Holistic Approach to Functional Anatomy of the Injured Ankle Joint

Antun Šalamon[1], Tomislav Šalamon[2], Vasilije Nikolić[3], Radivoje Radić[3], Tatjana Nikolić[4] and Ana Jo-Osvatić[2]

[1] Department of Surgery, University Hospital »Dubrava«, Zagreb, Croatia

[2] Department of Anatomy, School of Medicine, University of Zagreb, Zagreb, Croatia

[3] Department of Anatomy, School of Medicine, University »J. J. Strossmayer«, Osijek, Croatia

[4] Department of Physical Therapy and Rehabilitation Medicine, University Hospital of Traumatology, Zagreb, Croatia

A B S T R A C T

Talocrural joint injuries are among the most common injuries of the joints and therefore there is a need for a holistic approach to analysis of morphology, biomechanics and visualization of the talocrural joint ligamentary apparatus in different positions. The research was carried out on 20 fresh and conserved anatomical specimens of the lower leg on which X-ray, computed tomography, ultrasonography and stress analysis were performed before and after the lesion of ligaments. Also the gait of 130 adults without (100) and with ligament and joint capsule lesion (30) was analyzed by infrared telemetry. After complete discission of the lateral ligaments, arthrography and CT could register the lesion, while X-ray and ultrasonography could not detect it. Gait analysis of healthy and injured leg showed that the injured leg was significantly less loaded.

Key words: *talocrural (ankle) joint, ligaments, injury*

Introduction

Talocrural joint injuries are among the most common injuries of the joints. Statistical analyses of many authors reveal that approximately 10% of all injuries comprise capsular and ligamentar injuries, and about 40% of these injuries affect the talocrural joint. Increasing number of authors[1] report on diagnosis and therapy of isolated capsular and ligamentar injuries of the talocrural joint, emphasizing the fact that many physicians, and even specialists in traumatology, consider these injuries trivial, and conduct only symptomatic therapy with physical procedures, or do not immobilize the joint long enough[2]. The consequence of such

treatment is often loose, instable ankle, often with recurrent distortions and late posttraumatic arthrosis[3,4]. These apparently trivial injuries may thus cause certain invalidity if treated improperly, especially in professions where ankles are particularly under stress, as with field workers, athletes and ballet dancers. The treatment of isolated ligamentar ruptures with immobilization for 6 to 10 weeks as recommended by Böhler et al. back in 1976 does not always result in complete ankle stability. The thorn ligament and the capsule of the joint do not always heal in anatomical position, usually because of interposition of either fat, capsular or synovial tissues.

It is evident that there is a need for holistic approach to analysis of morphology, biomechanics[5,6] and visualization of the talocrural joint ligamentary apparatus[7] in different positions. Using several methods simultaneously in the treatment of this diagnostically and therapeutically problematic ligamentar injury of the talocrural joint will thus establish a minimum of diagnostic procedures in suspected injuries of the ankle ligamentar apparatus. Anatomical specimen is the best model for such kind of investigation. The same specimen could be X-rayed many times without overdoses risk and than could be dissected.

Materials and Methods

The research was carried out on 20 fresh anatomical specimens of the lower leg with all tissues preserved. In all specimens lateral capsular ligamentar injury
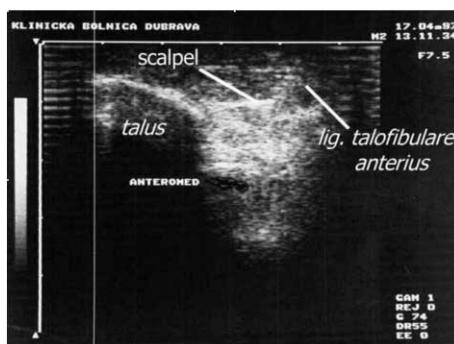

Fig. 1. Ultrasound image of of the lateral ligaments incision with a scalpel.

was simulated by transcutaneous discission. In the first phase the anterior talofibular ligaments were injured, first partially and then completely[7]. In the next phases, the posterior talofibular ligament and finally the calcaneofibular ligament were transected.

