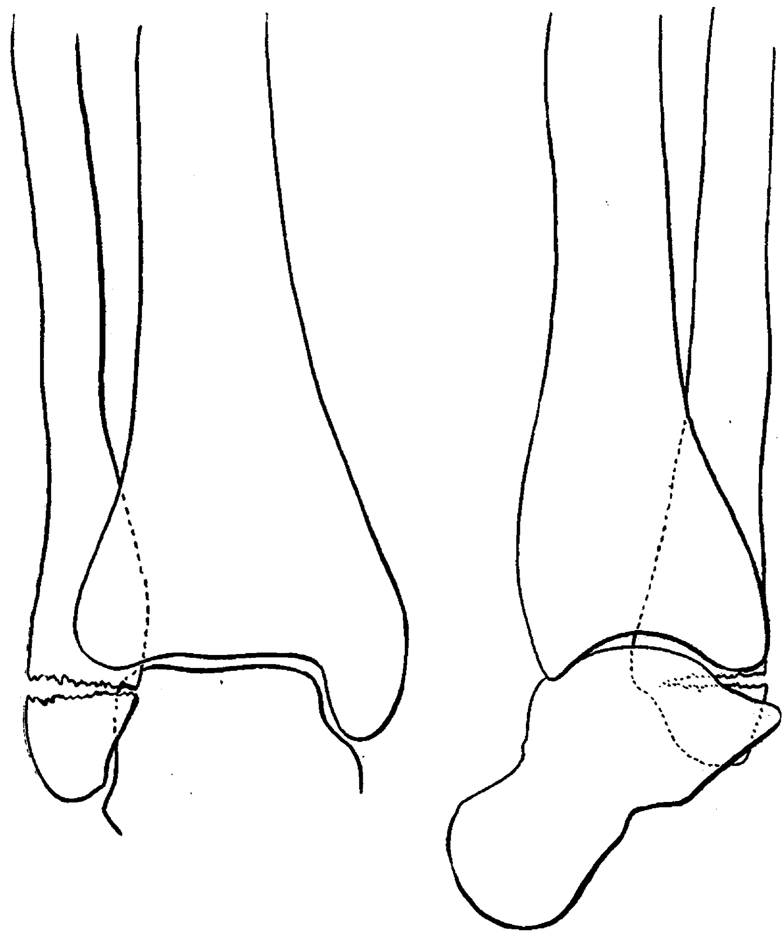

Fig. 37.—Fracture by adduction, first degree (C, I); avulsion of external malleolus. See page 118.

to the tarsus below. In the bat, the lower half of the fibula and the upper half of the ulna are retained.

It has seemed to me, from study of the skeletons in the Museum of the Academy of Natural Sciences of Philadelphia, that the fibula was best developed and extended farthest beyond the tibia at the ankle in those animals which

41. Humphry: Treatise on the Human Skeleton, Cambridge, 1858, p. 490.

were most nearly plantigrade, and in which, as in man, stability rather than agility was demanded. In digitigrades, such as the horse and camel, there is no fibula; in partial or less complete digitigrades (rhinoceros) it extends beyond the tibial plafond, but not below the level of the internal malleolus. In a still less complete digitigrade (almost a plantigrade), such as the elephant, it extends below the level of the internal malleolus, and there is outward rotation of the lower end of the tibia, as in man. In the gorilla, chimpanzee, orang-utan, etc., on the other hand, which are more plantigrade than digitigrade (but in which, as already noted, agility is retained at the expense of stability),

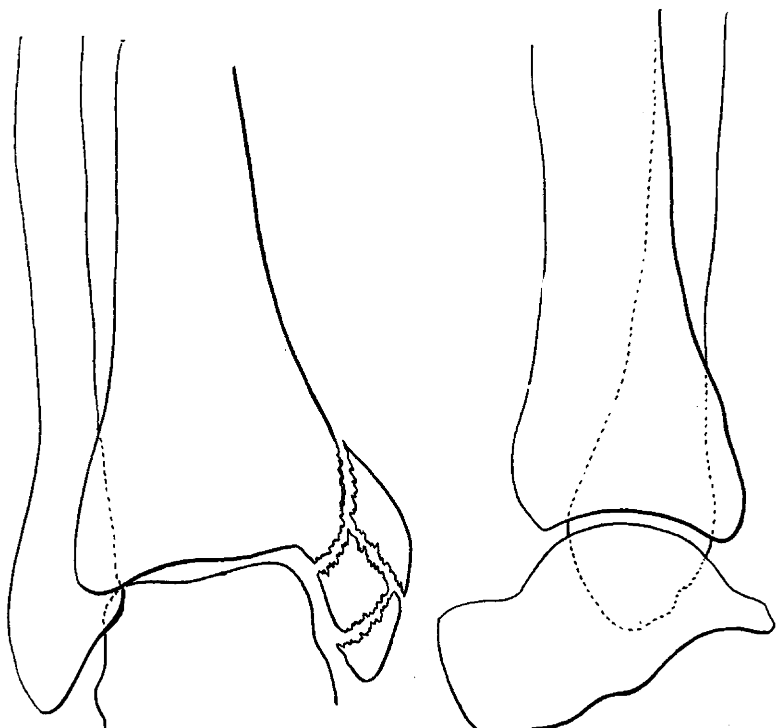

Fig. 38.—Adduction fracture, second degree (C, II, a); avulsion of external malleolus, represented by partial rupture of anterior fibers of external lateral ligament (rare) followed by compression fracture (note the comminution) of internal malleolus.

the lower end of the tibia has not rotated out as far as in man (in fact, not so far out as a transverse plane through the tibial condyles), and the fibula descends no lower than the internal malleolus. This lack of development of the fibula in these more or less anthropoid animals was noted by Bland-Sutton[42] (1888); and he further calls attention to the fact that in babies born with congenital clubfeet this deformity is merely a lack of normal development, the outward rotation of the lower end of the tibia not having occurred, and the external malleolus not having descended below the level of the internal.

42. Bland-Sutton: Am. J. M. Sc. **95**:376, 1888.

Evidently, he concluded, the external malleolus was developed only to aid members of the human race to walk in the erect posture; it was required to keep the foot steady and prevent it from turning outward into a position of extreme valgus. As Destot says, the external malleolus acts merely as a splint to maintain the direction of the foot.

But if this is so, why is the fibula a separate bone in man? Why is not the external malleolus merely a part of the tibia? To this I know of no better answer than that given by Bromfeild[11] (1773) that if it were a part of the tibia,

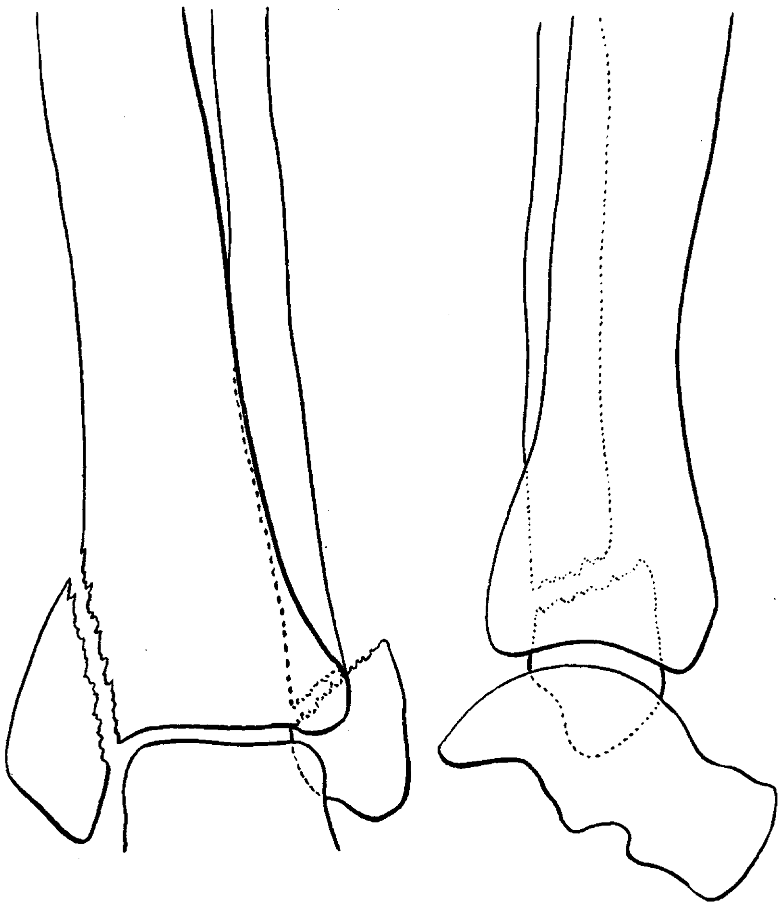

Fig. 39.—Adduction fracture, second degree (C, II, a); avulsion of external malleolus followed by compression fracture of internal malleolus.

and no give or play whatever occurred between the malleoli, no one could take more than a very few steps without fracturing one or other malleolus.

If a leg is studied from which all soft parts have been removed except the ligaments and the interosseous membrane, these phenomena may be observed:

In full plantar flexion (extension) of the foot, the anterior and middle bands of the external lateral ligament become tense and pull the external malleolus medially (and slightly downward and backward) against the tibia, keeping the external malleolus in close contact with the astragalus as this glides forward and presents to the intermalleolar space a slightly less diameter than in full dorsiflexion of the foot. In the latter movement, dorsiflexion, the anterior band of the external lateral ligament becomes lax, and as the external malleolus is forced away from the tibia and slightly upward, the anterior and posterior tibiofibular ligaments become tense, especially the anterior ligament; also, as flexion beyond a right angle occurs, much tension develops on the middle band of the external lateral ligament, and this pulls the malleolus backward: the posterior band of the external lateral ligament is always tense; it makes the astragalus and external malleolus practically one bone.

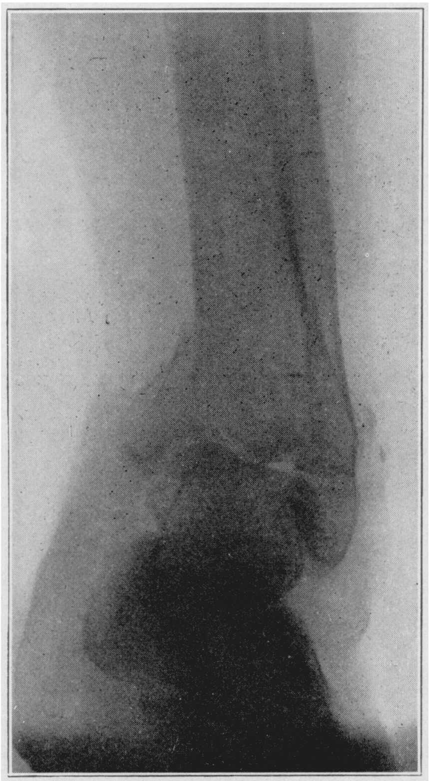

Fig. 40.—Adduction fracture, second degree (C, II, b); large tibial fragment extending into shaft replaces compression fracture of internal malleolus.

