

**MORPHOLOGIC STUDY OF THE ARTICULAR SURFACE OF
SUBTALAR JOINT IN THAIS: RELATION TO ARCH OF FOOT**

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Thesis
entitled

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MORPHOLOGIC STUDY OF THE ARTICULAR SURFACE OF SUBTALAR JOINT IN THAIS: RELATION TO ARCH OF FOOT

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ABSTRACT

The present study aims to investigate the variation of the talar articular facet pattern of subtalar joint in relation to the articular area as well as to the height of the medial longitudinal arch (MLA) in Thais. Three hundred and forty pairs of feet from 170 Thais cadavers (96 from males and 73 females, with average age of 68 years) were used. The soft tissue was dissected out to leave only the binding ligaments, the talus was then removed to expose the articular surfaces, the talar articular facets and medial aspect of 146 complete feet were photographed. The pattern of talar articular surface was classified. The arch height was described by normalized navicular height (NNH, navicular height and arch length ratio) and measurement of the articular area was done via Image tool program. The result showed that the variations of talar articular facets were classified into 7 types according to the number and configuration of the facets. The mostly found was type 5 (fused anterior and middle facets with a cylindrical shape). The non-fused facet showed significant greater NNH ($p < 0.01$) than fused facet. The arch group can be allotted into low, normal and high arch by using the first and third quartile of NNH as 0.178-0.237 was normal. The low arch group showed significant lesser area of articular facet than high arch group.

In conclusion, the results suggested that the talar articular facet pattern of subtalar joint are varied and also related to the height of the arch of the foot. The information of this thesis, therefore, provides fundamental knowledge for further study of biomechanics of foot and will be benefit for early detection of foot injury and its etiology in Thais.

KEY WORDS: SUBTALAR/ ARCH OF FOOT/ NORMALIZE NAVICULAR
HEIGHT

51 pages

ศึกษาสัณฐานของผิวข้อต่อข้อเท้าในคนไทยสัมพันธ์กับ โคน้ำเท้า

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษารูปแบบของผิวข้อต่อกระดูกด้านล่างของกระดูกของข้อต่อข้อเท้าในคนไทย และความสัมพันธ์ระหว่างความสูงของโคน้ำเท้าด้านใน ซึ่ง ศึกษาจากกระดูกเท้าของคนไทยจำนวน 340 ชิ้น จากอาจารย์ใหญ่ 170 ร่าง (ชาย 96 คู่และหญิง 73 คู่ มีอายุเฉลี่ย 68 ปี) เนื้อเยื่อโดยรอบจะถูกชำแหละออกให้เหลือแต่เอ็นที่ยึดกระดูก และกระดูกทาลัสจะถูกชำแหละออกเพื่อเปิดให้เห็นผิวข้อต่อกระดูกด้านล่างของกระดูกของข้อต่อข้อเท้าโดยกระดูกเท้าที่สมบูรณ์จำนวน 146 ชิ้น จะถูกนำมาถ่ายรูปบริเวณผิวข้อต่อกระดูกสันเท้าด้านบนทั้งหมด และ โคน้ำเท้าด้านในจากนั้นทำการจำแนกประเภทของผิวข้อต่อโดยการสังเกต แล้ววัดพื้นที่ผิวข้อต่อและความสูงของกระดูกนาคิวลาร์กับความยาวของโคน้ำเท้า ด้วยโปรแกรมคอมพิวเตอร์ จากนั้นนำมาคำนวณอัตราส่วนระหว่าง ความสูงของกระดูกนาคิวลาร์กับความยาวของโคน้ำเท้า เพื่อบ่งบอกถึงความสูงของโคน้ำเท้า ผลการศึกษาพบว่าสามารถแบ่งรูปแบบของผิวข้อต่อกระดูกสันเท้าด้านบนออกได้เป็น 7 แบบ โดยใช้จำนวนด้านและรูปร่างของผิวข้อต่อ โดยพบแบบที่ 5 มากที่สุด (แบบที่มีผิวข้อต่อด้านหน้าและด้านกลางกลางเชื่อมติดกันเป็นรูปทรงกระบอก) และพบว่าความสูงของโคน้ำเท้าในกลุ่มที่มีผิวข้อต่อด้านหน้าและตรงกลางแยกออกจากกันมีความสูงของโคน้ำเท้ามากกว่ากลุ่มที่เชื่อมติดกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.01$) ความสูงของโคน้ำเท้าสามารถแบ่งออกเป็น 3 กลุ่มคือ ต่ำ, ปกติ และสูง แบ่งจากค่าควอไทล์ที่ 1 และ 3 ของอัตราส่วนระหว่าง ความสูงของกระดูกนาคิวลาร์กับความยาวของโคน้ำเท้า จะมีค่าความสูงของโคน้ำเท้าปกติอยู่ในช่วง 0.178-0.237 ซึ่งพบว่าในกลุ่มที่มีโคน้ำเท้าต่ำ จะมีพื้นที่ผิวของข้อต่อน้อยกว่ากลุ่มที่มีความสูงของโคน้ำเท้าสูง

