Ideal Medial Malleolar Screw Length Based on the Tibial Epiphyseal Scar Location in Weight Bearing CT's

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STATEMENT OF PURPOSE

Medial malleolar fractures are one of the most common fracture types observed in the ankle joint and have been long fixated with two screws; however, the bone density of the distal tibia has potential for poor screw purchase due to compromised bone density. This is especially true in elderly populations with osteoporotic bone. The goal of this study is to define a zone of increased bone density in the distal tibia (as detailed in Figure 1) to define optimal screw length in medial malleolar fractures.

LITERATURE REVIEW

Current AO guidelines for medial malleolar fractures recommend two partially threaded cancellous screws across the fracture line (Figure 2). For the screws to cross the fracture line the threads must purchase the distal tibial metaphysis, which is an area of decreased bone density especially in elderly osteoporotic bone. In unstable bi-malleolar fractures the non-union rate for the medial malleolar fracture has been reported to be as high as 7%, and age is a main contributing factor (1). Screw fixation of fracture fragments and overall union rates are also complicated by the observed loss of trabeculae, declined cortical thickness, decreased density and content of the distal tibia in elderly patients (2). For these reasons it is important to define the highest quality bone in the distal tibia and employ its use in the elderly population. The epiphyseal scar of the distal tibia is the densest portion of distal metaphysis of the tibia, and it was suggested by Parker et al. for screw threads to purchase within this radio dense portion of bone in osteoporotic bone (3). It has been suggested that in patients 60 years or older shorter screws should be used to allow engagement in the epiphyseal scar (4). In 2010 it was determined through tomographic serial scans that the total bone mineral density of the tibia decays substantially proximal to the distal most 5% mark and does not regain its total bone mineral density until almost the halfway mark (5).

METHODOLOGY & PROCEDURE

This IRB approved retrospective review was performed on 97 weight bearing (WB) ankle CT scans in patients without history of ankle injury. WB coronal ankle CT scans were analyzed at the widest portion of the medial malleolus to measure the distance of the epiphyseal scar and distal – most 5% mark from the medial malleolus (Figures 3 & 4). The distal – most 5% mark was calculated with the use of Equation 1, which correlates tibial length to overall height based on gender (6). There were 44 patients over the age of sixty years which were analyzed separately to determine if there were any major differences in this vulnerable population, and statistical analysis performed to determine if any significant difference exists between this group and with patients under 60 years at $p < 0.05$ (Table 4). The optimal screw length for medial malleolar fractures was defined as the screw remaining distal to the 5% mark in the area of increased bone density with its threads purchasing the epiphyseal scar. Statistical analysis was performed to determine if any significant difference existed between male and female optimal screw length with $p < 0.05$ (Table 5).

Figure 1. Zone of Dense Bone in Medial Malleolar ORIF

The epiphyseal scar is located in the distal metaphysis of the tibia, and can oftentimes be easily visualized on X-ray and CT scan (red line). The distal – most 5% of the tibia (distal to the black line) contains dense bone with marked decrease in bone density proximal to this line (5). The area between the epiphyseal scar and distal – most 5% mark is highlighted in yellow. Ideal screw purchase would put the screw thread pattern beyond the fracture line while still purchasing the epiphyseal scar and the shaded zone of dense bone (4).

Figure 2. Optimal Medial Malleolar Screw Length

Current AO guidelines for bimalleolar fractures (a) recommend two partially threaded cancellous screws for medial malleolar fixation. Short screws may not get threads across the fracture (b) while long screws (c) have thread pattern in the area of poor bone density above the distal-most 5% line and may interfere with syndesmotic hardware. A number of variables exist like length of thread pattern and location of fracture line but there is likely an ideal screw length that would work for the majority of patients.

Figure 3. Measuring Epiphyseal Scar to Medial Malleolus

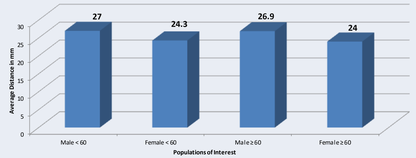
The distance from the medial malleolus to the epiphyseal scar was measured on the coronal WB CT section with the widest medial malleolus. Optimal screw length puts the threads beyond the fracture line with the thread pattern capturing the epiphyseal scar. Measurement AB therefore represents the orientation of a partially threaded screw and would be the maximum smooth shaft length.