The expansion of the intermalleolar space which occurs during dorsiflexion of the foot may amount to several millimeters. I have measured it by affixing a wire in each malleolus and bending the ends of these wires forward over the ankle joint until they crossed each other in parallel lines: by scratching a mark on each wire at the same point when the foot is in full plantar flexion, it is easy to measure the excursion as the foot is brought up into full dorsiflexion. This excursion, which exceeds two mm. and may approach three mm., allows the wider anterior diameter of the articular surface of the astragalus to pass back between the malleoli in dorsiflexion, while the downward drag of the anterior and middle bands of the external lateral ligament keeps the malleoli in contact with the small posterior diameter of the astragalus which presents between them in full plantar flexion. Destot[8] (1911) pointed out that inasmuch as the intermalleolar axis and the axis of rotation of the astragalus, in flexion and extension, do not coincide (they form an angle of about 30 degrees, open laterally, Figure 4), it is not a directly transverse diameter of the astragalus that presents between the malleoli at any point of flexion or extension, but a

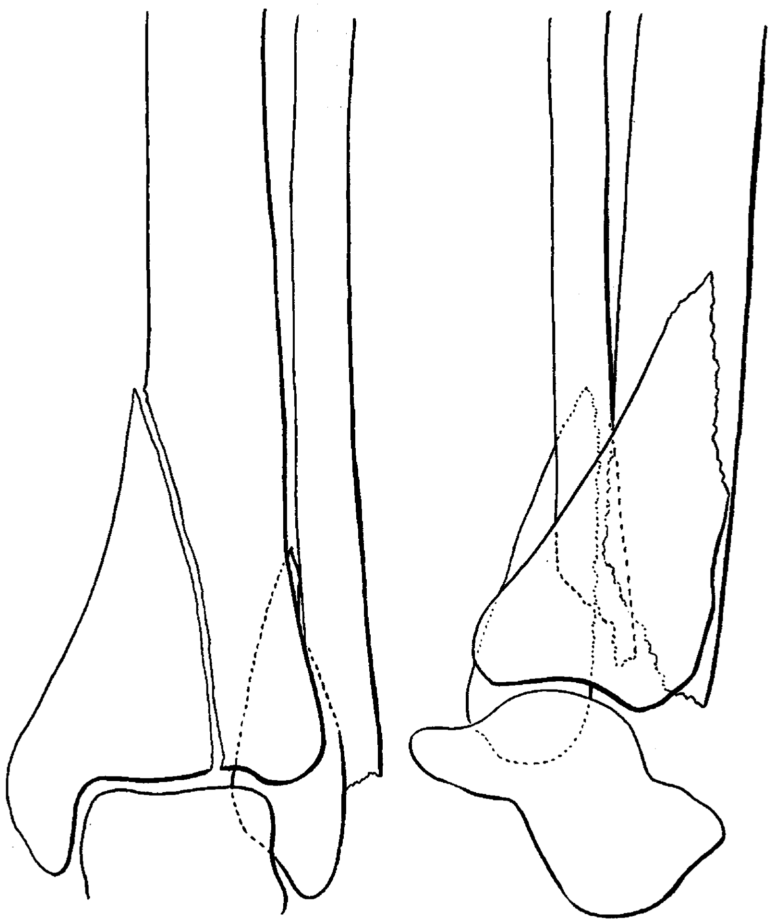

Fig. 41.—Adduction fracture second degree (C, II, b); splitting fracture of median articular surface of tibia replaces crush of internal malleolus. See page 118.

diameter of varying obliquity which is, however, always nearly the same in length; and he is inclined to ignore the existence of the movements of the external malleolus. And I have dwelt at some length on these movements because I have found them nowhere described and because there has been some dispute about them. Humphry[41] (loc. cit., p. 557) asserted that the increase of the distance between the malleoli was secured solely by the elasticity of the fibula, which bent inward toward the tibia in its lower fourth, when the external malleolus was forced outward. Nancrede[43] (1880), however, pointed out that an upward and downward movement of the fibula occurred, and asserted that Humphry's theory was "preposterous and untrue."[44] This is my own opinion also.

The upper end of the fibula can also be seen to move in flexion and extension of the foot at the ankle; in full plantar flexion (with median and downward movement of the external malleolus), the superior end of the fibula moves

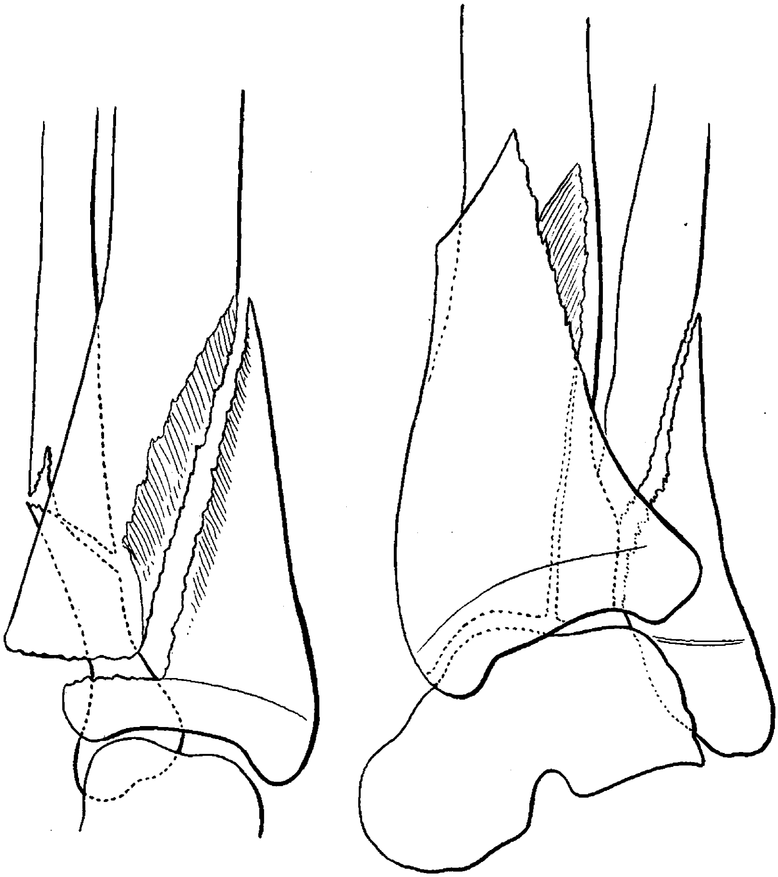

Fig. 42.—Adduction fracture, third degree (C, III); detachment of lower epiphysis with splitting of median surface of tibia.

slightly forward and rotates slightly outward, its anterior surface turning away from the tibia. This movement is due largely to the median and backward pull exerted on the external malleolus by the middle and posterior bands of the external lateral ligament. The head of the fibula slides backward and very slightly upward again in full dorsiflexion. Thus the chief movement of the

43. Nancrede: Phila. M. Times **10**:316, 1880.
44. Nancrede: Maryland M. J. **7**:76, 1880.

superior tibiofibular joint is an anteroposterior one (downward and forward, or upward and backward) around the inferior tibiofibular joint as a pivot; but these movements are so slight as to be scarcely appreciable.

Very little change occurs in the interosseous membrane during these movements, except in its lower fourth, where it spreads and becomes tense (the aperture for the anterior peroneal artery tends to become round from oval) as the external malleolus ascends and moves backward; and it again becomes relaxed when the external malleolus descends and moves mesially toward the

Fig. 43.—Adduction fracture, third degree (C, III); the supramalleolar fracture by adduction (type produced experimentally by Tillaux). See pages 71 and 119.

tibia. The strength of the interosseous membrane is much greater than usually supposed. Even when the lower end of the fibula is freed from its tibial attachments, very great force is required to rupture the interosseous membrane, and fracture of the fibula in its lower third is the nearly invariable sequel.

The normal movements of the ankle joint are those of flexion and extension—20 degrees of dorsiflexion and 60 degrees extension or plantar flexion, a total of 80 degrees approximately. This motion occurs around an axis which passes in the frontal plane somewhat below and in front of the tip of the external malleolus. This axis makes an angle of 30 degrees (thereabouts) with the bimalleolar axis. This arrangement accounts for the greater excursion forward of the lateral astragalar surface in relation to the external malleolus as compared with the motion which occurs between the median surface of the astragalus and the internal malleolus; as well as for the apparent deviation of the point of the foot medially in full plantar flexion, and laterally in full dorsiflexion.

If movements were possible in the ankle joint around an antero-posterior axis, they should be named adduction (tibial flexion) and abduction (fibular flexion), or movements in the frontal plane toward and away from the median line. These movements are quickly resisted by the tension on the lateral ligaments (Figs. 6 and 7), and if forced, the malleolus *away from which motion occurs* is torn off by its ligament, or the ligament itself ruptures (see the experiments of Hönigschmied, related on page 72). Motions of adduction and abduction in the foot normally occur in the subastragalar joint and permit the calcaneum without difficulty to accommodate itself to slight irregularities of the soil. But the calcaneum is attached to the astragalus by the extremely strong astragalocalcanean interosseous ligament; and when such movements are too extensive, they are transmitted directly to the astragalus and from it to the tibiofibular mortise where fracture of one or the other malleolus is the usual consequence. Not until that malleolus on which the pull comes has given way, or the corresponding ligament has ruptured, is the astragalus able to act on the other malleolus by a push so as to produce a compression fracture. Rare exceptions to this general rule occur, however, as when the calcaneum is itself first broken, and becomes so displaced as to press directly on the end of the fibula, producing a compression fracture of the external malleolus (Fig. 23).

Movements of rotation around the long axis of the leg may be attempted in the ankle joint by twisting the point of the foot toward or away from the median line. As pointed out by Maisonneuve [4] (1840), movements of inward rotation are almost inseparable from a movement of adduction, as the numerous joints in the anterior tarsus render the foot very mobile in this direction. Any movement toward outward rotation, however, converts the foot into a rigid lever, and motion is easily and with much force transmitted to the ankle joint, the astragalus attempting to turn so as to bring its long axis crosswise between the malleoli. Owing to physical laws, it is on the external malleolus that the greatest strain comes. Maisonneuve illustrated this by placing a ruler (which represents the foot) between two parallel volumes (which represent the malleoli): the volume which is moved is always that toward which the long end of the lever moves (Fig. 8); even if this volume be much heavier than the other it is easily moved by the greater leverage exerted. In movements of outward rotation, the foot, relatively to the tibia, is a lever of the first order, with its fulcrum on the anterior border of the fibula: the arm of the resistance will have, say, a length of 3 cm., that of the power 12 cm. (the length of the foot being taken as 15 cm. from the toes to the posterior border of the ankle joint). Relatively to the fibula, it is a

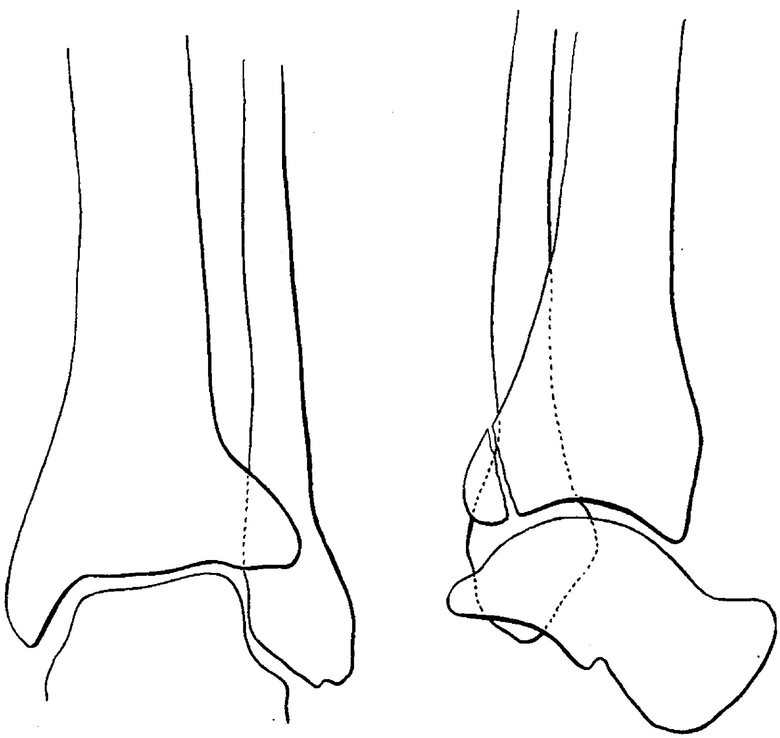

Fig. 44.—Isolated fracture of posterior tibial margin; no displacement; from compression upward and backward.

lever of the second order, with its fulcrum at the posterior border of the internal malleolus: the resistance, therefore, has an arm of 3 cm. (as in the other case) but the power has an arm of 15 cm. (the whole length from the point of the foot to the fulcrum). Thus the force which tends to fracture the fibula is as 12 is to 9, or as 4 is to 3. Such a mechanism as this (outward rotation of the foot) usually causes an oblique fracture of the lower end of the fibula (see Hönigschmied's [6] experiments, page 72); and if such a fracture be made by an osteotome it will be found that *external rotation is the only movement that will cause separation of the fragments* (Fig. 9). It is evident that the mechanism of this fracture, which is the most frequent of all fractures of the ankle (more than 25 per cent. of all cases), involves not only a push outward on the anterior border of the external malleolus, as noted by Maisonneuve, but also, as Hönigschmied pointed out, a pull inward on its posterior border by means of the posterior band of the external lateral ligament. The line of this fracture is oblique from above and behind, downward and forward. It is, properly speaking, a spiral fracture produced by torsion. Its obliquity varies greatly; but it is always higher on the posterior surface of the fibula than on its anterior, and the line of fracture passes through and involves the inferior tibiofibular joint. Almost invariably, its lower and anterior end extends to the external malleolus (in 90 per cent. of our cases): often just below the tibial plafond, sometimes as far down as the very tip of the malleolus. Thus in practically every instance the anterior inferior tibiofibular ligament remains intact, or even if partially ruptured, there results no true diastasis between fibula and tibia. At most, the lower fragment, comprising that part of the fibula posterior to the attachment of the anterior tibiofibular ligament, rolls outward and slightly backward around the unruptured posterior tibiofibular ligament as a hinge.

