ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 6, Issue, 6, pp.4869-4873, June, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

ANTHROPOMETRY OF THE MEDIAL MALLEOLUS

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ARTICLE INFO

Article History:

Received 2nd, May, 2015
Received in revised form 10th, May, 2015
Accepted 4th, June, 2015
Published online 28th, June, 2015

Key words:

Ankle, pilon fractures, anthropometric parameters

ABSTRACT

There is an increasing incidence of high velocity trauma to the ankle region resulting in not only malleolar fractures but also pilon fractures. Due to severe soft tissue trauma, minimally invasive techniques for fixation of pilon fractures have evolved requiring use of pre-contoured plates. The current study has been carried out to ascertain the various anthropometric parameters to help in designing of such implants. Twenty seven Cadaveric tibia and radiographs of ankles of twenty volunteers formed the material for the study. The length and width of medial malleolus in coronal and Sagittal planes, the angles subtended by various bends of the medial surface of medial 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 pilon fractures

INTRODUCTION

Injuries around the ankle due to high velocity trauma have a large incidence of pilon fractures. Of late, there is a growing awareness of the use of minimally invasive plate Osteosynthesis for these fractures (Bone 1987, Bourne 1989, Vander Griend 1996). For this various small and large contoured plates to fit over the antero-medial surface of the Medial malleolus have been designed.

These buttress plates need to be contoured well to confirm to the bony contour to prevent skin necrosis as the medial malleolus is subcutaneous. The dimensions of the plates used are also of vital importance. There is unfortunately a lacunae in the literature on anthropometric measurements of the medial malleolus which are so important for designing pre-bent plates for use for pilon fractures. The current study is an attempt to fill these lacunae.

MATERIAL AND METHODS

The study comprises of cadaveric and radiographic assessment of medial malleolus.

The study was carried out in three parts.

Measurements of the following in 27 Cadaveric Tibia (16 of Right Side and 11 of Left Side) (Fig. No. 1)

Figure 1 Cadaveric Tibia for study

A. Length of the Medial malleolus from the Tibial plafond to the malleolar tip (Fig. No. 2)

Figure 2 Technique for measuring Length of Medial malleolus

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B. Maximum Width of the medial malleolus in Sagittal plane (Fig. No. 3)

Figure 3 Technique to measure using Vernier Calipers the Sagittal width of Medial Malleolus

C. Maximum width of medial malleolus in coronal plane (Fig. No.4).

Figure 4 Technique to measure using Vernier Calipers the Coronal Width of Medial Malleolus

All measurements were made with Vernier calipers. Antero-posterior and 15 degree internal rotation radiographs of all 27 Tibia were obtained. Tibia were placed in proper anatomical positions on the x-ray plates with the use of plasticin to prevent rotations. The various angles subtended by the contours of medial surface of medial malleolus and the metaphyseal region were identified as Angle A, Angle B and Angle C (Fig. No. 5 and 6).

The medial surface of tibia was followed to its first medial bend. The angle of this bend was noted as Angle A. The second bend is the downward (inferior) bend as we follow the medial surface. The angle of this bend was labeled as Angle B. The medial surface then bends downwards and medially to the malleolar tip. The angle of this bend was labeled as Angle C. These were drawn on each radiograph and measured.

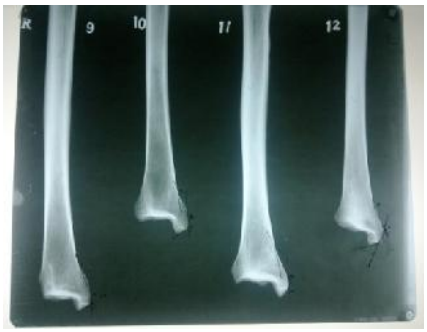

Figure 5 Showing Angles measured on the medial border of the medial malleolus in Neutral AP view

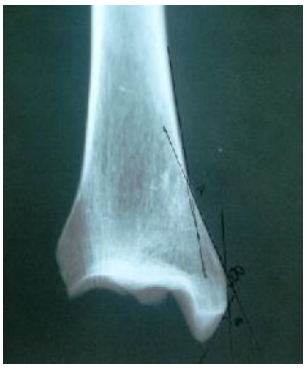

Figure 6 The three bends along medial surface of distal tibia and medial malleolus

Antero-posterior and 15 degrees internal rotation radiographs were obtained of both ankles of twenty volunteers after obtaining due consent from them. The Angle A1, Angle B1 and Angle C1 were drawn and measured in each radiograph (Fig. No. 7)

Figure 7 Angles measured in radiograph of ankle of a volunteer

Observations

The following are the measurements recorded in the cadaveric tibia as well as radiographs of ankle of volunteers.