All specimens, intact and in all phases of lesion, were examined with several radiographic and ultrasonographic methods. X-rays of these samples were made in antero-posterior and latero-lateral, as well as in oblique projections, and also in positions that simulated different ankle movements (Table 1). Focus-film distance was 80 cm. Ultrasonography was made also in different projections with linear probe 7.5 MHz (Figure 1). All specimens were also investigated by serial CT (Figure 2). Several intact specimens were injected by water-soluble contrast Rompacon into the joint cavity[8] and then first X-rayed in antero-posterior and latero-lateral projection (Figure 3) and by CT (Figure 4).

TABLE 1
NUMBER OF INVESTIGATED SPECIMENS BY SPECIFIC METHOD

Stage of lesion	X-ray				CT		Ultra-sound
	a-p	l-l	Stress	Contrast	Native	Contrast	
Intact	20	20	20	7	20	7	20
Injured	20	20	20	7	20	7	20

Fig. 2. CT (detail) of the talocrural joint.

Fig 4. CT arthrography after the lesion of all
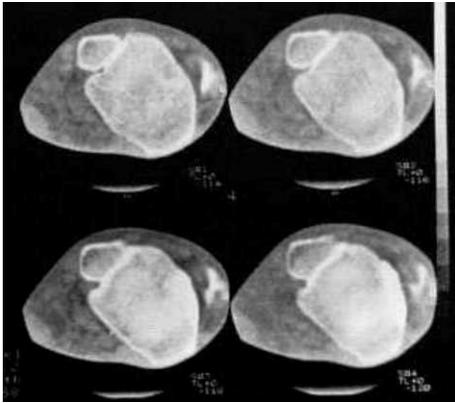the ligaments of the lateral group.

Fig. 3. Artrography after artificiallesion of the
ligaments (leaking of the Rompacon contrast
media from the joint capsula).

After successive lesions, from partial
to total, the degree of subluxation and the
angle of the talus position were measured
by analyzing mobility, first of the intact,
and than of the injured specimens in each
phase of the lesion. It was assessed in two
ways: by measuring on stressed X-rays
the distance between the overlapping point
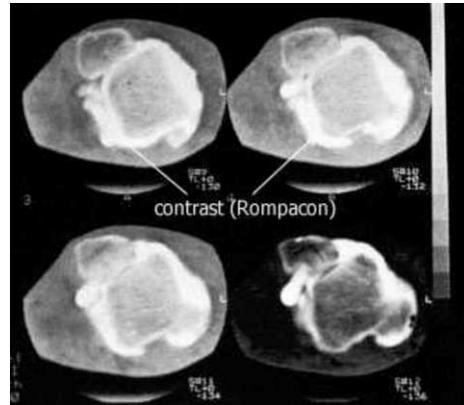of the fibular malleolus and the tibia, and

the upper lateral border of the talus, or
by measuring the angle between the line
passing through the two uppermost points
on the articular surfaces of the tibia and
the talus (Figure 5).

Contact pressure measurements were
performed by placing pressure-sensitive
foils (Fuji film Prescale). We used foils of
two sensitivities: low and super low. The
specimen was placed under stress in the
positions of plantar and dorsal flexion,
eversion and inversion and loaded stati-
cally. Loading (200N and 400N) was
transmitted axially through the tiba and
the fibula. In each position new foil was
placed between articular plates. Areas
under greatest pressure were shown in
most intense color and the intensity can
be determined in Pascals by specially de-
signed densitometers.