If this "mixed oblique" [45] fracture of the fibula, as Destot names it, is the sole lesion resulting from outward rotation of the foot, there is little or no displacement (Figs. 10 and 11). This was the case in all of the seventy-nine cases studied by Dr. Bromer and myself. If the force continues to act, the next lesion which is added is rupture of the internal lateral ligament (in twelve cases only, in our series), or, far more frequently, fracture of the internal malleolus, usually only of its anterior tip, seldom of its whole extent (Fig. 12). This combined lesion (oblique fracture of the fibula with fracture of the internal malleolus) occurred in thirty-two cases in our series, or in 10 per cent. of the entire number.[46] The displacement may be slight or marked. And in very many cases (fifty-one additional cases in our series), besides these two lesions, there is added the complication of fracture of the posterior margin of the tibia. Counting in all complications and variations, this type of fracture occurred in 100 cases or in 33 per cent. of the total 300 cases we have studied.

---

45. "Mixed" because involving the fibula both above and below the tibiofibular joint.

46. Chaput (Bull. et mém. Soc. de chir. de Paris **32**:1047, 1906) noted that among 130 cases of fracture at the ankle, of which he had studied the roentgenograms, 113 conformed to this oblique type of fracture of the fibula, against only seventeen cases in which the fracture was clearly above the malleolus.

Seldom does the obliquity of the fibular fracture pass so high as to be above the level of the anterior inferior tubercle of the tibia (Figs. 13 and 14): in three cases this tubercle was detached (in two of these there was no appreciable lesion at the internal malleolus, but in one, the internal malleolus was fractured), and in two others it is probable that a disjunction of the joint had occurred, as indicated by suggestive roent-

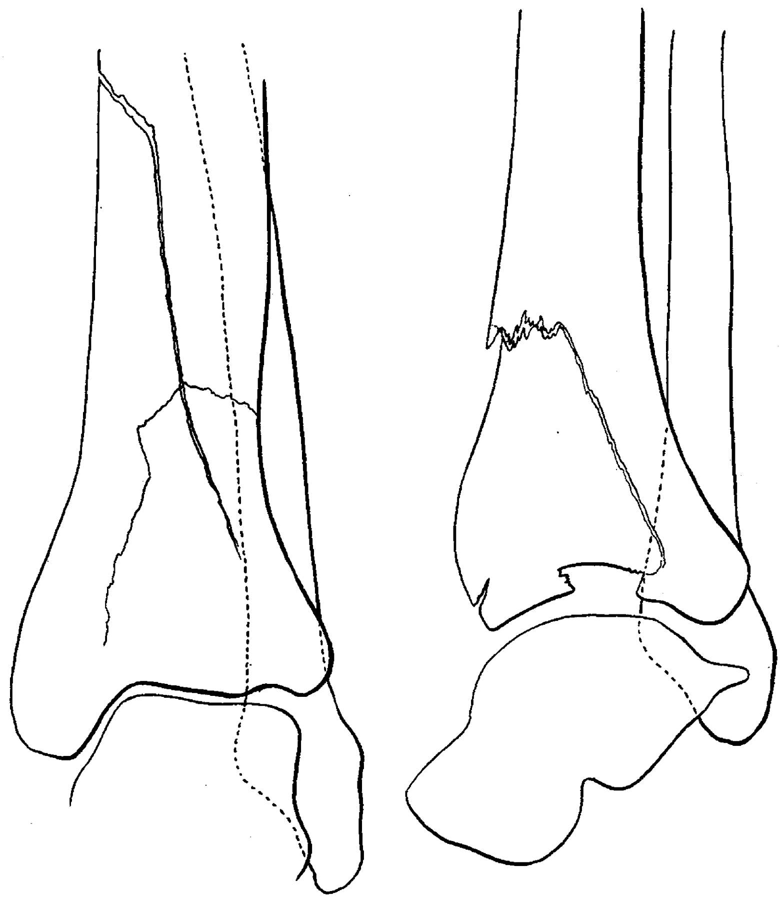

Fig. 45.—Comminuted fracture of tibial plafond; from compression upward.

gen-ray findings. This lesion (fracture of the anterior tibial tubercle, or diastasis of the tibiofibular joint) must occur previous to, even if nearly simultaneously with, the oblique fracture of the fibula;[47] because

47. Lapointe (Souligoux: Bull. et mém. Soc. de chir. de Paris **44**:1042, 1914) quite justly contends that if fracture of the anterior tubercle can occur as an isolated lesion (as in the case he reported), it must be admitted it may also occur as the first lesion of a more complicated fracture.

after the fibula is fractured its lower fragment (on which alone the force is acting) is already detached from the anterior tubercle of the tibia, and a continuance of the force would merely increase the separation. Moreover, there is lack of displacement in these isolated oblique fractures of the fibula merely because to permit displacement it is necessary that the internal malleolus (or its ligament) previously give way. If a tibiofibular diastasis (with or without separation of the tubercle) occurs (and if it occurs it must always occur previous to a fracture of the fibula, as already remarked), then the fracture of the fibula (by torsion still) occurs not through the inferior tibiofibular joint but above it, sometimes through its surgical neck, often through its true neck in the upper third of the fibula, as originally pointed out by Maisonneuve. That such a lesion in the upper third of the fibula can occur without appreciable bony lesion at the ankle cannot be denied. We have two such cases; and Quénu [48] went so far as to say that many more such fractures occur without diastasis than with it; and that they may occur even without any lesion at all at the ankle joint (Fig. 15).[49] It must also be recognized that diastasis is not necessarily followed by fracture of the fibula at any level, as shown in the lesion represented in Figures 16 and 17 in which the fibula detached the anterior inferior tubercle of the tibia, and in which, after rupture of the internal lateral ligament had occurred, the fibula was forced by the astragalus around back of the tibia by continuance of external rotation of the foot, as in the mechanism described by Huguier [50] (1848), though in his cadaveric experiments, as well as in the case illustrated by Destot (Fig. 67, p. 142 of his monograph), this displacement was accompanied by (and I believe succeeded by) a fracture of the upper end of the fibula.

In rare instances, the avulsing force on the internal malleolus may be so great as to cause fracture of the entire lower end of the tibia (or in children a separation of the epiphysis [51]) : this appears to have been the mechanism in four of our cases, which on a purely anatomic classification should perhaps be grouped with the supramalleolar fractures (Figs. 18 and 19).

The significance of the posterior marginal fragment, and the mechanism by which it probably is produced, will be discussed in another place (p. 112).

---

48. Quénu: Rev. de chir. **35**:897, 1907.

49. Long recognized as possibly due to pull of the biceps muscle. See a study by Lonhard (Deutsche mil.-ärztl. Ztschr. **43**:219, 1914).

50. Huguier: Union méd., Paris **2**:120, 1848.

51. In addition to the 300 cases of fracture of the ankle listed on page 122, we have records of at least nine cases diagnosed as epiphyseal separations; but as in these the roentgenograms available showed no gross separation at the epiphyseal line of the tibia, we have not included them in our statistics.

I desire to return now to the movement of *forced abduction,* a discussion of which has been intentionally postponed until disposition had been made of the much more frequent mechanism (outward rotation). We find in any large series of fractures at the ankle a certain number in which fracture of the internal malleolus is the only lesion (in our series this lesion occurred in more than 6.5 per cent. of the whole number). Now it is not rational to suppose that the same mechanism which at one time causes an isolated oblique fracture of the lower end of the fibula will at another cause an isolated fracture of the internal malleolus: they must be produced by different mechanisms. Experi-

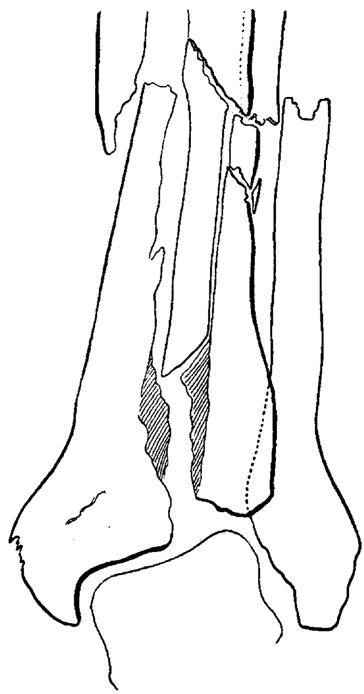

Fig. 46.—T or Y fracture involving ankle joint; from compression upward.

mentally, it is very clearly seen (note the experiments of Hönigschmied, detailed on page 72, that straight abduction (fibular flexion) of the foot has as its primary and most constant lesion fracture of the internal malleolus, or its equivalent, rupture of the internal lateral ligament. This is a prerequisite in order to free the astragalus sufficiently so that it may press directly on the external malleolus, which it does by rotation around an anteroposterior axis. The experiments of Bonnet [52] (1845), have been overlooked by most students. He showed, long

52. Bonnet: Traité des maladies des articulations, Lyon **2**:428, 1845.

before Tillaux or Hönigschmied, that abduction (fibular flexion) of the leg, while the foot was held in a vise, caused: first, fracture of the internal malleolus or rupture of the internal lateral ligament (Fig. 20), and, if the abduction was increased, a crushing or fracture of the external malleolus (Fig. 21), never of the fibula above the inferior tibiofibular joint. But sometimes no lesion of the external malleolus was caused even when the internal malleolus was widely separated. If, on the other hand, abduction of the foot was produced with the leg lying on its fibular side, but with the foot projecting free of the table, the same lesions occurred at the internal malleolus; but the fibula broke above the inferior tibiofibular ligaments at the point where it rested on the table.

