Anthropometric measurements of medial and lateral malleoli to study and aid better implant profile

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Abstract

Ankle fractures are amongst the commonest type of fractures treated by orthopaedic surgeons. The incidence of such fractures has increased since the last three decades in both the younger and elderly population, as well as due to increased vehicle accidents. Pre-reduction and pre-operative radiological assessments, extrapolated on long term clinical results, have helped to improve the management of these fractures. Without mentioning the nature of contouring to be done, restoration of proper tilts/rotation and malleolar lengths, especially in comminuted fractures can be very challenging. The current study has been carried out to ascertain the various anthropometric parameters to help in designing of such implants. Radiographs of Twenty Cadaveric ankle specimen were obtained and Anthropometric measurements of the lateral & medial malleolus of twenty cadaveric fibula & tibia of same specimen were carried out and the radiographs of ankles of 500 volunteers formed the material for the study. The length and width of lateral & medial malleolus in coronal and Sagittal planes, the angles subtended by various bends of the medial surface of medial malleolus and lateral surface of lateral malleolus in radiographs of cadaveric tibia and volunteers were measured. The data collected has been recorded and analyzed. It is hoped that the measurement of the various parameters will be of value for scientific designing of implants for fixation of malleolar fractures.

Keywords: Ankle fractures, medial malleolus, lateral malleolus, tibio-fibular syndesmosis, talar shift, anthropometric measurements

Introduction

Ankle fractures have shown a remarkable increase in incidence in recent times. Management of the wide variety of ankle fractures involves proper pre-reduction/assessment of pre-operative assessments of radiographs, and subsequent post-reduction and post-operative radiographs. Skinner (1914) was first to define “weight bearing lines” across the ankles joint in anteroposterior and lateral views. Robert Close (1956) described in details the talar shift due to syndesmotic instability and sectioning of the deltoid ligament. He described the importance of the medial clear space between medial malleolus and talus.

However, Joy *et al*. (1974) [1] gave precise anatomized criteria for assessment of malleolar and talar displacements. Sarkisian and Cody (1976) described the talocrural angle. Pettrone *et al*. (1983) [2] elucidated quantitative criteria for prediction of results after displaced ankle fracture.
De Souza *et al*. (1985) [3] in an excellent publication first pointed out the lateral bend of the lateral malleolus and its importance for pretending of plates applied over the region. The current study was undertaken on cadaveric tibia and fibula and on anteroposterior radiographs of both ankle of 500 volunteers to ascertain various anthropometric parameters of the medial/lateral malleolus and tibiofibular syndesmosis in the Indian population.

Material and Methods

Radiographs of 20 cadaveric specimen of ankle were obtained in Antero-posterior view and 15^0 internal rotation view (mortise view) and various angles depicting the lateral border of lateral malleolus and medial border of medial malleolus in radiographs were measured. Anthropometric measurements of the lateral malleolus of twenty cadaveric fibula as well as medial malleolus of twenty cadaveric tibias of same specimen were carried out. Length, along with coronal and sagittal width, was noted.
Anteroposterior neutral rotation and 15 degree internal rotation radiographs of both ankle joints were obtained in 500 adult male volunteers.
The following angles were measured in the antero posterior & 15 degree internal rotation (mortise view) radiographs of lateral and medial malleolus of cadaveric ankle specimen as well as on the radiographs of volunteers:

1. Width of ankle at tibial.
2. Talocrural angle.
3. Tibio fibular overlap.
4. Tibio fibular clear space.
5. Angle A on medial border of medial malleolus.
6. Angle B on medial border of medial malleolus.
7. Angle C on medial border of medial malleolus.
8. Angle A' on lateral border of lateral malleolus.
9. Angle B' on lateral border of lateral malleolus.
10. Angle C' on lateral border of lateral malleolus.
11. Medial malleolar length from tibial plafond to tip.
12. Lateral malleolar length from tibial plafond to tip.