A. Gross measurements.

1. Length of Medial Malleolus (As measured from Tibial plafond to the malleolar tip).
2. Maximum width of medial malleolus in Sagittal plane (at level of tibial plafond).
3. Maximum width of medial malleolus in coronal plane (At the level of tibial plafond.

B. Radiographic assessment on (Measurements in Anteroposterior (AP) view and 15 degree internal rotation (IR) views of cadaveric tibia and ankles of volunteers.

MEDIAL MALLEOLUS

There were 16 cadaveric tibia of right side and 11 cadaveric tibia of left side.

Gross measurements

1. **Length of Medial Malleolus: (**As measured from Tibial plafond to the malleolar tip)

Table No. 1

Length(mm)	Right	Left	Combined
MIN	12	12	12
MAX	15	17	17
MEAN	14.4	15.0	14.7
MODE	15	15	15
MEDIAN	15	15	15
SD	1.0	1.3	1.1

The maximum length of medial malleolus as measured from the tibial plafond to the tip was medial malleolus was 17mm, whereas the minimum measured was 12± 1.3mm, the average being 14.7±1.1mm.

Table No. 2

WIDTH SAGITTAL(mm)	RIGHT	LEFT	COMBINED
MIN	20	20	20
MAX	28	28	28
MEAN	23.6	24.6	24.1
MODE	23	27	23
MEDIAN	23	25	24
SD	2.1	2.7	2.36

2. **Maximum Width in Sagittal plane :** (At the level of tibial plafond)

The maximum width of medial malleolus in Sagittal plane measured at the level of tibial plafond was 28mm, whereas minimum was 20mm, the average was 24.1mm.

3. **Maximum Width in Coronal plane:** (At the level of tibial plafond.)

Table No. 3

Width coronal(mm)	Right	Left	Combined
MIN	11	11	11
MAX	14	14	14
MEAN	12.4	12.6	12.5
MODE	12	14	12
MEDIAN	12	13	12
SD	1.0	1.1	1.01

The maximum width of medial malleolus in coronal plane measured was 14mm, whereas minimum was 11mm, the average was 12.5mm.

Radiographic Assessment: (Measurements in AP view 0^0 and 15^0 Internal Rotation Views.)

1. **Angle A:** (Angle drawn on the medial bend seen over the medial surface of medial malleolus.)

Table No. 4

ANGLE A	Rt		Lt		COMBINED	
	AP 0^0	IR15^0	AP 0^0	IR15^0	AP 0^0	IR15^0
MIN	10	10	12	16	10	10
MAX	20	22	25	22	25	22
Mean	14.69	15.94	18.82	19.55	16.3	17.74
Mode	12	16	20	20	12	20
Median	14.5	15.5	20	20	17	18
SD	3.42	3.42	3.84	1.86	4.09	3.37

Maximum angle A measured was, AP 0^0 was 25^0 and 15^0 IR was 22^0; Minimum angle A measured was, AP 0^0 was 10^0 and 15^0 IR was 10^0; The average was, AP 0^0 was 16.3^0 and 15^0 IR was 17.74^0

2. **Angle B**: (Angle drawn on the downward bend seen over the medial surface of medial malleolus.)

Table No. 5

ANGLE B	Rt		Lt		COMBINED	
	AP 0^0	IR15^0	AP 0^0	IR15^0	AP 0^0	IR15^0
MIN	14	26	20	25	14	25
MAX	36	50	40	38	40	50
Mean	25.38	37.06	28.91	29.91	27.14	34.1
Mode	20	45	30	28	20	32
Median	25	36	30	30	28	32
SD	6.24	7.21	6.14	3.59	6.33	6.9

Maximum angle B measured was, AP 0^{υ} was 40^{υ} and 15^{υ} IR was 50^0; Minimum angle B measured was, AP 0^0 was 14^0 and 15^0 IR was 25^0;The average was, AP 0^0 was 27.14^0 and 15^0 IR was 34.1^0

3. **Angle C:(**Angle drawn on the lateral bend towards the malleolar tip seen over the medial surface of medial malleolus.)

Table No. 6

ANGLE C	Rt		Lt		COMBINED	
	AP 0^0	**IR15^0**	**AP 0^0**	**IR15^0**	**AP 0^0**	**IR15^0**
MIN	35	30	30	38	30	30
MAX	56	42	55	52	56	55
Mean	45.75	36.50	44.36	42.00	45.1	38.7
Mode	54	40	42	40	42	40
Median	45	37.5	42	40	42	40
SD	7.03	4.20	8.29	4.07	7.44	4.91

Maximum angle C measured was, AP 0^0 was 56^0 and 15^{υ} IR was 55^0; Minimum angle C measured was, AP 0^0 was 30^0 and 15^0 IR was 30^0; The average was, AP 0^0 was 45.1^0 and 15^0 IR was 38.7^0