In the mechanism of these fractures by abduction the influence of the tibiofibular ligaments is paramount:

1. If the tibiofibular ligaments hold, the fibula breaks across through the external malleolus proper (i.e., below the tibiofibular ligaments) and not above these ligaments by that "preposterous and untrue" mechanism to which Nancrede objected, namely, the inward bending of the fibula toward the tibia. It is not proper, perhaps, to deny that the latter mechanism might sometimes occur (all things are possible) in a patient with exceedingly relaxed ligaments; but I feel strongly inclined to state in the words of Souligoux (applied by him to the existence of an isolated fracture of the posterior tibial margin) that I do not believe such a mechanism exists, and will not believe it exists until somebody shows me its method of production. Of the 300 fractures which we have studied, we find only thirteen cases which seem to belong to this type (bimalleolar fracture by abduction): evidently the more nearly the movement of the foot conforms to the type of straight abduction, the more apt is diastasis, and as a consequence, fracture above the tibiofibular ligaments to occur (see below); while the more nearly it corresponds to external rotation (deviation of the point of the foot outward), the more certain is the fracture to be oblique in type, involving the inferior tibiofibular joint, but, as already explained, causing no true diastasis; hence the extreme rarity of true bimalleolar fractures by abduction (Fig. 22).[53]

2. If the tibiofibular ligaments rupture, then the fibula is freed from the tibia, and if the force continues (in life it is now the weight of the body borne chiefly, or at least abnormally, on the fibula), the fibula breaks "by flexion" and the break usually occurs where the fibula is weakest, through the surgical neck above the inferior tibiofibular ligaments. Study of roentgenograms or museum specimens of fractures

53. Mention has already been made (p. 99) of isolated fracture of the external malleolus associated with fracture of the calcaneum (Fig. 23).

of this type shows clearly two things: an evident tibiofibular diastasis, and a flexion fracture (Biegungsbruch) of the fibula. The typical mechanism of the flexion fracture is illustrated in Figure 24 (p. 79), copied from Messerer; and though at first glance some roentgenograms of fractures of the fibula at this height may not seem to indicate this mechanism clearly, more careful study (in nearly every case, at least, with which I am familiar) shows that the fracture conforms to the Biegungsbruch type: thus the line of fracture is either nearly transverse (rare), slightly oblique (frequent, Fig. 25), or (very frequent) is comminuted in the typical manner, with detachment of a wedge-

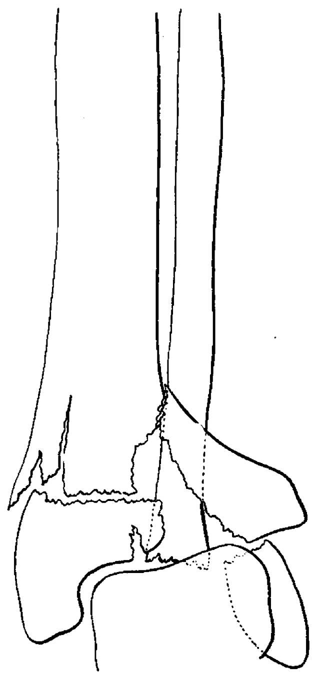

Fig. 47.—T or Y fracture involving ankle joint; from compression upward.

shaped fragment from the concavity of the bent bone (Figs. 26 and 35); that is to say, the wedge is on the lateral border of the fibula (apex toward the tibia) if the fibula was broken by straight abduction of its lower end, or on the posterior border (apex anteriorly) if it broke by posterior displacement of its lower end (Figs. 34 and 36).

Now it is a prerequisite for a bone (or any other similarly shaped structure) to be broken by indirect force through bending that one of its ends must be fixed and the other end movable. The upper end of the fibula is fixed by its attachments at the superior tibiofibular joint and by the interosseous membrane; and to permit fracture by bending of its shaft, under such circumstances, by means of indirect force applied to the external malleolus, it is first of all necessary that the lower end of the fibula be freed from its attachments to the tibia. If these attachments are not freed, it is extremely unlikely that a fracture by bending can occur; though it is possible to conceive of an exceptional instance in which such an event might occur, as, for instance, if the surgical neck of the fibula (as in the second mechanism described by Bonnet) were pressed against the edge of a table or similar object by abduction of the foot; but in such a case the action of direct violence in causing the fracture could not be excluded. In life it would be less unlikely for a fracture by compression to occur (the force being transmitted in the long axis of the fibula which was still rigidly attached to the unbroken tibial shaft); whereupon the fracture would present a very different appearance (Fig. 15); or even less unlikely for a fracture by torsion to occur, though for this mechanism also it is necessary for the two ends of a bone to be movable in opposite directions or for one to be fixed and the other movable. Torsion was held by Maisonneuve (and no doubt correctly) to be the mechanism by which was produced the fracture in the upper third of the fibula described by him as "fracture par diastasis;" and it is this mechanism (torsion) which causes it to be situated so close to the fixed end of the bone,[54] and which makes me class it as a variant of the fracture "by outward rotation of the foot" already discussed; and which convinces me that it does not belong in the same class with fractures produced by straight abduction of the foot, in which cases, I repeat, the fracture of the fibula occurs in its lower third and is caused by a bending mechanism.

It is true, of course, that the force may cease to act before the fibula breaks; in which case merely a diastasis results (Fig. 27).

Careful study of thirty cases of fracture of the fibula through its surgical neck in our series has shown the characteristics of a fracture by bending in all except two cases, in which it was clearly by torsion. When this lesion (by whatever mechanism) was unaccompanied by a diastasis of the inferior tibiofibular joint (or its equivalent, detachment of the anterior tubercle of the tibia), then the history has shown (in all but one case in which the history is unknown) either that the fracture was due to direct violence (Fig. 28) or that the clinical signs of a tibiofibular sprain were present though no diastasis was shown by the roentgen ray. Quénu[55] (1912), however, for whose opinion every student of fractures has great respect, held that diastasis was not a neces-

54. Once the lower end of the fibula is freed from the tibia, the interosseous membrane presents no obstacle to torsion.

55. Quénu: Rev. de chir. **45**:242, 1912.

sary accompaniment of this type of fracture, though he acknowledged its extreme frequency, a fact to which he had called attention in 1909; and as early as 1907, he had pointed out that this type of fracture was that which was most frequently accompanied by diastasis. But he was at that time (1907) inclined to the view that the fracture of the fibula occurred simultaneously with or even before the diastasis. But Destot [56]

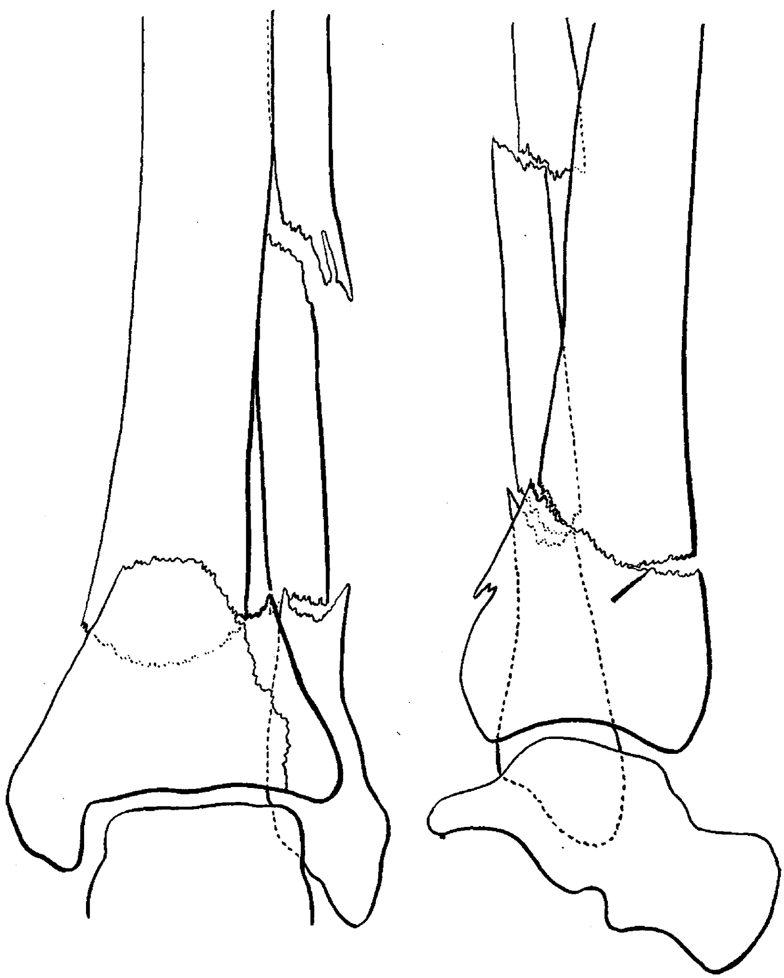

Fig. 48.—Comminuted supramalleolar fracture; probably by direct violence.

(1912) is firm in his belief that fracture of the fibula above the inferior tibiofibular joint demands as a preliminary a sprain or a diastasis of that joint. Is not then the legend to Figure 67, p. 142, in his monograph

56. Destot: Lyon chir. **8**:245, 1912.

(1911) inaccurate when it states that the diastasis shown was possible only because of the existence of a fracture near the head of the fibula?

Finally, as in fractures by outward rotation, the most advanced stage of abduction fractures may be regarded as one in which the entire lower end of the tibia is torn off as the representative of the internal malleolus; but in these also the fibula breaks characteristically by flexion through its surgical neck (Fig. 29)—it is not a mixed oblique fracture as in the third degree of fracture by external rotation already described (Figs. 18 and 19).

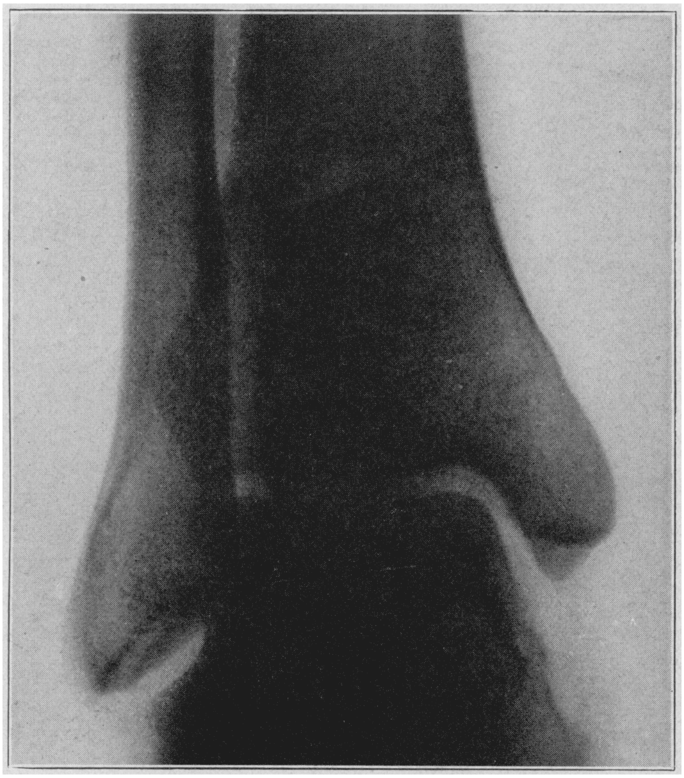

Fig. 49.—Anteroposterior view of ankle joint. See page 124.

Diastasis and Lateral Displacements of the Foot.—It is well to analyze more carefully what is meant by diastasis of the inferior tibiofibular joint.[57] It is easily seen in the prepared specimen that in all movements of the foot there is greater strain on the anterior than on the posterior inferior tibiofibular ligament; and that if the anterior

57. The criteria of diastasis from a roentgenographic study will be discussed by Dr. Bromer in his appendix to this paper.

ligament alone is divided, a separation of the fibula from the tibia to the extent of about 1 cm. becomes possible anteriorly, the fibula still being attached by the interosseous ligament and the posterior tibiofibular ligament. This degree of separation is sufficient to constitute a diastasis; lesser degrees, with incomplete rupture of the anterior tibiofibular ligament, and therefore without separation, constitute a sprain. But in many cases in which a temporary diastasis (disjunction) may have been present at the moment of the accident, it is no longer present when the

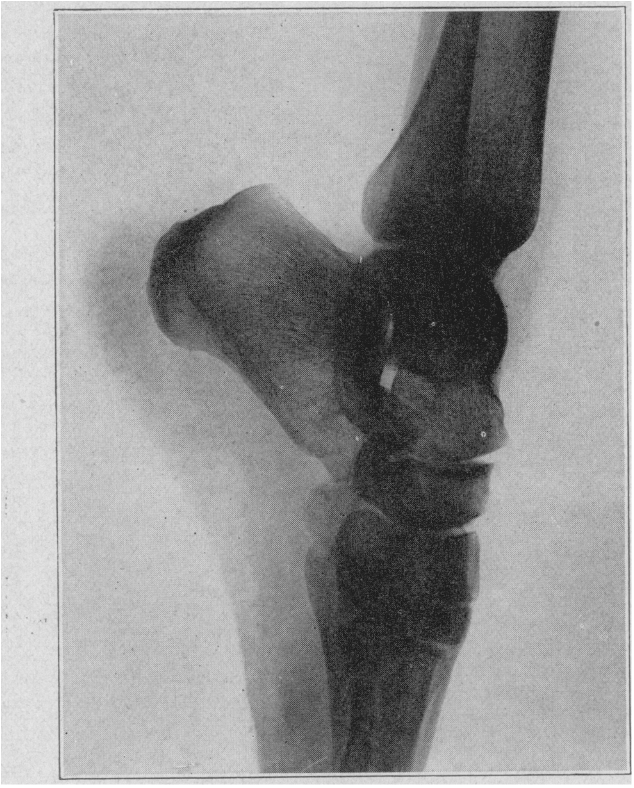

Fig. 50.—Lateral view, plantar flexion.

patient comes under the surgeon's care or is sent for roentgenologic study; and at the latter time can only be presumed to have existed by certain signs, especially evidences of a sprain fracture or detachment of the anterior tubercle of the tibia (Fig. 30).

