Acta orthop. Scandinav. 36, 408–417, 1965.

From the Department of Orthopaedic Surgery, University of Gothenburg, Sweden.
(Head: Professor Carl Hirsch.)

EXPERIMENTAL ANKLE-JOINT FRACTURES

By

CARL HIRSCH and JACK LEWIS

What the clinician sees in the case of an accident is the outcome of a series of events. The interpretation of this result is normally based on the case history, clinical findings and observations at surgery. This information provides the data for a reconstruction of the mechanism of various types of injuries.

Although these analyses are concerned with the biologic course of events in living issues, they do in fact only reflect the end phase of the action of the forces involved; the intermediate stages are concealed.

There are many reasons, both practical and purely scientific, for trying to understand the relationship between the mechanical force and its response in the tissues; the value of such knowledge in prevention and treatment is self-evident, while problems relating to the physical properties of various tissue elements are perhaps more of a theoretical nature.

In order to approach these problems it is evident that they must be examined by means of some form of model experiment; and as the very nature of the problems concerned with human accidents rules out the use of living subjects recourse must be had to autopsy specimens.

The study of traumatic effects on autopsy specimens is, of course, subject to many obvious sources of error. The muscles, the circulation and the mechanism of nervous regulation are no longer functioning. On the other hand, it is not certain that these factors necessarily invalidate an experimental approach to carefully defined problems. To a limited extent muscles can be simulated by controlled pullies and circulation can be added to fresh autopsy sections.

It is always possible to compare the experimental results with clinical

---

Paper presented at the Scandinavian Orthopaedic Association meeting in Helsingfors 1964.

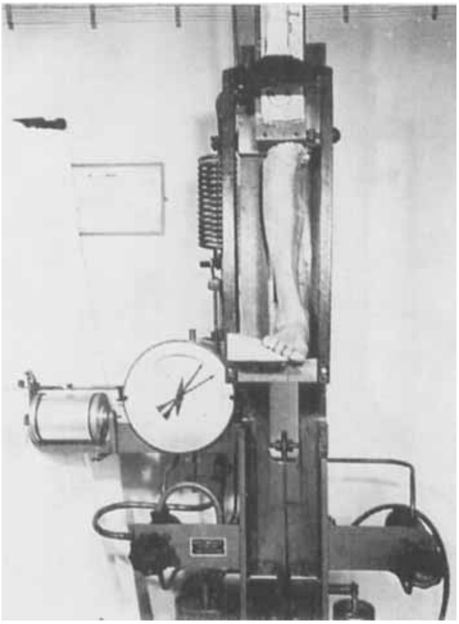

Fig. 1.
Experimental arrangement for compression tests on ankle joint in fresh disarticulated autopsy legs. The foot is positioned by various types of wooden plates.

experience, and to interpret the results in a clinical context. If the findings in model experiments differ from what we consider we are able or would like to accept, there is usually the opportunity of checking on the clinical cases. This is particularly true of the extent and appearance of the injuries. Model experiments are particularly valuable for studying details, which may serve as a guide for clinical verification.

The object in model experiments is to subject parts of the body to mechanical forces and to provide a basis for the study of the action of

Position	Kp. Force	Fracture
Plantarflexion 45 degrees	725	proximal ttibia
,,	925	os calcis
,,	900	tibial plateau
,,	700	tibial plateau
Dorsalflexion 45 degrees	225	talar neck
,,	315	talar body
,,	160	distal tibia-fibula
,,	100	distal tibia-fibula

Fig. 2.
Compression loading flexion injuries.

Fracture Lateral Malleolus	Deltoid Tear	Fracture Medial Malleolus	Kp. Force
	+		450
	+		325
	+		325
		+	145
+	+		300
+	+		335
+	+		520
+		+	265
+		+	330
+		+	325

Fig. 3.
Compression pronation injuries.

Fracture Lateral Malleolus	Rupture Fibular Calcaneal Ligament	Rupture Anterior Fibular Talar Ligament	Fracture Medial Malleolus	Kp. Force
+				170
+				210
+		+		200
+		+		200
+		+	+	330
+		+	+	395
+			+	420
	+			190
	+	+		255
				185

Fig. 4.
Compression supination injuries.

the forces; the magnitude, direction and speed of the force can be determined. The deformation of the involved tissue elements can be followed up to the point of failure, *i.e.* when injury is inflicted. The course of events can be interrupted and intermediate effects analysed.