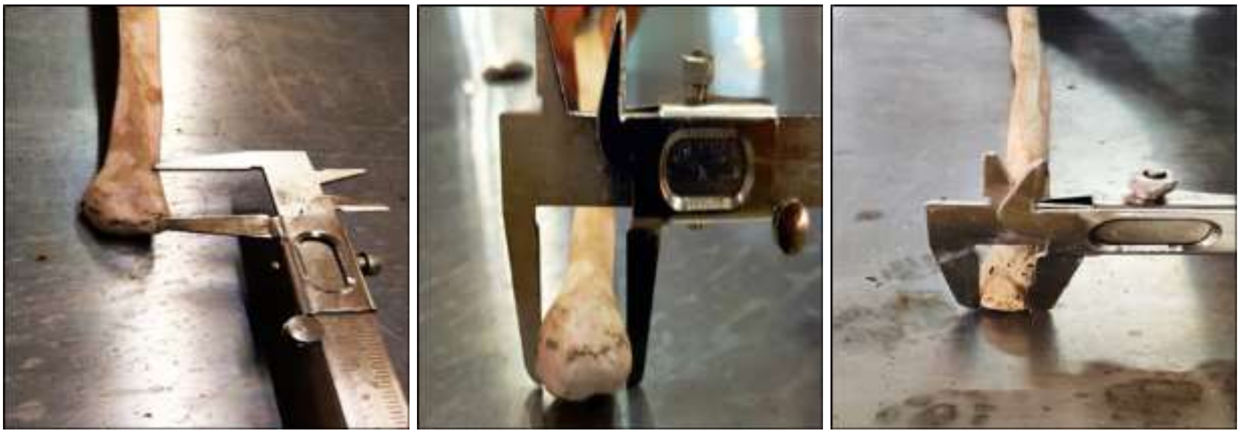
Measurement of angle in x-rays

Measurement of angles in volunteer x-rays

Cadaveric specimen of lower limb for study **Cadaver specimen under X-ray machine**

Cadaver X-rays **Cadaveric bones: tibia & fibula**

Technique to measure using Vernier Callipers the sagittal Width, length and coronal width of Medial Malleolus



Technique to measure using Vernier Callipers the length, Coronal Width & sagittal width of lateral Malleolus

Observations

The average length of medial malleolus from tibial plafond was 16.5mm while that of lateral malleolus was 29.58mm. The average talocrural angle was found to be 75 degree range being 71 degree to 78 degree in AP view. In AP neutral view the tibiofibular overlap was 14.3mm (range 7.00mm to 25mm) while the tibiofibular clear space was 4.1mm (range 1.0mm to 8.0mm. The same in 15 degree internal rotation was 4.5mm (range 2.00mm to 8.00mm). The lateral bend of the lateral malleolus was found to be ranging between 9 degree to 20 degree average being 17.5 degree. The medial bend of medial malleolar cortex was found to be 12 degree to 36 degree average being 22.5 degree.

Table 1: The values of the various parameters can be seen in the following table: zero degree Anteroposterior radiograph (Sample size-250)

Parameter (Both sides combined)	Minimum	Maximum	Average
1. Width of ankle at tibial plafond (mm)	49mm	76mm	65.7mm
2. Width Maximum (mm)	51mm	78mm	68.65mm
3. Taloaural angle	71	78	75
4. Tibio fibular over lap	7 mm	25mm	14.3mm
5. Ube fibular clear Space	1mm	8mm	4.1mm
6. Angle A	12	36	22.5
7. Angle B	18	33	25.8
8. Angle C	33	61	44.62
9. Angle A'	9	20	17.5
10. Angle Er	13	26	19.8
11. Angle C'	21	46	35.4
12. Medial malleolar length	12mm	18mm	16.5mm
13. Lateral Malleolar Length	24mm	37mm	29.58mm

Table 2: Parameters in 15 degree Internal Rotation Radiography (Sample Size-250)