If, in addition to division of the anterior tibiofibular ligament, one divides also the feltlike interosseous ligament, then a separation of the fibula from the tibia almost to the distance of 3 cm. may be possible; but even with this amount of diastasis of the anterior border of the fibula from the tibia, these bones are still united by the posterior tibiofibular ligament, so that the fibula is not entirely freed from the tibia though its lower end has become so movable as easily to permit a fracture by flexion.

Section of the posterior inferior tibiofibular ligament, as, indeed, noted by Quénu [58] (1907) permits only an insignificant separation of the fibula and tibia; and Quénu thinks that in life rupture of this ligament never occurs—at any rate it seems certain that this ligament is never ruptured alone, but only in conjunction with rupture of the anterior and interosseous ligaments. It is to be noted furthermore that it is next to an unheard of thing for the astragalus to be separated from the external malleolus, owing to the almost indestructible posterior band of the external lateral ligament; so that diastasis is not produced by a wedgelike action of the astragalus described by so many writers. I know of no case of true ascent of the astragalus between the tibia and fibula unaccompanied by the external malleolus: even in the beautiful case of diastasis recorded by Millikin,[59] though it is truly said that "the astragalus was jammed up between the outer surface of the tibia and the unfractured fibula" yet the astragalus had not been detached from the fibula and, therefore, cannot have acted as a wedge in driving the bones apart, though it certainly acted as a prop to keep them asunder. I have been at pains to reproduce this lesion on the cadaver, demonstrating that it is quite possible for the astragalus to become lodged against the outer surface of the tibia, between the latter bone and the fibula, without rupture of the posterior band of the external lateral ligament; though, of course, it is necessary to divide the internal lateral ligament and the inferior (anterior and posterior) tibiofibular ligaments, as well as the interosseous ligament and the interosseous membrane (the latter as far up as the upper third of the leg). And unless, in addition to the above, the anterior and middle bands of the external lateral ligament were divided, the astragalus maintained itself only in very unstable equilibrium between tibia and fibula; though no doubt in life, the stability would be greater owing to muscular tension. Moreover, in the type of fracture with diastasis in which the fibular fragment is accompanied by a fragment detached from the external surface of the tibia (as in Cooper's illustration copied by Vidal de Cassis), and which is usually described as exhibiting ascent of the astragalus between the bones of the leg, or along the outer side of the tibia, the astragalus carries with it the external malleolus (the lower fibular fragment), so that in no true sense has the astragalus ascended between the bones. Of course, it is true that dislocation of the astragalus may occur, forward or backward, detaching it from the fibula; and there is no

58. Quénu: Rev. de chir. **35**:897, 1907.
59. Millikin: Ann. Surg. **69**:650, 1919.

denying the possibility of its being dislocated upward between the intact tibia and fibula. All that I contend is that for it to become detached from the external malleolus in fractures of the leg bones at the ankle must be extremely rare, as there does not appear to be any such case on record.[60]

The Posterior Marginal Fragment of the Tibia, and Posterior Displacement of the Foot.—The existence of this fragment as the sole osseous lesion in a certain number of cases now on record,[61] including one of our own, proves that it may be the earliest stage of a lesion involving the ankle joint. But as there never has been any displacement of the fragment in these isolated lesions, it cannot be considered of much importance unless associated with a fracture of the fibula. As already noted, the existence of this fragment as a complicating lesion was well known to Cooper; it was noted by Earle[62] (1828) and by

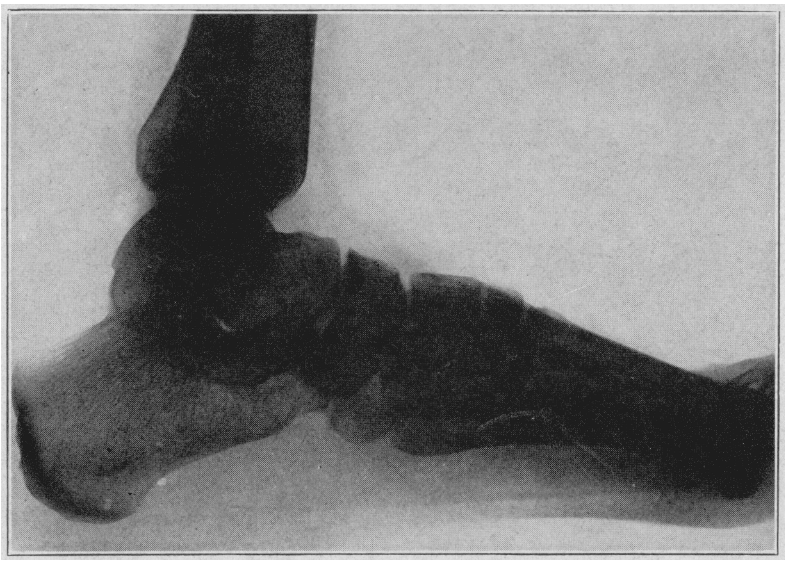

Fig. 51.—Lateral view, dorsiflexion.

60. Gross (System of Surgery, Ed. 5, Philadelphia **2**:85, 1872) says Druitt refers to such a case, but I have been unable to find the original report to ascertain the exact lesions. Wendel (Beitr. z. klin. Chir. **21**:146, 1898) collected five cases of upward dislocation without fracture; but the exact lesions do not appear to have been determined definitely in any case.

61. Tanton (Footnote 29, p. 165) refers to twenty cases recorded prior to 1916. As an isolated lesion it was first observed by Meissner (Beitr. z. klin. chir. **61**:136, 1909).

62. Earle: Lancet **2**:346, 1828-1829.

Adams [63] (1835); it was observed at necropsy by Dupuytren "with surprise" according to Malgaigne [64] (1832); Thaon [65] presented a necropsy specimen and said he had often seen this fragment in experiments made by Tillaux; it was clearly and accurately if succinctly described by Nélaton [66], (1847), and the fragment was recognized as a serious complication by Edmund Andrews [67] (1883, 1897). Since the introduction of the roentgen ray, it has been studied by Chaput [68] (1899, 1907), Bondet [27] (1899), Grashey [69] (1907), Meissner [61] (1907), Plagemann [70] (1911), Destot [8] (1911), Quénu (1912-1915), and by Stimson (in every edition of his book since 1899). Hence it was with surprise that surgeons who were tolerably familiar with the literature of their profession, as well as with fractures of the ankle, saw Cotton [71] (1915) describe it as "a new type of ankle fracture" which "has never been adequately described in print and has apparently escaped the notice even of those who deal with fractures habitually;" and noticed his complacent comment that in certain circles it was called "Cotton's fracture;" as well as his statement that he believed there were no necropsy specimens.[72] Cotton, however, did well to call attention to its frequency; as did Speed in a paper which was not published until after Cotton's paper was read, though it appeared in print before the latter.

The mechanism by which this fracture is produced is almost certainly, as contended by Lucas-Championnière,[73] a crushing force from below upward; [74] it is possible that traction by the posterior inferior

63. Adams, in Todd: Cyclopedia of Anatomy and Physiology, London **1**:161, 1835-1836.

64. Malgaigne: Gaz. méd. de Paris **3**:647, 1832.

65. Thaon: Bull. Soc. anat. de Paris **45**:212, 1870.

66. Nélaton: Eleménts de path. chir., Ed. 2, Paris, **3**:296, 1874.

67. Andrews in Ashhurst: International Encyclopedia of Surgery, New York **3**:707, 1883; also in Internat. Clinics, Philadelphia, 1897.

68. Chaput: Bull. et mém. Soc. de chir. de Paris **25**:776, 1899; Les fractures malleolaires, Paris, 1907.

69. Grashey: Fortschr. a. d. Geb. d. Röntgenstrahlen. **11**:152, 1907.

70. Plagemann: Beitr. z. klin. Chir. **73**:688, 1911.

71. Cotton, F. J.: A New Type of Ankle Fracture, J. A. M. A. **64**:318 (Jan. 23) 1915.

72. In addition to the necropsy specimen which figures in Cooper's Plate XVII (reproduced here as Fig. 3), those described by Stimson and that of Thaon, already alluded to, there are in the Mütter Museum of the College of Physicians of Philadelphia three necropsy specimens showing this posterior marginal fragment. The most recent of these specimens has been in the museum for a period at least of forty years. (A description of these specimens will be published elsewhere by Dr. Bromer and myself.)

73. Lucas-Championnière: Bull. Soc. anat. de Paris **45**:212, 1870.

74. Rochet (Rev. d'orthop. **1**:269, 1890) produced it experimentally by dropping a weight of 60 kilograms, from a height, on the upper end of the tibia while the foot was in plantar flexion.

tibiofibular ligament, through the medium of the fractured lower end of the fibula, may aid in displacing the fragment, even if it cannot be the sole cause of its detachment. The size of the fragment varies from a small portion of the lip to a large fragment, extending 10 cm. up the posterior surface of the shaft. McKnight, at the meeting of the Philadelphia Academy of Surgery, May 2, 1921, showed a roentgenogram (anteroposterior view only) of a fracture which I believe conformed to this type, though the fragment was the largest with which I am acquainted: the fragment (an isolated lesion, without displacement) included nearly all the posterior lip of the tibia, as well as its entire lateral (fibular) border; and the apex of the large wedge extended to a point about 10 cm. above the articular surface, on the posterolateral border of the tibia.

TABLE 1.—Incidence of Posterior Marginal Fractures

	Total Ankle Fractures	Posterior Marginal Fractures Associated	Isolated	Total	Per Cent.
Ashhurst and Bromer........	300	57	1	58	19
Chaput (Les fractures malléolaires, Paris, 1907)......	136	42	0	42	30
Destot (Quénu: Bull. et mém. Soc. de chir. de Paris, **39**: 165, 1913).................	1700	139	6	145	8.5
Quénu (Rev. de chir. **45**:260, 1912)	129	11	1	12	9.3
Sear (M. J. Australia, **1**:526, 1917)	156	26	3	29	18.6
Speed (Surg., Gynec. & Obst. **19**:73, 1914)................	161	16	0	16	10

Incidence of Associated Posterior Marginal Fractures

Type	Ashhurst and Bromer No.	Per Cent.	Destot No.	Per Cent.
Fibula, oblique mixed..................	0	....	0	....
Low Dupuytren	51	88	89	64
Bimalleolar	0	....	17	12
Pott's	5	8.6	29	20
Adduction	1	1.7	0	....
Maisonneuve	0	....	4	3
	57		139	

The lesion corresponds, as Tanton [29] (loc. cit., p. 171) has noted, to Rhea Barton's fracture of the posterior margin of the radius.

It is a much more frequent complication than commonly supposed. Among our 300 cases it was present no less than fifty-eight times, or in 19 per cent. of all the cases; and in 51, or 50 per cent., of those conforming to the "low Dupuytren" type.

