Foot and Ankle Surgery 25 (2019) 323–326

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Characteristics of anterior inferior calcaneal cortex

T. Harnroongroj*, S. Jiamamornrat, T. Tharmviboonsri

Department of Orthopaedics and Rehabilitation, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

ARTICLE INFO

Article history:
Received 28 April 2017
Received in revised form 13 December 2017
Accepted 13 December 2017

Keywords:
Anterior inferior calcaneal cortex
Surface anatomy
Width
Length
Cortical thickness
Percutaneous screw fixation
Tongue type calcaneal fracture

ABSTRACT

Background: Minimal invasive surgery of calcaneal fracture provided satisfactory outcomes. In tongue type calcaneal fracture, percutaneous screw usually purchases in anterior inferior calcaneal cortex. However, there was no detail about the cortex of anterior inferior calcaneus so the surface anatomy and cortical thickness of this area were studied.

Methods: 88 calcaneus from embalmed cadavers were enrolled. Anterior part of the inferior cortex was identified. Surface anatomy was examined. Length, anterior and posterior widths were measured. Anterior inferior calcaneal cortex was divided into anterior, middle and posterior segments. The cortical thickness at middle, medial most and lateral most of 3 segments were measured.

Results: Anterior inferior calcaneal cortex was a long trapezoidal shape with well-defined borders as a dense and thick cortical bone, convex relief from medial and lateral walls. Mean(SD) length was 33.40 (3.46) millimeters (mm). Median(min,max) of anterior and posterior width were 10.50(8.21,19.26) mm and 14.00(10.05,20.42) mm, respectively. Mean(SD) of middle cortical thickness of anterior and middle segment were 3.12(0.76) and 3.72(0.74). Median(min,max) middle cortical thickness of posterior segment was 3.13(1.62,6.51) mm. Whereas, of the medial most were 1.31(0.78,3.11), 1.31(0.90,2.57) and 1.26(0.85,2.61) mm and of the lateral most were 1.17(0.67,2.64), 1.38(0.80,2.55) and 1.31(0.84,2.61) mm, respectively. Inter-intraobserver reliabilities of the measurements were >0.79. The statistical analysis showed the middle cortex is significantly the thickest ($P < 0.001$) and posterior width is significant wider than the anterior ($P < 0.001$).

Conclusions: Anterior inferior calcaneal cortex has special characteristics in term of surface anatomy, width and thickness. For the percutaneous screw insertion from posterosuperior to anterior inferior calcaneus in tongue type calcaneal fracture, we recommend that screw should purchase in middle cortex due to maximal cortical thickness as well as its cortical width could accept 6.5 or 7.0 mm screw without screw extrusion.

1. Introduction

The current trend of the surgical treatment of the calcaneal fractures has become toward the minimal invasive surgery. Earlier reports [1–5] revealed the benefit of minimal invasive surgery included less wound complications with comparable quality of reduction to the conventional open reduction and internal fixation technique, via lateral extensile exposure. Various surgical techniques of minimal invasive surgery were reported with satisfactory results [1–5]. The favorable minimal invasive surgery of the calcaneal fractures was mini open approach to reduce and fix the posterior facet fragment via “sinus tarsi approach” combined with percutaneous screw fixation of calcaneal body.

There are various screw insertion techniques for fixation of calcaneus. In calcaneal osteotomies and subtalar arthrodesis, screw is usually introduced from posterior inferior calcaneal tuberosity as an entry point [6–8]. In minimal invasive percutaneous screw fixation of calcaneal fracture, there are many screw trajectory methods depended on fracture configurations [9]. However, for tongue type calcaneal fracture, one of the common method is the screw trajectory from posterosuperior calcaneus purchasing in anterior inferior calcaneal cortex or the cancellous part of anterior calcaneus [10–14].