Results

Experiments were performed on 20
anatomical specimens. Only arthrogra-
phy and CT can detect lesion of the ante-
rior talofibular ligament, while X-ray and
ultrasonography (US) could not adequa-
tely detect it. Leaking of water-soluble
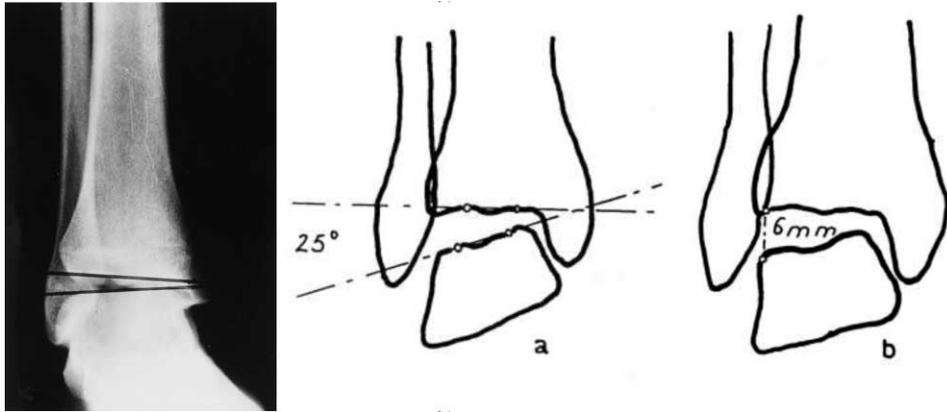contrast Rompacon from the joint cavity

Fig. 5. X-ray (A-P) with marked tibiotalar angle after the lesion of lateral ligaments.

in periarticular tissue on lateral side is the most evident proof of lesion. After complete discission of lateral capsular ligamentar apparatus, lesions were registered also by ultrasonography and by stress X-rays. On anatomical specimens with injected contrast by ultrasonography is diagnosed as intraarticular liquid. Edema or tenosinovitis could not be recognized on our anatomical specimens.

The tibiotalar angles were increased proportionally with stage of ligament lesion (Table 2). In the first group, where only anterior talofibular ligament was discissed, the tibiotalar angle was 8–10 degrees (in comparison with less than 5° in intact specimens). In the joints with lesion of anterior talofibular and calcaneo-fibular ligaments the tibiotalar angle was 10–15 degrees and in the third group, where all three lateral ligaments were discissed, the tibiotalar angle was between 30 and 45 degrees.

Measurements of contact pressure with pressure-sensitive foils give us a good image of the articular cartilage stress distribution. Figure 6 shows the intraarticular stress distribution in talocrural joint, determined by pressure-sensitive foil on intact (A) and injured specimens after discission of the lateral ligament groups (B). The mean stress on the articular cartilage of the intact joints, loaded with 200 N, was 260 kPa and maximal stress was up to 600 kPa, while with loading force with 400 N mean stress was 540 kPa and

TABLE 2
THE TIBIOTALAR ANGLE IN INTACT SPECIMENS AND AFTER DISCISSION OF
THE LIGAMENTAR APPARATUS

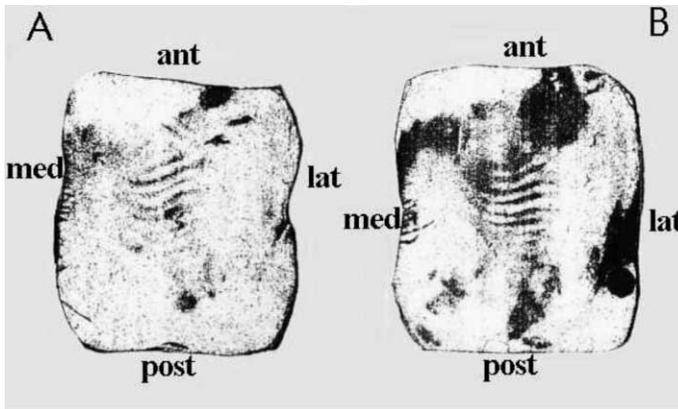| Stage of lesion	The angle of the talus position (°)				
	N	X	SD	Min.	Max.
Intact samples	20	3.6	0.9	2	5
Partial lesion of ant. talofibular ligament	20	5.8	0.8	3	7
Total lesion of ant. talofibular lig.	20	9.2	0.4	8	10
Total lesion of ant. and calcaneofibular lig	20	11.9	1.2	10	15
Total lesion of lateral ligamentar apparatus	20	38.4	8.6	30	45

Fig. 6. The distribution of intraarticular pressure load on intact (A) and injured (B) specimens of the talar trochlea (greater color intensity = greater pressure load).

maximal stress was 1,270 kPa. In injured joints a concentration of greatest pressures was in anterior and medial parts of the joint up to 1470 kPa, with loading force of 200 N and up to 3,210 kPa with loading force of 400 N (Table 3). The results of the measurement of pressure distribution in tibiotalar joint show that the lesion of the lateral group of ligaments causes the concentration of greatest stress in the medial and posterior parts of the trochlea tali, which will inevitably lead to the damage of articular cartilage and later arthrotic changes, if not treated properly.