The object in this account is to describe some fracture experiments on the ankle joint. The emphasis has been placed on the interpretation of the type and its mechanism.

Fig. 5.
The foot is fixed to a plate which can be placed in desired positions. The tibial condyles are attached to a vise and held by screws. The mounted specimen is subjected to compression by a lever system acting on the footplate. Rotation movements can then be applied.

Fracture Lateral Malleolus	Syndesmosis Injury	Deltoid Tear	Fracture Medial Malleolus	Torque: Kp.-Meters
	+	+		8.0
	+	+		6.8
+		+		7.2
+		+		8.4
+		+		8.0
+			+	8.0
+			+	7.2
+			+	7.2
+				7.6
+				7.6
+				7.6
+	+			7.2

Fig. 6.
External rotation injuries without supination or pronation.

Fracture Lateral Malleolus	Syndesmosis injury	Deltoid Tear	Fracture Medial Malleolus	Torque: Kp.-Meters
+		+		6.4
+	+			6.0
+	+			10.0
+	+		+	8.0
+		+	+	8.4
+		+	+	4.8
			+	10.0

Fig. 7.
External rotation pronation injuries.

Fracture Lateral Malleolus	Syndesmosis injury	Deltoid Tear	Fracture Medial Malleolus	Torque: Kp.-Meters
+	+	+		5.6
+		+		6.0
+	+		+	4.0
+			+	4.8
+			+	5.6
+				5.6
				4.0

Fig. 8.
External rotation supination injuries.

The study was performed on fresh autopsy specimens. The leg was exarticulated at the knee joint and mounted in specially designed compression units (Figs. 1 and 5).

In the first series of experiments (Fig. 1) the foot was placed in a given position and the force was applied in the longitudinal direction of the leg. The force was increased at a constant rate, and its magnitude was read off on a scale. The total deformation of the specimen was also recorded. When the force no longer increased and the specimen no longer presented any resistance, the experiment was discontinued. These events were usually accompanied by a "trauma noise". Radiographs were taken in two planes before and after the experiments. The specimen was then unmounted, frozen and dissected for examination of the damage inflicted.

Fracture Lateral Malleolus	Rupture Anterior Fibular Talar Ligament	Rupture Fibular Calcaneal Ligament	Fracture Medial Malleolus	Torque: Kp.-Meters
	+			7.6
	+			5.6
	+			5.6
	+	+		5.6
	+	+	+	8.0
+				8.0
				5.2
				8.8
				6.0

Fig. 9.
Internal rotation injuries.

Fig. 10.
External rotation without supination or pronation: Bimalleolar fracture.

Fig. 11.
External rotation supination spiral fracture of lateral malleolus.

The results of the 28 experiments are illustrated in the tables (Figs. 2–4).

In the second series the foot was fixed on a movable plate, which permitted dorsal and plantar flexion, pronation, supination and rotary movements (Fig. 5). The condyles of the tibia were locked. During the course of the experiment the specimen was loaded with a constant

Fig. 12.
Internal rotation: Rupture of anterior talofibular ligament and fibular calcaneal ligament.

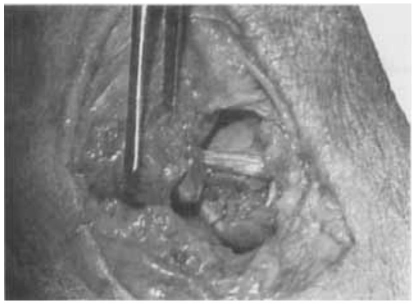

Fig. 13.
Internal Rotation: Anterior fibular talar ligament avulsed from talus.

Fig. 14.
External rotation supination: Fracture medial malleolus with posterior tibial tendon trapped.

Fig. 15.
Internal rotation: Rupture of anterior fibular talar ligament and fibular calcaneal ligament.