Previous biomechanics studies described a role of cancellous bone in generation of screw holding power, emphasized that there was a better strength of fixation if the end of the screw was in the cortical bone than in the cancellous bone [15,16]. So, in the percutaneous screw fixation of tongue type calcaneal fracture, the screw ended in the cortex of anterior inferior calcaneus could give

* Corresponding author at: Department of Orthopaedics and Rehabilitation, Faculty of Medicine, Siriraj Hospital, Mahidol University, 2 Prannok Street, Bangkoknoi, Bangkok 10700, Thailand.
E-mail addresses: ultradeutsch@gmail.com, tmthr@mahidol.ac.th (T. Harnroongroj).

https://doi.org/10.1016/j.fas.2017.12.009
1268-7731/

better screw holding power and better stability of the fracture fixation than ended in the cancellous part of anterior calcaneus. Up to the current knowledge, there was no study about cortical characteristics of the anterior part of inferior calcaneus. This knowledge might had benefit for the application for improving efficacy of the percutaneous screw fixation of tongue type calcaneal fracture.

Our objective is to study the characteristics of the anterior inferior calcaneal cortex included surface anatomy and cortical thickness.

2. Patients and methods

The study was approved by the Institutional Review Board. We obtained 88 feet from 44 embalmed cadavers, consisted of 26 males and 18 females, which were allocated from department of anatomy of our institute. The mean age was 52 (37–75) years old. We excluded the cadavers with the deformity or any pathologic bony lesion of the calcaneus.

Each cadavers were prepared in the same manners. All soft tissues around the calcaneus were removed. The boundaries of anterior inferior calcaneal cortex were identified in term of anterior and posterior ends included medial and lateral borders. Anterior end was identified as a line of calcaneal capsular attachment to the calcaneocuboid joint. Posterior end was identified as an ending point of cortex of anterior inferior calcaneus which directly attached to the inferior aspect of the calcaneal tuberosity. Medial and lateral borders were identified as a meeting point of medial and lateral aspects of cortex of anterior inferior calcaneus with the medial and lateral calcaneal walls.

Surface anatomy of the cortex of anterior part of inferior calcaneus was studied. The measurements of all variables were done using digital vernia caliper. Length was measured as a maximum distance between the anterior and posterior ends (OP) (Fig. 1). Anterior and posterior width were measured at the anterior and posterior ends, as distances between medial and lateral borders, perpendicular to the length of anterior inferior calcaneal cortex, respectively (AB and CD) (Fig. 1). Length of anterior inferior calcaneal cortex was divided equally into anterior, middle and posterior segments at X and Y. Then, transverse osteotomies were done at the middle of each segments (Dotted lines) (Fig. 1). On cut surface of each segment, medial and lateral most aspects of anterior inferior calcaneal cortex were identified as meeting points of medial and lateral ends with medial and lateral calcaneal walls, as R and M, respectively. The middle of anterior inferior calcaneal cortex was identified as mid-distance between R and M, as K (Fig. 2). The cortical thickness was measured as a distance from K, perpendicular to outer cortical surface to the inner cortex at L, as KL. In the same manner, cortical thickness at medial most and lateral most aspects of anterior inferior calcaneus were measured as RS and MN, respectively (Fig. 2).

Each measurements were performed by 2 foot and ankle surgeons at 2-week interval for inter- and intra observer reliability assessment. A “Kolmogorov–Smirnov Test” was used to test the normality of the distribution of each variables. The data was reported as mean and standard deviation (SD) for normal distributed data and median, minimum and maximum (min, max) for non-normal distributed data. The reliability of the measurements were assessed with intra-class correlation coefficients. The data was statistically analyzed by Kruskall–Wallis Test and Mann–Whitney U Test and considered significant difference with $P < 0.05$.

3. Results

Surface anatomy of the anterior inferior calcaneal cortex was a dense, thick, convex relief and arranged itself as a long trapezoidal shape and well-defined borders along the long axis of calcaneus (Fig. 3).