Discussion

Arthrography and CT images of the injured talocrural joint showed that these methods could be used only to diagnose larger ligamentar lesions. Measurements of the distance between the point where the contours of tibia and fibular malleolus overlap and the most prominent part of the lateral border of the talus were not taken into consideration because the possibility for error was too great. The measurement of the tibiotalar angle[11] in stressed X-rays is a more accepted method of diagnosing the lesion of the lateral group of ligaments, and this was the method we employed in measuring the size of lesion of the lateral group of ligaments in the talocrural joint.

Articular cartilage will function normally on intermittent loads, with pressures within given optimal range. Articular cartilage is a highly elastic and porous structure so the range of optimal pres-

TABLE 3
INTRAARTICULAR PRESSURE IN INTACT AND INJURED (AFTER TOTAL LIGAMENTAR DISCISSION) TALUCRURAL JOINT MEASURED BY PRESSO-SENSITIVE FOILS (FUJI)

Axial loading force [N]	Intraarticular pressure (stress) [kPa]		
	Intact (N=7)		Injured (N=7)
	Mean	Maximal	Maximal
200	266	600	1470
400	540	1270	3210

sure depends on its composition, structure and thickness. The size, shape and position of the contact surface and the pressure change in different movements and positions of the joint, depending on the shape of articular bodies and resulting force.

Pressure is not equally distributed over the contact surface of the joint; there are areas of different intensities and areas of maximal pressures. But these areas also change their position depending on the position of articular bodies and possible non-homogeneity of the articular cartilage and subhondral bone. Biomechanical processes in the joint are very complex, which justifies the attempts and need for most exact determination of pressure distribution between articular surfaces in different phases of movement, as we proved in part by this investigation. Our results of the measurement of pressure distribution in tibiotalar joint show that in the lesion of the lateral group of ligaments the concentration of greatest pressures is in the medial and posterior parts of trochlea tali, which will inevitably lead to the damage of articular cartilage and later arthrotic changes if not treated properly, as confirmed by Šantić et al.[6] The shape and configuration of articular bodies determine the size of contact surface that transmits the pressure from one articular body to another within the ankle. If unhealed distortions or insufficiencies of the ligamentar apparatus result in inadequate contact between articular surfaces (greater pressure on smaller area), arthrotic changes and later invalidity will result.

For the purpose of preventing arthrotic changes based on the detailed analysis of inadequate pressure distribution many authors[8,12,13] have tried to design the method of measuring the pressure on different parts of articular surfaces and so predict the occurrence of arthrosis. That enables the correction of the treatment methods for such lesions, which have been explored by biomechanical system for telemetry according to Šantić[6,9].

Rehabilitation objectives are restoring the full ranges of motion of ankle joint in all planes, improving the strength of muscles affected by the injury or immobilization and restoring the gait to its pre-injury level[14]. During rehabilitation treatment we must consider age (poor healing of skin and bone, osteopenia), systemic disease (diabetes, metabolic bone disease), articular involvement (posttraumatic arthritis) and foot compartment syndrome. In addition to various exercises proprioception training must be instituted for all patients. Other physical therapeutic treatment modalities could be also used such as cold, magnetotherapy, ultrasound, electrotherapy and electrical stimulation as a part of strengthening program, as well as medication if necessary.

Conclusion

After analyzing the possibilities of diagnosing ligamentar rupture of the talocrural joint and its instability, and assessing the value of different diagnostic procedures we conclude:

1. Smaller lesions of the ligaments of the talocrural joint can be mistaken for milder distorsion and therefore mistreated.