There is sometimes confusion between this posterior marginal fragment and the intermediate fragment ("third fragment of Tillaux"), as remarked before.[23] The posterior tubercle of the tibia, which limits posteriorly the gutter for the reception of the fibula (Fig. 4), and to which is attached the posterior tibiofibular ligament, may be fractured by the pull of this ligament. It appears then in lateral roentgenograms as an infraction or sprain fracture, but does not involve the ankle joint. In the true marginal fractures, on the other hand, the line of fracture always extends into the tibial plafond; the fragment (contrary to what is said by Tanton) usually remains attached to the external malleolus

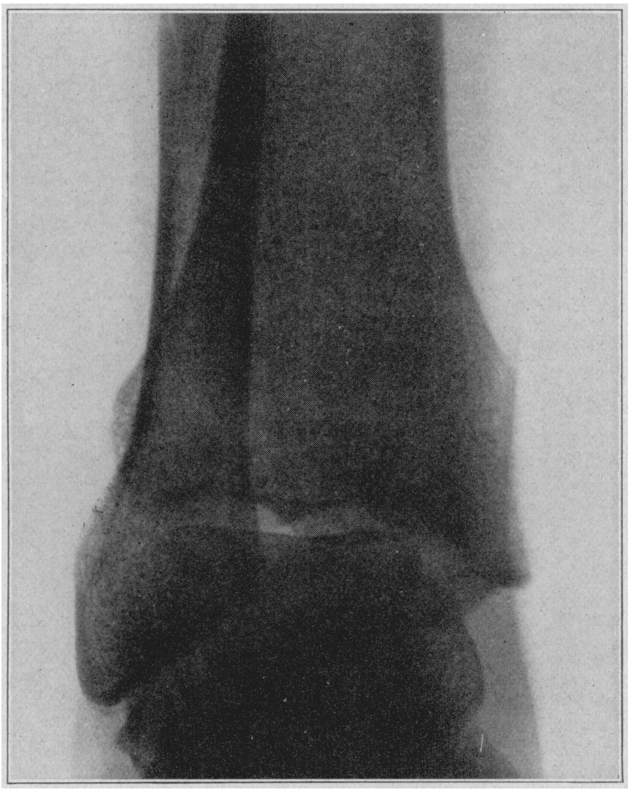

Fig. 52.—Rotation outward, obliterating outline of the posterior tubercle. (Same happens in mesial deviation of the tube.) The anterior tubercle overlaps the lateral margin of the fibula.

by the posterior tibiofibular ligament, and is often displaced backward with the external malleolus; sometimes (more frequently than thought) it may be detected in anteroposterior roentgenograms as a deltoid fragment; and, if large, its shadow sometimes overlaps that of the median border of the tibia, giving a double contour.

The posterior marginal fragment, as already remarked, may occur as an isolated lesion; only once in our series (Fig. 44). It may be associated with (*a*) merely a diastasis, with sprain fracture of the anterior tubercle of the tibia (Fig. 31); (*b*) it may accompany the mixed oblique fracture of the fibula in the various stages of the fracture by outward rotation, being small (Fig. 32), medium sized (Fig. 33), or large (Fig. 34); and (*c*) it occurs also with fractures by abduction (Figs. 35 and 36), though very much less frequently than with external rotation fractures. Quénu has had one case in which fracture of the internal malleolus was the only other lesion, and another fracture of precisely the same type has come under our notice since our series of 300 cases was completed.

Its presence is not necessary to permit the occurrence of posterior displacement of the foot (Figs. 16 and 25), but certainly favors it. This posterior displacement is very rare without the posterior marginal fragment. Either a posterior marginal fragment must exist, or there must be rupture of the posterior inferior tibiofibular ligament. It is only a continuance of the force (now the weight of the body) after the fracture has been produced, that causes the displacement, since there are in our series no less than fourteen instances (out of a total of fifty-eight posterior marginal fractures) with slight if any displacement.

The factors which permit posterior displacement of the foot deserve a few words. Quénu was the first, I believe, to point out that the essential lesion is freeing the lower end of the fibula from the tibia; and I may remark that this necessity is merely a corollary of what has been insisted on so often in these pages, namely the indissolubility of the union between the astragalus and the fibula. I cut everything else at the ankle (tendons and ligaments as well as all other soft parts) leaving only the middle and posterior bands of the external lateral ligament attaching the external malleolus to the foot. Under these circumstances even an incomplete posterior dislocation of the foot cannot occur (except by rotation of the foot inward around the long axis of the leg, a mechanism which does not occur in life). I then cut the middle band of the external lateral ligament; but still no posterior displacement could be produced. Next I fractured the fibula 7.5 cm. (3 inches) above its tip; but this did not permit posterior displacement. Finally, I divided the anterior inferior tibiofibular ligament, and even the interosseous ligament; but so long as the fibula remained attached to the tibia, and the atragalus to the fibula, no posterior dislocation could be produced. On another foot, I divided all structures uniting the foot to the fibula except the middle band of the external lateral ligament; but no dislocation of the foot was possible; then I divided also the posterior inferior tibiofibular ligament and the interosseous ligament (which allowed less diastasis than when the anterior tibiofibular ligament was divided), but still no posterior dislocation of the foot was possible except by rotating it inward around the one remaining ligament as a pivot.

As a result of these investigations, it may be concluded that either the middle or the posterior band of the external lateral ligament is sufficient to hold the astragalus against the external malleolus, and that (even after fracture of the internal malleolus or rupture of the internal lateral ligament) *no backward dislocation of the foot can occur* (1) unless the astragalus is freed from the external malleolus by rupture of both the middle and posterior bands of the external lateral ligament (a lesion which apparently has not been recorded in association with

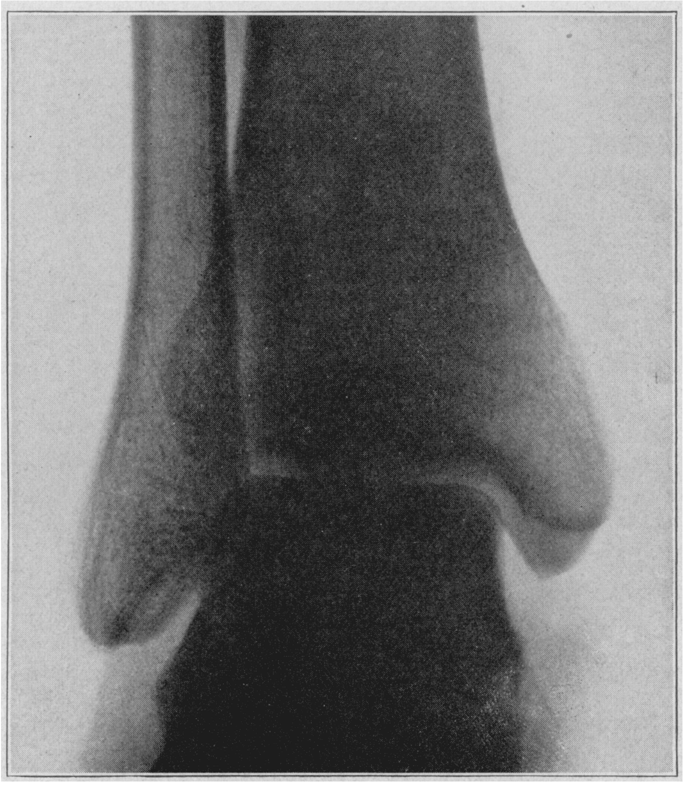

Fig. 53.—Rotation inward; very little change from the normal. (Same happens in lateral deviation of the tube.)

fractures at the ankle); (2) or unless the external malleolus is freed from the tibia (*a*) by diastasis of the inferior tibiofibular joint, with or without detachment from the tibia of an intermediate fragment; (*b*) by fracture of the fibula in such a way as to detach with the lower fragment of the fibula the fibular insertions of both the middle and posterior bands of the external lateral ligament (in other words, unless a virtual diastasis occurs, but one in which the intermediate fragment belongs to the fibula instead of to the tibia). One very frequent fracture of the fibula (the mixed oblique of Destot) fulfils these requirements; as does another less usual, namely a transverse fracture of the external malleolus proper below the level of the tibia. But as the latter fracture usually is subperiosteal or incomplete, and without displacement, it follows that posterior displacement of the foot with this lesion is unknown.

Therefore, the fractures which may be accompanied by posterior displacements of the foot are those of the Pott or Dupuytren type. in which diastasis is the rule; and those of the low Dupuytren variety, in which the fracture of the fibula is of the mixed oblique type. Quénu [75] is wrong, I am sure, in claiming (1912) that the existence of a posterior marginal fragment is a necessary condition for the occurrence of a posterior subluxation (Figs. 16 and 25); but it is well to remember that the distorted shadows of a roentgenogram in a case of fracture of the low Dupuytren variety, in any of its stages, may mislead the observer into the belief that a posterior displacement is present, when the appearances are due entirely to an outward rotation of the astragalus around the long axis of the leg.

Forced Movements of Adduction (Tibial Flexion).—Since the time of Cooper and that of Maisonneuve and Bonnet, there has been little dispute about the mechanism of these fractures: it has been generally recognized that a tearing off of the external malleolus is the first lesion (Fig. 37), followed by a compression fracture of the internal malleolus (Figs. 38 and 39); or, when the weight of the body forces the tibia heavily on the displaced astragalus, a splitting upward of the tibial shaft occurs, the line of fracture commencing at some point of the articular surface, splitting this in the sagittal plane and terminating on the median border of the tibia at a variable distance above the internal malleolus (Figs. 40, 41 and 42). The more nearly longitudinal the line of fracture, the less necessary will it be for the external malleolus to be fractured as a preliminary step: such fractures verge into those due to comminution upward in the long axis of the limb. Stimson [76] (1912) gives an admirable illustration of such a longitudinal fracture of the tibia without any lesion of the fibula. But if the displacement in these longitudinal fractures is marked enough, the fibula may break secondarily (by flexion or torsion) above the inferior tibiofibular joint, as the lower end of the fibula is carried inward with the astragalus (Fig. 41). A variant of this type is the lesion recorded by Silhol [77] in which the fibular fracture is replaced by an intermediate

75. Quénu: Rev. de chir. **46**:1912.
76. Stimson: Fractures and Dislocations, Ed. 7, Philadelphia, 1912, Plate 27.
77. Silhol: Bull. et mém. Soc. de chir. de Paris **42**:819, 1916.

fragment detached from the tibia. Even in one of our own cases (Fig. 40), there is an intermediate fragment, in addition to the fracture of the fibula.

The supramalleolar fracture by adduction, produced experimentally by Tillaux, and already mentioned on page 71, may be considered the most advanced degree of this type (Figs. 42 and 43.)

SUMMARY

These then are the abnormal movements—external rotation, abduction, adduction—which are responsible for the great majority (95 per cent.) of fractures about the ankle: external rotation causes about 61 per cent., abduction about 21 per cent., and adduction about 13 per cent. of the lesions. The remaining small proportion (5 per cent.) consists chiefly of those fractures which may be recognized either as caused by compression in the long axis of the limb, or by direct crushes; or even by very rare forced movements such as straight flexion or extension, internal rotation, etc. The fractures by compression in the long axis of the limb include (*a*) the isolated fractures of the tibial margins (anterior, posterior [Fig. 44], median or even lateral), which Sear [78] speaks of as "vertical plane fractures;" (*b*) comminuted fractures of the tibial plafond (Fig. 45), and (*c*) T or Y-fractures involving the ankle joint (Figs. 46 and 47), which may be regarded as an advanced degree of the supramalleolar V-fractures described by Gosselin,[79] the latter usually being complicated by a fissure extending into the ankle joint, the mechanism being the same as in those of the radius with comminution of the wrist fragment.[80] The supramalleolar fractures of Malgaigne [81] (1847) are thus distributed according to their mechanism, some into those by adduction, others as due to compression in the long axis of the limb, and a few probably due to direct violence (Fig. 48). We count no supramalleolar fracture as one involving the ankle unless it falls within 4 cm. of the joint level (Richet, 1875). Fractures as close to the ankle joint as 4 cm. compromise its functions as surely as do supracondylar fractures of the humerus compromise those of the elbow.