The data showed non-normal distribution of most variables. Whereas, length and middle thickness of the anterior and middle segments showed normal distribution. Mean(SD) length of anterior inferior calcaneal cortex was 33.40(3.46) millimeters (mm). Median(min,max) anterior and posterior widths were 10.50 (8.21,19.26) and 14.00(10.05,20.42) mm, respectively (Table 1). Mean(SD) middle cortical thickness of anterior and middle segments were 3.12(0.76) and 3.72(0.74). Median(min,max) middle cortical thickness of posterior segment was 3.13 (1.62,6.51) mm. Whereas, of medial most were 1.31(0.78,3.11), 1.31(0.90,2.57) and 1.26(0.85,2.61) mm and of lateral most were

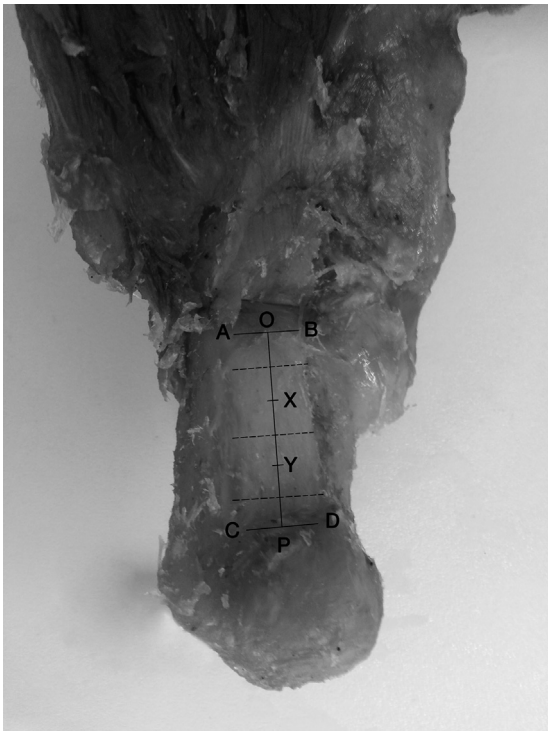

Fig. 1. The boundary of anterior inferior calcaneal cortex. OP, AB and CD represented length, anterior and posterior widths respectively. OX, XY and YP were anterior, middle and posterior segments, respectively. Dotted line was an area of performing transverse osteotomy.

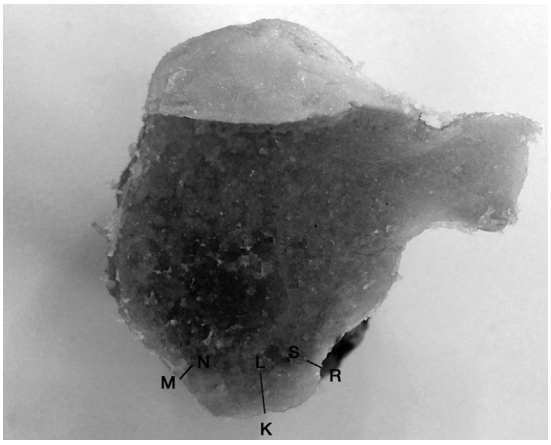

Fig. 2. Cut surface of middle segment of anterior inferior calcaneal cortex showed the cortical thickness at the middle, medial most and lateral most aspects as KL, RS and MN, respectively.

Fig. 3. Surface anatomy of anterior inferior calcaneal cortex showed a long trapezoidal shape with a dense bone and convex relief from medial and lateral walls.

1.17(0.67,2.64), 1.38(0.80,2.55) and 1.31(0.84,2.61) mm, respectively (Table 2).

The inter-intraobserver reliabilities were more than 0.79 (Tables 1 and 2). The statistical analysis demonstrated that the middle cortex of anterior inferior calcaneal cortex was the thickest compared to medial most and lateral most aspects ($P < 0.001$). Among the 3 segments, middle cortex of the middle segment was the thickest ($P < 0.001$). Additionally, posterior width was significant wider than the anterior ($P < 0.001$).

4. Discussion

The results of our study demonstrated that the cortex of anterior part of inferior calcaneus was a well-defined border structure and had a dense, thick, convex relief. On the cross section of the osteotomy showed that the cortex at the middle of anterior part of inferior calcaneus was the thickest compared with even, medial most or lateral most aspects. Among 3 segments, cortex of the middle segment was the thickest. As well as, the study revealed that the posterior width of anterior inferior calcaneal cortex was significantly wider than the anterior.