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LIST OF ABBREVIATIONS

%	Percent
cm ²	Square centimeter
NNH	Normalize navicular height
AL	Arch length
NH	Navicular height
SD	Standard deviation
<i>p</i> -value	Probability of obtaining a result at least as “Impressive” as that obtained
ICC	Intra-class Correlation Coefficient

CHAPTER I

INTRODUCTION

Subtalar joint is an important joint of the lower extremity which plays a role in distributing forces from the leg to the foot.¹ In standard anatomy textbook, the subtalar joint consists of calcaneal articular facets of talus and talar articular facets of calcaneus.² For orthopedic definition and the other study, the subtalar joint includes the talocalcaneal part of the talocalcaneonavicular joint since it plays a crucial part in inversion and eversion. This work defines the subtalar joint as mentioned in orthopedic definition while other study may use differently due to one's advantage. The subtalar joint is divided into two parts: the first is anterior subtalar joint that is an articulation between inferior surfaces of the head and neck of talus and anterior and middle facets of calcaneus which is joined by plantar calcaneonavicular ligament. The second, posterior is an articulation between inferior surface of body of talus and posterior facet of calcaneus. The two articulations are separated by the sinus tarsi and tarsal canal.³

Foot arch is the prime structure to transfer body weight to ground and to absorb ground force from outside world while standing or walking. In order to provide proper function, the foot needs to have an appropriate arch form and height. The arch of foot acts as shock absorber and contributes to the adjustability of the foot on different terrain. It is supported by the arrangement of the tarsal bones and surrounding soft tissues such as ligament, fascia and muscles. Clinical practice guideline from American college of foot and ankle surgeon commented that poor biomechanical alignment, ligament sprains, direct force trauma and muscle strain can cause arch pain which commonly found in flatfoot while high arch is less common.⁴ However, clinical finding also described the high arch as deformity which caused malfunction of the foot as well as neurological sign. Foot with abnormal arch height is unable to absorb the shock of heel strike during gait cycle and increase abnormal stress to the soft tissue of foot and lower leg.⁵ The variation of arch height can also effect the

structures of subtalar joint particularly the configuration of articular surface, since there has been several reported on various types talar and articular surfaces.

Previous studies on talar articular surface have been classified into several types according to the number of articular facet. Bunning⁶ divided the talar articular surface into three types; group A have 3 articular facets, group B have 2 articular facets and group C has 1 articular facet.

Shiraishi⁷ studied the differences in anterior and middle articular facets on calcaneus and divided into 6 types. type 1 is a double ellipsoid and anterior articular facet is smaller than middle articular facets, type 2 is fused like a Gourd-form with smaller anterior articular facet, type 3 is a double ellipsoid but anterior and middle articular facets are partially in contact, type 4 is a double ellipsoid clearly separated and anterior and middle articular facets have similar sized, type 5 is fused as cylinder-form and type 6 was an others form such as has only anterior or middle articular facet.