Now, it is because of the impossibility of classifying together anatomically lesions which, as Stimson says, are merely alternative, or whose differences are due to the early cessation of the force before the typical form has been reached; or, I may add, to its continuance after the typical stage has been passed—it is because of this impossibility, I

78. Sear: M. J. Australia **1**:526, 1917.
79. Gosselin: Gaz. d. hôp. **28**:218, 1855.
80. Gosselin: Bull. et mém. Soc. de chir. de Paris **5**:147, 1863.
81. Malgaigne: Fractures, Paris, 1847, p. 818.

repeat, that I believe a classification based on mechanism, imperfect though it be, is, nevertheless, more easily understood and remembered. And it is for this purpose that Dr. Bromer and I have ventured to

TABLE 2.—CLASSIFICATION OF THREE HUNDRED ANKLE FRACTURES

A. Fractures by External Rotation			
1. First Degree: Lower end of fibula only ("mixed oblique")		79	(26 %)
2. Second Degree: Same, *plus* rupture of internal lateral ligament or fracture of internal malleolus ("low Dupuytren") Viz.,		100	(33 %)
(*a*) Internal lateral ligament, uncomplicated..........	13		
Internal lateral ligament complicated by posterior marginal fragment of tibia....................	13		
(*b*) Internal malleolus, uncomplicated...............	32		
Internal malleolus complicated by posterior marginal fragment of tibia......................	42		
3. Third Degree: Same, *plus* fracture of whole lower end of tibia, representing the internal malleolus.................		5	(1.7 %)
Total Fractures by External Rotation..............		184	(61 %)
B. Fractures by Abduction (Fibular Flexion)			
1. First Degree: Internal malleolus only....................		20	(6.6 %)
2. Second Degree: Same *plus* fracture of fibula (transverse, above or below tibiofibular joint).......................		41	(13.7 %)
(*a*) Below inferior tibiofibular joint (no diastasis) ("bimalleolar fracture")........................	13		
(*b*) Above inferior tibiofibular joint (with diastasis) ("Pott's fracture," "Dupuytren type")..........	28		
3. Third Degree: Internal malleolus represented by whole lower end of tibia......................................		2	(0.66%)
Total Fractures by Abduction......................		63	(21 %)
C. Fractures by Adduction (Tibial Flexion)			
1. First Degree: External malleolus only, transverse, at or below level of tibial plafond............................		27	(9 %)
2. Second Degree: Same, *plus*			
(*a*) Internal malleolus below level of tibial plafond ("bimalleolar fracture")........................	3		
(*b*) Median surface of tibia up and in from joint surface	8	11	(3.6 %)
3. Third Degree: Same, *plus* whole lower end of tibia ("supramalleolar fracture by adduction")................		2	(0.66%)
Total Fractures by Adduction.....................		40	(13.3 %)
D. Fractures by Compression in Long Axis of Leg			
1. Isolated Marginal Fractures.......................	1		
2. Comminution of tibial plafond........................	3		
3. T or Y-fractures ("V-fractures of Gosselin")..........	4		
Total Fractures by Compression in Long Axis of Leg		8	(2.7 %)
E. Fractures by Direct Violence (Supramalleolar types).........		5	(1.7 %)

arrange our series of fractures as shown in Table 2. Our aim has been to place under each mechanism, first, the simplest resulting form of fracture, and to advance thence to more complicated lesions, noting at the same time in their appropriate places the variants and the complications of the simple or the more complex lesions which were encountered. It is true that it is not always easy to determine the mechanism, even with all the aid derived from the clinical history, the roentgen ray and a knowledge of the lesions which can be produced on the cadaver; but the more one studies the subject, the fewer exceptions he will find to the general laws of mechanics; and the more his

TABLE 3.—ANATOMOPATHOLOGIC CLASSIFICATION OF THREE HUNDRED ANKLE FRACTURES

A. Fibula, Below Inferior Tibiofibular Joint				
1. Alone (slight or no displacement, often subperiosteal)	27	(9 %)		
2. Same, *plus* internal malleolus below tibial plafond (includes bimalleolar fractures by adduction and by abduction)	16	(5.0 %)		
3. Same, plus split of tibia up and in	8	(2.6 %)	51	(17 %)
B. Fibula, Obliquely Through Inferior Tibiofibular Joint				
1. Alone (slight or no displacement, often subperiosteal)	79	(26 %)		
2. Same, plus rupture of internal lateral ligament	26	(9 %)		
3. Same, *plus* fracture of internal malleolus	74	(25 %)	179	(60 %)
C. Fibula, Above Inferior Tibiofibular Joint				
1. Alone (slight or no displacement, often subperiosteal)	0	(.......)		
2. Same, *plus* rupture of internal lateral ligament and diastasis	8	(2.7 %)		
3. Same, *plus* fracture of internal malleolus and diastasis	20	(6.6 %)	28	(9.3 %)
D. Tibia, Involving Ankle Joint				
1. Internal malleolus alone (slight or no displacement, often subperiosteal)	20	(6.6 %)		
2. Isolated marginal fractures	1	(0.33%)		
3. Comminuted, T and Y-fractures	7	(2.3 %)	28	(9.3 %)
E. Supramalleolar Fractures, Not Involving Ankle Joint Directly	14	(4.3 %)	14	(4.3 %)

experience increases, the easier will it become to recognize the variants from the typical lesions. Those fractures which have given us most concern are the true bimalleolar fractures with little or no displacement, since these may be caused possibly by external rotation, certainly both by abduction and adduction. But as the total number of these fractures observed is small (sixteen cases or only 5 per cent. of the entire series), and as even among this number the mechanism was reasonably certain in all but ten cases (3 per cent. of the entire series), the margin of error is small.

TABLE 4.—Catalog of Three Hundred Fractures Involving the Ankle

		No. Cases
A. By Rotation of the Astragalus Outward Around the Long Axis of the Leg		
I. First Degree: Lower end of fibula only. Oblique or spiral fracture from above and behind, down and front, the line of fracture passing through the inferior tibiofibular joint. Line varies from nearly transverse to nearly longitudinal, but is always higher on posterior than on anterior surface of fibula. In 84 per cent. of cases the lower anterior end of line of fracture was on anterior surface of external malleolus between its tip and the anterior inferior tubercle of the tibia; in 8 per cent. of cases it was above the anterior tubercle (when there was diastasis or the tubercle was detached); and in 8 per cent. it passed through the fibula at the level of the anterior tubercle on the tibia. Slight or no displacement	76	
Variant: fracture of fibula in *upper third* from lesion at ankle (Maisonneuve, 1840)	1	
(In this case there was incomplete fracture of fibula below its head (Fig. 17) but without bony lesion at ankle)		
Complication: intermediate fragment	2	
	—	79
II. Second Degree: Fibula as in first degree, *plus* rupture of internal lateral ligament or fracture of internal malleolus. There may be slight or considerable lateral displacement; but in uncomplicated cases there is rarely a real posterior displacement, the apparent posterior displacement seen in lateral roentgenographic views being due usually to outward rotation which distorts the shadows.		
(*a*) Internal Lateral Ligament (in roentgenograms this lesion is differentiated from first degree only by presence of lateral displacement of astragalus from internal malleolus with slight displacement of lower fibular fragment)	12	
Variant: Diastasis without fracture of fibula (Fig. 16)	1	
First Complication: Fracture of posterior tibial margin. Line of fracture usually extends about 2 cm. up along posterior surface of tibia, and running down thence nearly vertically, detaches a mere chip or more often one fourth to one third of the articular surface; rarely as much as one half	10	
Variant: Diastasis without fracture of fibula, but with posterior marginal fragment (Fig. 31)	1	
Second Complication: Intermediate fragment	0	
Third Complication: Second fracture of fibula in upper third (Maisonneuve's fracture; these two cases occurred in opposite legs of same patient)	2	
(*b*) Internal Malleolus	32	
(with slight or no displacement, twenty cases)		
First Complication: Fracture of posterior tibial margin (Figs. 32, 33, 34)	40	
(slight or no displacement, fourteen cases)		
(lateral and posterior displacement twenty-six cases)		
Second Complication: Intermediate fragment	2	
	—	100
III. Third Degree: Internal malleolus represented by whole lower end of tibia		5
(This will include most cases of separation of lower epiphysis of tibia)		
Total Fractures by Mechanism of Outward Rotation		184

TABLE 4.—Catalog of Three Hundred Fractures Involving the Ankle—(*Continued*)

		No. Cases
B. By Abduction (Fibular Flexion) of Foot		
I. First Degree: Fracture of internal malleolus only, transverse, at or below level of tibial plafond. No displacement		19
II. Second Degree: Rupture of internal lateral ligament or fracture of internal malleolus, as in first degree, followed by fracture of fibula more or less transverse either below or above inferior tibiofibular joint		
(*a*) Fracture of fibula below inferior tibiofibular joint (i.e., of external malleolus proper) with fracture of internal malleolus or rupture of internal lateral ligament	13	
(with no displacement, three cases; internal malleolus displaced more than external, four cases; both malleoli equally displaced, six cases)		
Variant: Crush of calcaneum (replacing fracture of internal malleolus) followed by compression fracture of external malleolus	1	
(*b*) Fracture of fibula above inferior tibiofibular joint (in lower third), the line of fracture indicating a fracture by flexion (Biegungsbruch), with slight or no torsion; slightly oblique, often comminuted with detachment of a wedge-shaped fragment from the surface of flexion, and its apex toward the surface of extension	28	
	—	42
1. Fracture of fibula alone, or with rupture of internal lateral ligament ... 6		
Variant: Diastasis without fracture of fibula ... 2		
2. Fracture of fibula with fracture of internal malleolus at or below level of tibial plafond ... 12		
First Complication: Posterior marginal fragment of tibia (Figs. 35 and 36) ... 5		
Second Complication: Intermediate fragment ... 3		
III. Third Degree: Internal malleolus represented by whole lower end of tibia (This will include some cases of separation of lower epiphysis of tibia)		2
Total Fractures by Mechanism of Abduction		63
C. By Adduction (Tibial Flexion) of Foot		
I. First Degree: Fracture of external malleolus, transverse, at or below level of tibial plafond. Slight or no displacement, often subperiosteal	26	
Complication: Posterior marginal fragment of tibia (infraction)	1	
	—	27
II. Second Degree: Fracture of external malleolus as in first degree, *plus:*		
(*a*) Fracture of internal malleolus below level of tibial plafond	2	
Variant: Fracture of external malleolus represented by rupture of external lateral ligament	1	
(*b*) Fracture of median surface of tibia up from tibial plafond	8	
	—	11
III. Third Degree: Fracture of fibula usually above inferior tibiofibular joint, *plus* fracture across tibia above ankle joint (Tillaux, 1872)		2
Total Fractures by Mechanism of Adduction		40
D. By Compression in Long Axis of Leg		
I. Isolated marginal fractures of tibia: anterior margin, none; posterior margin, 1; median margin, none; lateral margin, none	1	
II. Comminution of tibial plafond	3	
III. T or Y-fractures of Tibia into Ankle-Joint	4	
	—	8
E. Fractures by Direct Violence (Supramalleolar Types)		5
Grand Total		300

It will be noted that in our classification the fibular lesion dominates the clinical picture in the first two classes (those of outward rotation and abduction), and that these correspond to the first grand division of Destot's classification—those fractures in which the equilibrium of the foot is involved; while the third, fourth and fifth classes correspond to Destot's second division—those fractures which involve the tibial pestle and compromise the function of support. For the sake of completeness we also give an anatomopathologic classification, constructed on the same principles (Table 3).

Following the classifications is a catalog of the lesions encountered in this series of cases, which, with the aid of the classifications as a guide, we hope may prove of interest to students of fractures (Table 4).