The current trend of the surgical treatment for the calcaneal fracture is in favor of "minimal invasive surgery" in order to reduce the complication correlating to the wound problems such as infection or dehiscence. Earlier studies [1–5] showed the comparable results of minimal invasive surgery to the conventional open reduction and internal fixation. The components of minimal invasive surgery were composed of first, posterior calcaneal facet reduction and fixation via sinus tarsi or it's modified approaches and fixation with screw or the mini-calcaneal locking plate. The second component was a reduction of calcaneal body fracture to restore the calcaneal height, Bohler's and Gissane's angle via percutaneous reduction and screw fixation. In tongue type calcaneal fracture, one of the common method for percutaneous screw fixation is the screw trajectory from posterosuperior calcaneus as an entry point purchasing the anterior inferior calcaneal cortex [10–14]. In order to provide the best strength of screw holding power and stability of the fixation, the end of the screw purchased in the cortical bone was better than the cancellous [15,16]. Correlating to our study, we suggested that the percutaneous screw should be aimed and ended in the middle of cortex of anterior part of inferior calcaneus, especially at the middle segment. Because this area had the thickest cortex among medial most and lateral most aspects, as well as, the middle cortex of anterior or posterior segments. Consideration on the average 11 mm width of the cortex of anterior part of inferior calcaneus, we could safely use large diameter screws, as 6.5 or 7.0 mm screw without the concern of the problem of implant extrusion out of the cortex.

This research provided a new knowledge about surface anatomy and cortical characteristics of anterior inferior calcaneus in term of shape, length, width and cortical thickness which have not been studied before. The benefit of this knowledge could be applied to the screw fixation of tongue type calcaneal fracture in order to improve stability of the fixation. Moreover, the knowledge about the width of the anterior part of inferior calcaneal cortex reflected that the large diameter screw, as 6.5 or 7.0 mm could be accepted to purchase without implant extrusion off the cortex of the anterior part of inferior calcaneus.

Table 1
Anterior and posterior width including length of anterior inferior calcaneal cortex (mm).

Variables	Mean(SD) 95%CI Median(min,max) (n = 88)	Interobserver reliability (n = 88)	Intraobserver reliability (n = 88)
Width			
Anterior	10.98(1.90) 10.58–11.38 10.50(8.21,19.26)	0.80	0.87
Posterior	14.03(1.84) 13.64–14.42 14.00(10.05,20.42)	0.76	0.81
P-value	<0.001		
Length	33.40(3.46) 32.67–34.13 33.13(27.12,46.92)	0.79	0.89

Table 2
Thickness at middle, medial most and lateral most of anterior, middle and posterior segment of anterior inferior calcaneal cortex.

Segment	Cortical thickness (mm) Mean(SD) 95% CI Median(min,max) (n = 88)			P-value	Inter-intraobserver reliability (n = 88)		
	Middle	Medial most	Lateral most		Middle	Medial most	Lateral most
Anterior	3.12(0.76) 2.96–3.28 3.01(1.87,5.47)	1.47(0.48) 1.37–1.57 1.31(0.78–3.11)	1.28(0.38) 1.20–1.36 1.17(0.67–2.64)	<0.001	0.81, 0.88	0.83, 0.88	0.84, 0.90
Middle	3.72(0.74) 3.57–3.88 3.77(1.44–5.55)	1.41(0.39) 1.33–1.49 1.31(0.90–2.57)	1.48(0.40) 1.40–1.57 1.38(0.80–2.55)	<0.001	0.85, 0.90	0.80, 0.88	0.88, 0.89
Posterior	3.27(0.85) 3.09–3.45 3.13(1.62,6.51)	1.40(0.41) 1.31–1.48 1.26(0.85,2.61)	1.44(0.42) 1.35–1.52 1.31(0.84–2.61)	<0.001	0.78, 0.85	0.76, 0.80	0.82, 0.85
P-value	<0.001	0.504	<0.001				

The limitations of our study were firstly, the age of specimens that we used in the study were rather old. They might not wholely represent the cortical characteristics of the anterior inferior calcaneus in younger patients which were the common age for the calcaneal fracture. Second, in the real clinical setting, sometimes, the fracture line entered the cortex of the inferior calcaneus so the consideration of using proper screw diameter for fixation could be differ to this cadaveric study which had no fracture extended to this area. And third, our study did not include the posterior cortical part of inferior calcaneal tuberosity. This area had clinical importance as it was a common entry point of the screw fixation in calcaneal osteotomy or subtalar arthrodesis. It was also a common location of screw purchasing in the fixation of posterior calcaneal tuberosity avulsion fracture. Further anatomical study in this area is recommended as this knowledge could provide additional clinical benefit to our study.