2. X-ray, CT as well as arthrography can diagnose only large injuries of the lateral ligaments.

3. Tibiotalar angle measuring gives a good insight into the joint lesion, because the greater tibiotalar angle implies the lesion of the lateral group of ligaments and justifies operative exploration.

4. Every positively diagnosed lesion of the ligaments of the talocrural joint should be treated operatively to reconstruct the joint capsule (capsuloplasty) and thorn ligaments.

5. Experiments with pressure-sensitive foils proved that an inadequately treated lesion of the talocrural joint leads to uneven and non-proportional load on the articular cartilage, which can result in arthrosis and permanent invalidity of patients.

R E F E R E N C E S

1. LIU, S. H., K. E. JACOBSON, J. Bone Jt. Surg. (Br), 77 (1995) 55. — 2. WATSON-JONES, R.: Fractures and joint injuries. (Livingstone LTD., Edinburg -London, 1976). — 3. XENOS, J. S., W. J. HOPKINSON, M. E. MULLIGAN, E. J. OLSON, N. A. POPOVIĆ, J. Bone Jt. Surg., 77 (1995) 847. — 4. WEBER, B. G., W. HUPFUER, Arch. Orthop. Unfall-Chir., 65 (1969) 251. — 5. NIKOLIĆ, V., M. HUDEC: Principi i elementi biomehanike. (Školska knjiga, Zagreb, 1998). — 6. ŠANTIĆ, A., V. BILAS, I. LACKOVIĆ, Period. Biol., 104 (2002) 305. — 7. ŠALAMON, A.: Clinical, anatomical and biomechanical characteristics of the capsular and ligamentar injury of the upper ankle joint. In Croat. Ph.D. Thesis. (School of Medicine, University of Zagreb, Zagreb, 1998). — 8. CASS, J. R., B. F. MORREY, Y. KATOH, E. Y. S. CHAO, Clin. Orthop., 198 (1985) 110. — 9. ANDRIĆ, V., M. BIELEN, V. NIKOLIĆ, A. JO-OSVATIĆ, A. ŠALAMON, Period. Biol., 104 (2002) 311. — 10. ŠALAMON, A., V. NIKOLIĆ, A. JO-OSVATIĆ, V. ANDRIĆ, Period. Biol., 104 (2002) 317. — 11. ZWIPP, H., S. RAMMELT, R. GRASS, Clin. Pediatr. Med. Surg., 19 (2002) 195. — 12. BONNIN, J. G., J. Bone Jt. Surg., 47 (1965) 609. — 12. PAUL, U., M. LÛNING, Beitr. Orthop. Traumatol., 6 (1978) 305. — 13. HOPPEMFELD, S., V. L. MURTHY: Treatment and rehabilitaion of fractures. (Lippincott, Williams and Williams, Philadelphia, 2000).

R. Radić

School of Medicine, University »J. J. Strossmayer«, J. Huttlera 4, 31000 Osijek, Croatia

HOLISTIČKI PRISTUP FUNKCIONALNOJ ANATOMIJI OZLIJEĐENOG GLEŽANJSKOG ZGLOBA

S A Ž E T A K

Ozljede talokruralnog zgloba ubrajaju se među najčešće ozljede zglobova. Stoga je potreban holistički pristup morfologiji, biomehanici i vizualizaciji ligamentarnog sustava ovog zgloba u različitim položajima. Istraživanje je izvršeno na 20 svježih i konzerviranih anatomskih preparata potkoljenice na kojima je prije i nakon oštećenja ligamenata izvršena rentgenska i ultrazvučna analiza, kao i analiza opterećenja. Također je pomoću infracrvene telemetrije proučavan hod na 100 zdravih ispitanika i na 30 ispitanika s oštećenom zglobnom čahurom ili drugom lezijom gornjeg nožnog zgloba. Nakon potpunog puknuća lateralnih ligamenata, lezija se može zamijetiti artrografijom i kompjutoriziranom tomografijom, dok se rentgenom i ultrazvukom ona ne može registrirati. Analiza hoda zdrave i ozlijeđene noge pokazuje da je ozlijeđena noga značajno manje opterećena.