ROENTGEN-RAY STUDY OF THE ANKLE JOINT

By Dr. Bromer

I. THE NORMAL ANKLE JOINT—ANATOMY

By means of the roentgen ray, the structure of the ankle joint can be most satisfactorily demonstrated. The tibiofibular mortise is shown (Fig. 49), and below it the trochlea of the astragalus fitting into it as a tenon. The "plafond" and the "cheeks" of the mortise are easily recognized, likewise the longer external malleolus and the anterior and posterior tubercles of the fibular groove. In the lateral view (Fig. 50), the low projection of the posterior lip, called by Destot the posterior malleolus, reinforcing the mortise posteriorly, can easily be visualized; and the point where it meets the trochlear surface of the astragalus, acting as a check on the latter when the foot is in plantar flexion as in walking, is most noticeable. (The degree of plantar flexion in the roentgenogram is much greater than is assumed in walking, but is used more fully to demonstrate the check). In this view, the longer external malleolus is shown overlapping the shadow of the internal malleolus. With stereoscopic plates they usually can be fairly well distinguished. The lateral tubercle on the posterior surface of the astragalus (os trigonum) is the farthest posterior shadow of the astragalus. In the interpretation of roentgenograms of the ankle joint, due care must be exercised not to diagnose a sprain-fracture of the posterior tubercle, where an accessory bone, the os trigonum, often is found. In general, no fracture exists, and it is this bone that is present if the surfaces of the fragment are smooth and rounded.

II. FUNCTION AND MOVEMENTS OF THE ANKLE JOINT

The roentgen ray can be used to demonstrate the movements of the ankle joint. Thus the rotation of the astragalus about the axis previously described by Dr. Ashhurst in full dorsiflexion and plantar flexion is shown in Figures 50 and 51. The movements of the fibula were shown in the following way: A normal ankle was examined; the ankle and leg of the subject being securely bound to the table, a Bowen stereoscopic plate holder was placed beneath the ankle joint. Lateral views were made first with the foot in full dorsiflexion, then later with the foot in full plantar flexion. Great care was exercised that the position of the leg—i.e., tibia and fibula—was not altered. The stereoscopic plate holder gave an exact duplicate position for the second exposure. The tube was in no way shifted. Anteroposterior views were taken in the same way. In this plane, the heel was allowed to project as far as possible over the edge of the plate holder in order to obviate any change in height of the tibia above the plate due to change of position of the os calcis. The superior tibiofibular articulation was examined in the same way.

It was found that these views could be superimposed over diffused strong light. As an additional check the distances between the same relative points were accurately measured. The fact that the images of the tibia could be accurately superimposed would tend to rule out any possibility of error due to change in height of tibia. It was found that in full plantar flexion in the anteroposterior view the fibula moved inward and downward 1 mm. or, vice versa, so much expansion and movement upward occurred in full dorsiflexion. No change of the fibula in relation to the tibia could be found in the lateral views.

With regard to the upper extremity of the fibula, the forward movement of the fibula in plantar flexion was shown in the lateral view by an increase of 1 mm. in the distance between the posterior lip of the upper extremity of the fibula and the posterior border of the tibia. In the same way in the anteroposterior view the head of the fibula was found lying farther in toward the midline with the foot in plantar flexion than it was with the foot in dorsiflexion. All of these measurements were made by means of calipers, and the same level was obtained by means of superposition of the films over diffused strong light.

III. SOME DIFFICULTIES ENCOUNTERED IN INTERPRETATION OF THE ROENTGENOGRAMS OF THREE HUNDRED CASES

During the intensive study of the roentgenograms, from the point of view of roentgen interpretation, most interesting questions arose, necessitating definite solutions before any classifications or any theories of mechanism could be determined. These questions came almost entirely from a lack of standardized technic. The 300 cases had been examined by four different roentgenologists. The technic of only one of them was known. Immediately, the question arose: Does not this, or that, represent some variation from the real normal, produced by variations in the procedures of these different roentgenologists, rather than a pathologic condition?

Textbooks on roentgenology describe certain more or less standardized positions for examination of the ankle joint. They point out anatomic landmarks above which to center the target of the tube. But none of them describe the variations in shadow which may occur: for instance, from increased or decreased target plate distance, or from variations produced by lateral shifting of the target, or by variations in posture of the joint. It would seem that opportunities for error are numerous. The very nature of hospital dressings—so different in the various institutions—constitutes one of the most prolific sources of error. The difficulty of exact centering through a plaster-of-Paris dressing or of an ankle encased in a fracture box is obvious.

The discussion which follows may seem to be far-fetched to some and futile to others. I am well aware of the conditions under which many busy roentgenologists work. I realize that a plate or film placed under an ankle with the target at any given distance above it, and the perpendicular assumed or guessed at, with a proper exposure technic will result in a so-called excellent negative. We admit that in a busy hospital service most of our patients were so examined. We admit that to the best of our knowledge no patients in any way afterward suffered, clinically, from such unstandardized examination at our hands. It is entirely probable that many clinicians can and will say, Why more? But I contend that in our study of these cases we were greatly hampered by such methods in arriving at definite conclusions. Gross lesions are usually apparent and easily diagnosed. The fine points in diagnosis are the difficult ones. It is only by exact methods that the science of diagnosis is advanced and the sum total of our knowledge of the subject increased.

The first difficulty that arose, the solution of which was of utmost importance, was the exact determination of just what on the roentgenogram determines diastasis of the lower tibiofibular junction. The normal ankle joint was roentgenographed under all possible conditions, in an effort to study the possible variations in shadows of the normal due to changes in technic. It was first examined at various target plate distances with the foot and target in the perpendicular plane; then the same ankle was roentgenographed with the leg in different angles of rotation and also with the foot in full dorsiflexion and plantar flexion, and again with the target deviated to either side from the perpendicular plane. A study of these results shows the necessity for the roentgenologist's deciding on one target plate distance for all examinations, also for him to formulate or design some scheme for quickly securing in each case the same perpendicular plane of the ankle and target, especially in the anteroposterior view. A long upright rod with another at right angles, attached to its lower end, can readily be made and used for this purpose (goniometer).

From the results obtained on the roentgenograms showing the variations in target plate distance, it can be assumed that shadows on roentgenograms follow certain rules. Thus, as this distance decreases, all shadows proportionately increase provided there is no shift of the target in any direction, or any change in the position of the ankle, as, for instance, rotation of the limb. Thus the distance between the shadow of the line of the posterior tubercle on the fibular groove and that of the mesial margin of the fibula is increased if the target is moved nearer the plate, but likewise the width of the fibula and tibia seems to be proportionately increased. However, by no possible manipulation of the tube to either side up to 75 degrees from the perpendicular, or by inward or outward rotation of the leg to 80 degrees can the shadow of the most lateral point of the anterior tubercle be made to pass to the median side of the shadow of the median border of the fibula. (It seemed that the above-mentioned angles were the limits of the possible errors that could have been made in the roentgenograms of our series). Hence it was felt that we could safely say that whenever this did happen, tibiofibular diastasis was established. In fact, if the space between the lateral margin of the fibula and the lateral border of the anterior tubercle exceeds more than two thirds of the width of the fibula, it is most probable that the first degree of diastasis (Fig. 36) exists. This would seem to be certainly the case if the roentgenogram was made with the foot and ankle and tube in the absolute perpendicular plane (Figs. 49, 52 and 53).

Chaput [39] (1912) gave figures in millimeters showing variations of the "clear space" as he called it between the line of the posterior tubercle and the mesial border of the fibula, and claimed that if this space exceeded more than 3 mm., or if the area of the overlapping shadows of fibula and anterior tibial tubercle was less than 10 mm., diastasis was present. The objection to this as compared with the above method is obvious. Measurements on the roentgenogram vary greatly with changes in technic, target plate distance, etc., with age periods and in the different sexes. So a method establishing a means of estimation proportionate for each individual case is manifestly the best.

The larger the clear space between these bones, the greater the degree of diastasis. If there is additional roentgen evidence of a sprain fracture or detachment of the anterior tubercle, there is double assurance (Figs. 30 and 31). But here again one must make due allowance for the fact that when the patient reaches the roentgenologist reduction often has been established. The clear space will then not be abnormally wide, and diastasis can only be presumed to have existed by the evidence of a sprain fracture or a fracture of the anterior tubercle. If these are not present, then no diagnosis of diastasis can be made by the roentgen ray. It seems possible that by a very complete study of normal ankles in both sexes, and in all age periods under identical conditions of technic, more absolute criteria can be established whereby this diagnosis can be made.

The clear space between the internal malleolus and the astragalus in the anteroposterior view is also a most interesting study. What determines the earliest or first degree of lateral displacement of the astragalus? This certainly is of the utmost importance in the determination of such displacement, particularly the so-called outward displacement. It was found that a 10 degree inward rotation of the leg increased this clear space, that the same amount of external rotation correspondingly decreased it; that variations in target plate distance proportionately increased or decreased it as the case might be, that tibial and fibular flexion of the foot both decreased it. So if a minute, careful diagnosis is to be made, the absolute perpendicular must be maintained. Had we had all roentgenograms of the 300 cases studied, made under identical technic, such diagnoses could have been made. We feel that quite a considerable degree of displacement had to be present, in fact so much that it would be apparent under any condition, any position of tube or ankle, before we could say definitely in the foregoing cases that a lateral dislocation existed. Probably also a better idea of rupture of the internal lateral ligament can be obtained by means of this clear space. Thus, when the internal malleolus is intact in the pure abduction fractures, this space may afford an idea of whether or not the internal lateral ligament has ruptured. Here again faulty methods prevented exact conclusions, and this again emphasizes the possibility of study under standardized conditions.

Study of the fibular groove led to the definite conclusion that the anterior tubercle always casts the more lateral shadow, the posterior tubercle the more mesial. This was confirmed by placing pieces of lead of different sizes on the lips of the groove in a living subject and then roentgenographing the ankle. It was noted, in the negatives made with deviations of the tube and change in position of the ankle, above described, that in the perpendicular plane the line of the posterior tubercle was always clearly defined, that this clear definition persisted when the leg was rotated in or with lateral deviation of the target; but with the leg rotated out or with mesial deviation of the target, this line had a tendency to disappear, becoming merged with the dense shadow of the thicker middle portions of the tibia. It is apparent that such variations may materially interfere with the exact determination of just what constitutes the so-called posterior fragment. It may also interfere in the same way with recognition of the intermediate fragment. If this line remains intact, the posterior tubercle is not injured and the posterior inferior tibiofibular ligament is also probably not affected. It is possible that a deltoid shaped posterior marginal fragment broken from the tibia at a point mesial to and behind the posterior tubercle may be so displaced that its shadow overlaps the line of the posterior tubercle. The exact portion fractured can then only be determined by means of stereoscopic plates, and even then this is sometimes impossible. A fracture with such displacement was produced on a dried specimen, likewise another involving the posterior tubercle so as to interfere with the line of the latter on the roentgen-ray negative. In the anteroposterior view, they were indistinguishable, both appearing to be fractures of the posterior tubercle. However, stereoscopic films showed quite plainly the character of the first, i. e., a fragment displaced behind the tubercle and really not involving it.

In conclusion, this study has shown that while the roentgen diagnosis of the gross lesions of the ankle joint is a comparatively easy matter for the trained roentgenologist, the finer points of diagnosis so necessary to a thorough understanding of the mechanism are entirely dependent on more exact methods of technic than are often now employed.[82]

---

82. In addition to the footnotes already given, the following, selected from more than 250 articles studied in the preparation of this paper, will be found of interest:

Bruns: Die Lehre von den Knochenbrüchen, Stuttgart, 1887, p. 57.

Farabeuf: Précis de manuel operatoire, Paris, 1909, p. 835.

Hamilton: Practical Treatise on Fractures and Dislocations, Philadelphia, 1860, pp. 443 and 685.

Messerer: Ueber Elasticität und Festigkeit der Menschlichen Knochen, Stuttgart, 1880, Plate 14, Figures 7, 11 and 3.

Quénu: Bull. et mém. Soc. de chir. de Paris **32**:943, 1906; Rev. de chir. **36**:62, 1907; Bull. et mém. Soc. de chir. de Paris **38**:1070, 1912; ibid. **45**:1142, 1919.

Scudder: Treatment of Fractures, Ed. 8, Philadelphia, 1915, p. 545.

Tillaux: Traité d'anatomie topographique, Paris, Ed. 2, 1878, p. 1023; Gaz. d. hôp. **59**:89, 1886.