5. Conclusions

Anterior inferior calcaneal cortex has special characteristics in term of surface anatomy, length, width and thickness. As the results of study, we suggest that screw fixation for tongue type calcaneal fracture to the anterior inferior calcaneal cortex should purchase in the middle cortex in order to achieve maximal cortical thickness of screw purchase. Moreover, the cortical width of anterior inferior calcaneus could accepted 6.5 or 7.0 mm screw without extrusion out of the cortex.

Conflict of interest

The authors declare that there is no potential conflict of interest in this study.

Acknowledgements

The authors thank the Department of Anatomy of our institute and the donors of the cadavers included their families, who gave us the opportunity to accomplish our research.

References

[1] Pillai A, Basappa P, Ehrendorfer S. Modified Essex Lopresti/Westheus reduction for displaced intra-articular fractures of the calcaneus. Acta Orthop Belg 2007;73:83–7.
[2] Schepers T. The sinus tarsi approach in displaced intra-articular calcaneal fractures: a systematic review. Int Orthop 2010;35:697–703.
[3] Abusenna AS. Closed reduction and Kirschner wires fixation for the treatment of calcaneal fractures. AAMJ 2011;9(3):227–42.
[4] Tomesen T, Biert J, FrÖlke JPM. Treatment of displaced intra-articular calcaneal fractures with closed reduction and percutaneous screw fixation. J Bone Joint Surg Am 2011;93:920–8.
[5] Abdelgaid SM. Closed reduction and percutaneous cannulated screws fixation of displaced intra-articular calcaneal fractures. Foot Ankle Surg 2012;18:164–79.
[6] Kheir E, Borse V, Sharpe J, Lavalette D, Farndon M. Medial displacement calcaneal osteotomy using minimally invasive technique. Foot Ankle Int 2015;36(3):248–52.
[7] Hungerer S, Eberle S, Lochner S, Maier M, Hogel F, Penzkofer R, Augat P. Biomechanical evaluation of subtalar fusion: the influence of screw configuration and placement. J Foot Ankle Surg 2013;52:177–83.
[8] Matsumoto T, Glisson RR, Reidl M, Easley ME. Compressive force with 2-screw and 3-screw subtalar joint arthrodesis with headless compression screws. Foot Ankle Int 2016;37(12):1357–63.
[9] Weber M, Lehmann O, Sagesser D, Krause F. Limited open reduction and internal fixation of displaced intra-articular fractures of the calcaneum. J Bone Joint Surg Br 2008;90-B:1608–16.
[10] Mauffrey C, Bailey JR, Hak DJ, Hammerberg ME. Percutaneous reduction and fixation of an intra-articular calcaneal fracture using an inflatable bone tamp: description of a novel and safe technique. Patient Saf Surg 2012;6(6):1–5.
[11] Devendrappa H, Santosh, Kumar P. Management of tongue shaped intra-articular calcaneal fracture with Essex Lopresti technique. Indian J Orthop Surg 2016;2(1):115–8.
[12] Sangeorzan BJ, Benirschke S, Mills W. Technique of minimally invasive reduction and small fragment fixation of tongue-type calcaneal fractures. Oper Tech Orthop 2004;14(1):36–40.
[13] Kan YY, Fong HY. Percutaneous fixation of displaced calcaneal fracture. J Orthop Trauma Rehabil 2011;15:5–9.
[14] Dalal BY, Suthar RK, Tank PY, Rathod B, Damor H. Functional outcome of intra-articular tongue type of calcaneal fractures treated with percutaneous technique. Int J Res Orthop 2013;2(4):371–6.
[15] Harnroongroj T, Techataweewan A. Determination of the role of the cancellous bone in generation of screw holding power at metaphysis. Clin Biomech 1999;14:364–6.
[16] Neto RB, Rossi JDMBA, Leivar TP. Experimental determination of bone cortex holding power of orthopedic screw. Rev Hosp Clin Fac Med Sao Paulo 1999;54(6):181–6.