Parameter (Both sides combined)	Minimum	Maximum	Avenge
1. Width of ankle at tibial plafond (mm)	54mm	77mm	63.8mm
2. Width Maximum (mm)	58mm	76mm	69.4mm
3. Talocrural angle	76	87	80.1
4. Tibio fibular overlap	1	8	
5. Tibio fibular clear space	2	8	
6. Angle A	12	36	10.80
7. Angle B	16	36	26.8
8. Angle C	27	64	41.5
9. Angle A’	11	21	16.1
10. Angle B’	12	24	21.5
11. Angle C’		51	33.60
12. Medial malleolar length	19mm	17mm	15.2mm
13. Lateral Malleolar length	22mm	95mm	26.9mm

Table 3: The parameters on cadaveric bones were as follows

Parameter	Minimum		Maximum		Average	
A. Tibia (Sample size-20)						
Gross (mm)						
1. Length of Medial malleolus from Tibial plafond.(mm)	13		14		13.7	
2. Coronal width.(mm)	11		12		11.5	
3. Sagittal width.(mm)	22		25		23.5	
Radiographs	AP	IR	AP	IR	AP	IR
1. Angle A	15	10	20	21	18.7	17.9
2. Angle B	22	42	31	50	28.5	38.5
3. Angle C	40	40	52	50	46.2	46.6
B. Fibula (Sample size-20)						
Gross (mm)						
1. Length of lateral malleolus from Top of facet for Talus.(mm)	22		26		24.58	
2. Coronal width.(mm)	16		20		17.85	
3. Sagittal width.(mm)	21		25		23.6	
Radiographs						
1. Angle A’	9		15		12.6	
2. Angle B’	2		8		6.5	
3. Angle C’	29		40		35.7	

Discussion

The ankle joint is a very important weight bearing joint. Being exposed and having no musculature to protect it, it is subjected to a lot of stresses. With increase in automation on the roads and sporting activities, ankle fractures have shown a very rapid increase in their incidence. There is an increase in the incidence of fractures of the distal tibia and fibula, especially pilon fractures, due to the high speed motor cycles on the road. This high velocity trauma results in severe soft tissue damage.

Open reduction and internal fixation in such situations has a huge risk of wound breakdown necessitating subsequent plastic surgical procedures (Wyrsch *et al*. 1996) [9]. Such management may also result in deep infections leading on to amputations in some cases.

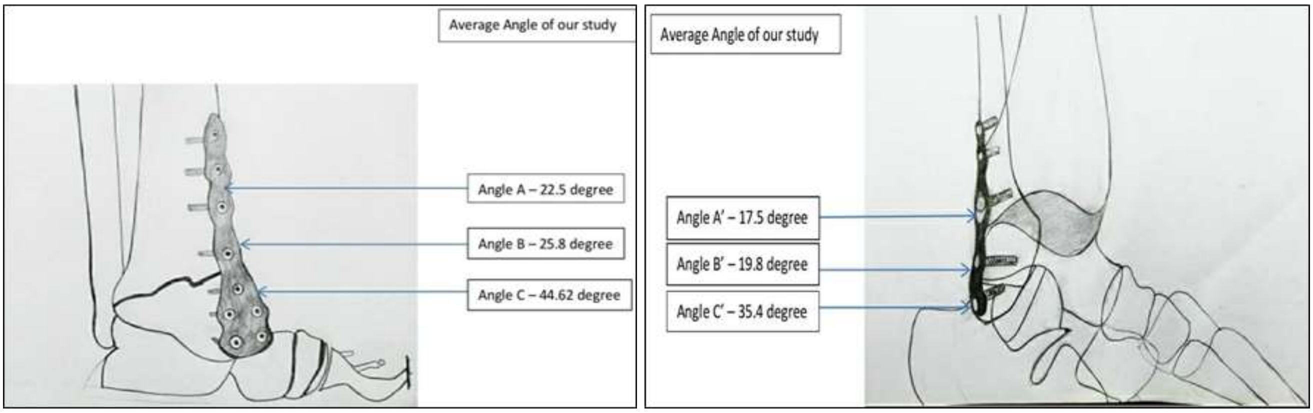
Recently there has been a growing interest in the use of low profile plates contoured over the medial aspect of distal tibia and fibula including medial and lateral malleolus, with/or without external fixation for the management of such fractures. The locking pilon plate was developed in 2002. Various shapes of the medial buttress plates for use with MIPO techniques are now in use.