Fig. 16.
Internal Rotation: Peroneus longus tendon trapped within the ankle joint.

weight, usually body-weight. The loading could be varied at will in different experiments. The force applied in the rotational movement was read off on a spring balance. These specimens, too, were radiographed before and after the experiment. After freezing they were dissected for analysis of the damage.

The results of these 35 experiments are presented in Figs. 6–9.

Figs. 10–12 illustrate some radiographs taken just as the experiment was discontinued.

Figs. 13–16 show examples of damage to soft tissues.

DISCUSSION

The damage to the joint capsule, ligaments, tendons and skeletal tissue seen in these experiments does not in itself bring forward any new findings. Attention centres rather on the distribution and extension of the injuries in the series of specimens. There is today a tendency in many centres towards open reduction and reconstructive surgery in ankle lesions. Although it seems to be attractive it is still too early to assess the value of extensive surgical repair with respect to the long-term result. Surgery has, of course, its technical limitations as far as the capsule and ligaments are concerned. The tendency to choose this form of treatment has, however, the advantage that the extent and frequency of the injuries can be better recorded and the results appreciated with regard to different kinds of injuries. For such purposes even experiments on autopsy specimens may be justified as a guidance.

They may also serve as a method for classification of ankle joint injuries. The experiments presented do not seem to support fully earlier interpretations. The anatomical appearance does not explain the mechanism of trauma and does not permit terms of injuries expressed by force direction.

SUMMARY

In the experimental studies performed, the following conclusions were reached.

1. Whenever forces act against normal ankle unit function, multiple lesions are likely to occur.
2. In ankle injuries a medial and lateral component are frequently present, sometimes consisting of bilateral bone lesions, a bone lesion and an opposing soft tissue lesion, or bilateral soft tissue lesions.
3. More soft tissue injury is present than is usually expected.
4. Simultaneous lesions occur more frequently than serial ones.
5. Forces that coincide with normal ankle function are well tolerated.
6. In compression loading the ankle can tolerate large forces, failure occurring proximal or distal to the ankle.
7. The force required for internal or external rotational injuries is small.

RESUME

Dans les étude expérimentales pratiquées, on arrive aux conclusions suivantes:

1. Lorsque des forces s'opposent à la fonction normale de la cheville, des lésions multiples peuvent apparaître.
2. Dans les lésions de la cheville, un composant médial et latéral sont fréquemment observés consistant parfois en des lésions bilatérales de l'os, une lésion osseuse et une lésion opposée des tissues mous, ou des lésions bilatérales des tissues mous.
3. Généralement, il y a plus souvent une lésion des tissus mous qu'on ne l'aurait cru.
4. Des lésions simultanées se produisent plus fréquemment que des lésions en série.
5. Les forces qui coïncident avec la fonction normale de la cheville sont bien tolérées.
6. Dans la charge de compression, la cheville peut tolérer de grandes forces, le défaut apparaissant proximalement ou distalement à la cheville.
7. Les forces requises pour des lésions de rotation interne ou externe sont peu importantes.

ZUSAMMENFASSUNG

Durch die ausgeführten experimentellen Studien gelangte man zu folgenden Schlussfolgerungen.

1. So oft Kräfte auf eine normale Knöcheleinheitsfunktion einwirken, kommt es wahrscheinlich zu vielfachen Schädigungen.

2. Bei Knöchelschäden ist häufig eine mediale und laterale Komponente vorhanden, die manchmal in einer doppelseitigen Knochenbeschädigung, einer Knochenbeschädigung und einer andersseitigen Weichtteilbeschädigung oder eine doppelseitigen Weichteilbeschädigung besteht.

3. Eine ausgedehntere Weichteilbeschäidgung als man gewöhnlich annimmt ist vorhanden.

4. Gleichzeitige Schädigungen entstehen häufiger als auseinanderfolgende.

5. Kräfte, die mit normaler Knöchelfunktion zusammenfallen werden gut vertragen.

6. Bei Kompressionsbelastung kann der Knöchel grosse Kräfte ertragen. Ein Schwichten tritt nur proximal oder distal vom Knöchel auf.

7. Die Kraft welche notwendig ist um Auswärts- oder Einwärtsrotationsschäden zu erzeugen, ist nur gering.