Jan Bruckner reported the similarity of articular facet of calcaneus and measured area of the articular surface which showed that the joint with 3 articular facets has lesser articular surface area and probably diminished the joint mobility.⁸ This was supported by Drayer-Verhagegen that the non-fused facets found less arthritic change and gave more stability to the joint than the stretch or fused articular facet.⁹ Therefore, it presumably concludes that shape and number of the articular facet of the calcaneus can affect the stability of subtalar joint.

Concurrently, shape of the foot is maintained by arch of foot. The arch of foot is composed of tarsal and metatarsal bones which aligned in curved. It plays an essential role in absorbing and distributing forces from the body during standing and moving on different terrain. The arch of foot can be classified into two types: transverse arch and longitudinal arch. The latter is subdivided into medial and lateral longitudinal arches. Transverse arch is found in the mid segment of foot which each foot forms half of a dome. The dome is formed by the tarsal and metatarsal bones. The medial longitudinal arch is higher than the lateral. The posterior part of the calcaneus forms a common posterior pillar for both longitudinal arches. The lower lateral arch passes from the pillar through the anterior part of calcaneus, cuboid, and lateral two metatarsal bones whereby the cuboid is a keystone. The medial arch passes from the head of the talus that forms the keystone of the arch at its summit between the

sustentaculum tali and the navicular bone. The anterior pillar is continued through the navicular to the three cuneiforms and the medial three metatarsal bones.¹⁰

The medial longitudinal arch of foot is of great important for bipedal locomotion and also is highly variable in its structural character. Normally, foot can be classified into high, normal, and low arches. Foot type is associated with lower extremity problems.¹¹ People who have flat foot condition or reduction of medial longitudinal arch height is trend to produce pronation of subtalar joint. On the contrary, people with a high arch give the opposite result.⁸

Talus is the keystone of medial longitudinal arch. It articulates with posterior calcaneal facet as posterior subtalar joint and anteriorly with middle and anterior facets of the calcaneum as anterior subtalar joint. The talar articular surface of subtalar joint has been reported in various patterns^{6,7} and also related to the stability of the joint.⁹ However, there is scanty report on the relationship between arch height and the pattern of calcaneal articular facets. Thus, this study aims to examine the relationship of the articular facet types and the arch height of foot in Thais.

CHAPTER II

OBJECTIVES

The study is aimed to examine the subtalar joint of the Thais cadaver in various aspects:

1. To investigate the anatomy of subtalar joint and surrounding structures.
2. To examine the pattern of the talar articular facets of the subtalar joint.
3. To measure the subtalar articular area on the calcaneus.
4. To measure the height of medial longitudinal arch.
5. To study the relationship of talar articular facet pattern and the arch

height

CHAPTER III

LITERATURE REVIEW

3.1 Anatomy of subtalar joint

Subtalar joint is a plane synovial joint. Its articular surfaces consist of posterior calcaneal articular facet of talus articulates with posterior talar articular facet of calcaneus and inferior surface of talar head articulates with the anterior and middle facets of calcaneus. For orthopedic concern, the subtalar joint includes talocalcaneonavicular joint as a functional unit that moves simultaneously to produce inversion and eversion.

The subtalar joint is divided into two parts. The anterior talocalcaneal joint is an articulation between inferior surface of head of talus and anterior and middle concave facets of calcaneus. Posterior talocalcaneal joint is an articulation between inferior concave surface of body of talus and posterior convex facet of calcaneus. Both are separated by the sinus tarsi and tarsal canal.³

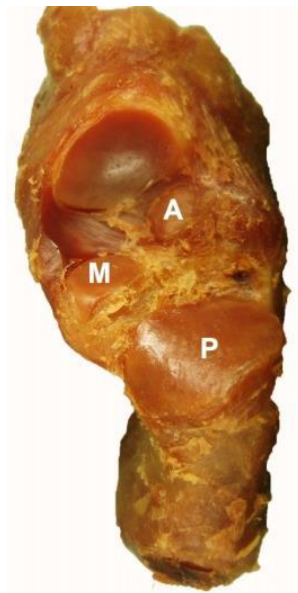


Figure 3.1: The articular facets of subtalar joint on the superior surface of calcaneous
A = anterior facet, M = middle facet and P = posterior facet.