Helfet *et al*. 1997 [10] were amongst the first to use MIPO technique for distal tibial fractures. Hazarika *et al*. 2006 [11] treated 20 patients who had open and closed distal tibial fractures with minimally invasive locking plate osteosynthesis. Borens *et al*. 2006 [12] have reported their results of treatment of 17 patients with minimally invasive technique and the use of low profile plates for management of select pilon fractures. Their technique involves per-operative contouring of the plate under fluoroscopy. Abdel Salaam Eid 2010 has used an anatomical pre-bent plate rather than a manually contoured semi-tubular plate as used by Helfet *et al*. MIPO technique was used in 17 patients for fixation of the Anatomical Distal Tibial Plate. As recently as 2015, Clifford Wheeles has commented that to prevent soft tissue complications, meticulous contouring of the plate is essential.

Since the medial malleolus is subcutaneous with the tibialis posterior tendon in close relation posteriorly it is important that implants in this region are thin, narrow and properly contoured to fit snugly on the bone.

It should further be recognized that there are different methods of managing malleolar fractures like tension band wiring, use of single four or six and a half millimeter cannulated cancellous screw with or without ‘K’ wires, use of two four millimeter cannulated cancellous screws, etc. With properly designed pre contoured plates, these may soon be in use for select medial malleolar fractures.

This study is an attempt to develop data to enable the designing and use of pre-contoured plates in the region especially those reaching up to the tip of the medial malleolus. This will obviate the need for per-operative contouring of the plates sparing the Surgeon of the time, energy and fluoroscopic exposure for the same. In our study we found out the parameters of angles of the cadaveric tibia and fibula and angles drawn on the volunteers where nearly similar however, the little variation present is due to placement of the cadaveric specimen on the radiographic cassette in both AP view and 15 degree internal rotation view. Hence we recommend Average Angle A-22.5 degree, Average Angle B-25.8 degree, Average Angle C-44.62, Average Angle A’-17.5 degree, Average Angle B’-19.8 degree & Average Angle C’-35.4 for pre-contouring of low profile plates.



Low Profile plating for medial and lateral malleoli showing good contouring of plate

Conclusions

From the study of the anthropometry of the malleoli the following conclusions can be drawn:

- It is important to obtain zero degree anteroposterior and 15 degree internal rotation views (along with lateral views) of not only the injured ankle but also the uninjured ankle. Comparison of parameters like the talocrural angle, and medial and lateral malleolar lengths on normal side is especially important for pre-operative assessment and planning, per-operative assessment of reduction, and for long term assessment of results.
- One of the most important information obtained in this study is the defining of the exact curves of the medial surface of the medial malleolus and the lateral border of lateral malleolus for exact molding of the plates applied over these regions.
- Many of these parameters have been defined for the first time in literature.
- We have also found differences of the lateral bend of lateral malleolus as well as the length of lateral malleolus from other studies from western literature.
- We hope that the study will be helpful in not only assessment of ankle injuries but also for establishment of treatment protocols (plating).
- Finally, we have described three bends of lateral border of lateral malleolus and medial border of medial malleolus. These values of these bends have been measured on radiographs of cadaveric bones, and zero degree anteroposterior and 15^0 internal rotation radiographs of volunteers. These values will be of help in manufacturing prebent plates for tibial plafond, and medial & lateral malleolar fractures.

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