Normal Ankle Radiographs of 20 Volunteers (20 Right ankles and 20 Left ankles)

Medial Malleolus Angles

4. **Angle A1 :(** Angle drawn on the medial bend seen over the medial surface of medial malleolus on the ankle radiographs)

Table No. 7

ANGLE A	Right		Left		COMBINED	
	AP 0^0	**IR15^0**	**AP 0^0**	**IR15^0**	**AP 0^0**	**IR15^0**
MIN	10.0	12.0	10.0	12.0	10	12
MAX	34.0	32.0	34.0	32.0	34	32
Mean	18.70	18.45	20.40	20.05	19.5	19.25
Mode	17	12	15	12	17	12
Median	17.00	18.00	19.50	19.00	18	19
SD	5.69	5.63	6.42	5.87	6	5.7

The maximum Angle A measured was, AP 0^{υ} was 34^{υ} and 15^{υ} IR was 32^0; Minimum Angle A measured was, AP 0^0 was 10^0 and 15^0 IR was 12^0; The average was, AP 0^0 was 19.5^0 and 15^0 IR was 19.25^0

Table No. 8

ANGLE B	Right		Left		COMBINED	
	AP 0^0	IR15^0	AP 0^0	IR15^0	AP 0^0	IR15^0
MIN	15.0	15.0	19.0	21.0	15	15
MAX	30.0	35.0	31.0	32.0	31	35
Mean	23.50	25.70	23.80	26.95	23.6	26.3
Mode	20	22	21	22	21	22
Median	24.00	26.50	22.50	27.00	23	27
SD	4.67	5.74	3.90	3.86	4.2	4.8

5. **Angle B1 :**(Angle drawn on the downward bend seen over the medial surface of medial malleolus on the ankle radiograph)

The maximum Angle B measured was, AP 0^0 was 31^0 and 15^0 IR was 35^0;Minimum Angle B measured was, AP 0^0 was 15^0 and 15^0 IR was 15^0;The average was, AP 0^0 was 23.6^0 and 15^0 IR was 26.3^0

6. **Angle C1:** (Angle drawn on the lateral bend towards the malleolar tip seen over the medial surface of medial malleolus on the ankle radiographs.)

Table No. 9

ANGLE C	Rt		lt		COMBINED	
	AP 0^0	IR15^0	AP 0^0	IR15^0	AP 0^0	IR15^0
MIN	35.0	29.0	31.0	29.0	31	29
MAX	58.0	62.0	58.0	62.0	58	62
Mean	42.05	41.70	40.10	39.65	41.075	40.6
Mode	44	40	42	41	42	40
Median	42.00	40.00	41.00	40.00	42	40
SD	4.78	7.87	5.96	6.43	5.4	7.1

The maximum angle C measured was, AP 0^0 was 58^0 and 15^0 IR was 62^0 ;Minimum angle C measured was, AP 0^0 was 31^0 and 15^0 IR was 29^0;The average was, AP 0^0 was 41.075^0 and 15^0 IR was 40.6^0

DISCUSSION

There is an increase in the incidence of fractures of the distal tibia, 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). 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 including medial 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 were amongst the first to use MIPO technique for distal tibial fractures. Hazarika *et al*, 2006 treated 20 patients who had open and closed distal tibial fractures with minimally invasive locking plate osteosynthesis. Borens *et al*, 2006 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 angles drawn on the volunteers where nearly similar however, the little variation present is due to placement of the cadaveric tibia on the radiographic cassette in both AP view and 15 degree internal rotation view. Hence we recommend Average Angle A – 18.1 degree, Average Angle B – 27.7degree, Average Angle C – 41.2 degree for pre-contouring of low profile plates.

Limitation Of The Study

While the various bends of the medial surface of medial malleolus have been meticulously recorded and analyzed the rotational bend of the antero-medial surface of the distal tibia towards the medial surface of the medial malleolus has not been observed and analyzed. We have also not analyzed the level of the broadest width of the medial malleolus. These features are the focus of our continued study on cadaveric tibia and will be reported in future.

CONCLUSION

The study has analyzed the parameters on which pre-bent plates for fixation of pilon fractures are to be designed with standardized parameters, especially for the Indian population. It is hoped that better anatomical plates will be designed to improve the techniques of application and thereby minimize complication rates in these difficult fractures. We recommend that if precontoured plates are not available, our parameters may be used for pre-contouring of low profile plates. Final contouring per-operatively will then be easier and faster.

Acknowledgement

The authors wish to thank the entire technical team institution for their support and assistance with this research.

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How to cite this article:
Raza HKT *et al*., Anthropometry Of The Medial Malleolus. *International Journal of Recent Scientific Research Vol. 6, Issue, 6, pp.4869-4873, June, 2015*

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