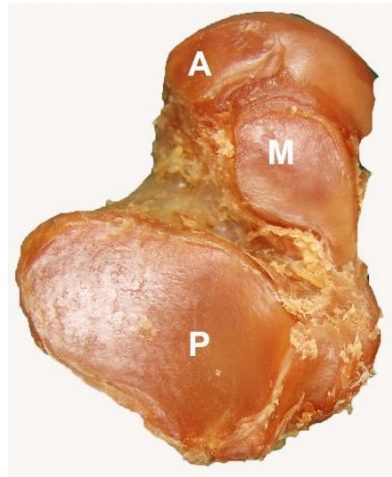


Figure 3.2: The articular facets of subtalar joint below the inferior surface of talus bone; A = anterior facet, M = middle facet and P = posterior facet.

The articular surfaces of subtalar joint are held together by various ligaments including; cervical ligament, lateral talocalcaneal ligament, medial talocalcaneal ligament, posterior talocalcaneal ligament and interosseous talocalcaneal ligament.^{2, 12} (Figure 3.3 and 3.4) Addition to these major ligamentous support, the surrounding soft tissue such as plantar fascia, intrinsic muscles of the foot and tendon of tibialis posterior.

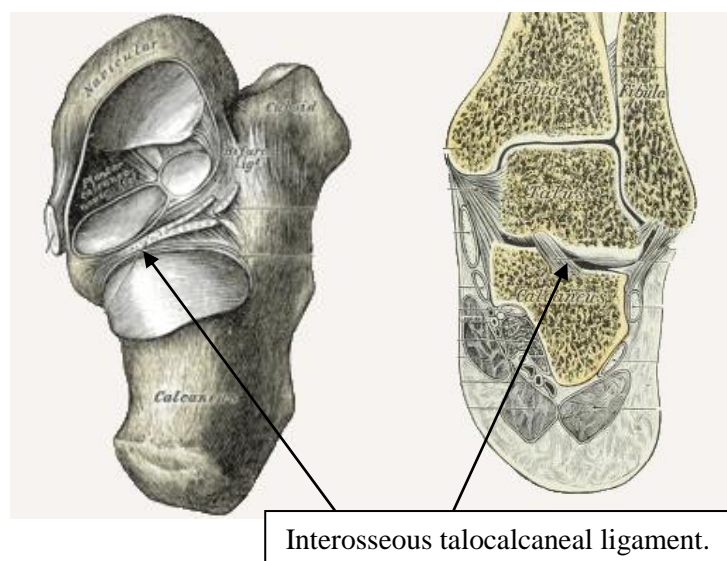


Figure 3.3: Interosseous talocalcaneal ligament.

(Adapted from: <http://archive.org/stream/anatomyofhumanbo1918gray#page/356>)