Equation 1. Correlating Tibial Length and Patient Height[6]	
Male (cm)	Height = 71.361 + 2.575 (tibial length)
Female (cm)	Height = 65.344 + 2.691 (tibial length)

Figure 4. Measuring Distal – Most 5% to Medial Malleolus

The medial malleolus to distal – most 5% mark was measured on the coronal WB CT slice with the widest medial malleolus. Screw threads beyond this point will purchase less dense bone in the medullary canal with potential to not have purchase in the epiphyseal scar. Measurement CD was performed to mimic medial malleolar screw orientation used in medial malleolar ORIF. The distal – most 5% mark was calculated with the use of Equation 1 and is represented by the solid black line.

Graph 1. Distance of Epiphyseal Scar from Medial Malleolus



Graph 2. Distance of Distal – Most 5% from Medial Malleolus

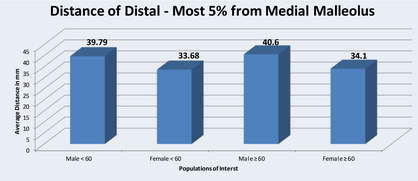


Table 1. Patient Characteristics	
Sample Size	97 patients
Time Frame	2017-Present
Average Age	52.7 (19-88)
# of Patients ≥ 60 years old	44
# of Patients < 60 years old	53
Male – Female	45-52

Table 2. Distance Between Epiphyseal Scar & Distal – Most 5% of Tibia		
Measurement of interest	Male: Mean ± SD (mm)	Female: Mean ± SD (mm)
Epiphyseal Scar to Medial Malleolus < 60	12.75 ± 2.91	9.39 ± 2.38
Epiphyseal Scar to Medial Malleolus ≥ 60	13.66 ± 2.98	11.12 ± 3.11

Table 3. Comparison of Distance Between Epiphyseal Scar & Distal – Most 5% of Tibia < 60 vs. ≥ 60 Years Old			
	T-Test	p - Value	p < .05
Males	1.71	.0945	Not Significant
Females	3.74	.000482	Statistically Significant

Table 4. Optimal Screw Length for Medial Malleolar Fractures		
	Male: Mean ± SD (mm)	Female: Mean ± SD (mm)
< 60 years old	40 ± 3.03	34 ± 2.49
≥ 60 years old	40 ± 3.69	34 ± 2.44

Table 5. Comparison of Optimal Screw Length Between Males & Females		
T-Test	p- Value	p < .05
16.584	<.00001	Statistically Significant

Table 6. Percentage of Cases Where Calculated "Optimal" Length Met Desired Criteria (threads in epiphyseal scar and within dense zone)		
	Male	Female
Proportion achieving ideal placement in tibia	37/45 (84%)	35/52 (69%)

RESULTS

- 97 WB ankle CT scans evaluated in uninjured ankles
- In males < 60 years old there was a 12.75 mm zone of increased bone density, as compared to 13.66 mm in those ≥ 60 which was not statistically significant.
- In females < 60 years old there was 9.39 mm zone of increased bone density, as compared to 11.12 mm in those ≥ 60 which was a statistically significant difference.
- Optimal partially threaded screw length for medial malleolar ORIF are on average 40 mm for males and 34 mm for females regardless of age.
- 84% of males and 69% of females achieved fixation in the zone of increased bone density with the above mentioned optimal screw length.
- A statistically significant difference in optimal screw length was noted between males and females.

ANALYSIS AND DISCUSSION

The present study defines a zone of increased bone quality in relation to the medial malleolus and an ideal screw length for medial malleolar fractures that takes full advantage of the superior distal bone density while still purchasing the radiodense epiphyseal scar. This study identified ideal screw length for medial malleolar fractures at 34 mm for all females and 40 mm for all males using partially threaded screw fixation. Given the data that 84% of males and 69% of females achieved appropriate fixation with the average ideal screw lengths it is the hope of this study that time in the operating room can be decreased . Limitations of this study include inability to account for variability of screw anatomy dimensions as well as the minute variability in medial malleolar fracture patterns that may be experienced in practice. Another shortcoming is that the basis of this study was based on CT measurements without clinical application yet established. Future research could determine the exact bone mineral density at smaller slices than the 5% slices that were used in Capozza et al. Further research will also need to be performed to test the clinical application of this data in cadaveric or live models.

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