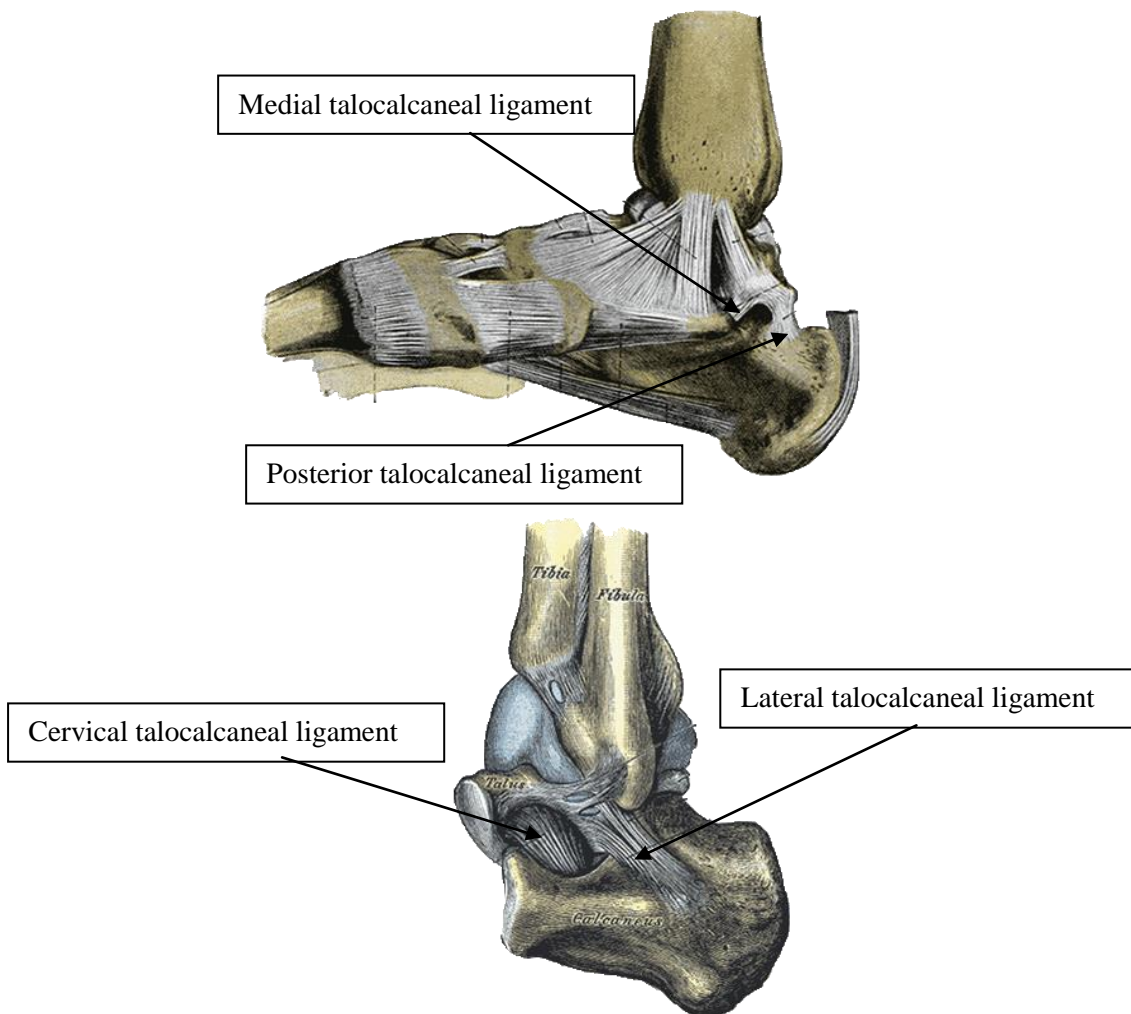


Figure 3.4: Medial talocalcaneal ligament, posterior talocalcaneal ligament, anterior talocalcaneal ligament and lateral talocalcaneal ligament.

(Adapted from: <http://archive.org/stream/anatomyofhumanbo1918gray#page/356>)

Blood supply of the subtalar joint is provided by the three major arteries: dorsalis pedis (branch from anterior tibial), posterior tibial and peroneal arteries. (Figure 3.5) The anterior part is supplied by the arteries of the sinus tarsi which supplemented by direct branches from the lateral tarsal of dorsalis pedis artery and the peroneal artery. The posterior part is supplied by calcaneal anastomotic arcade between the tibialis posterior artery and the peroneal artery and by the proneal artery proper.¹²

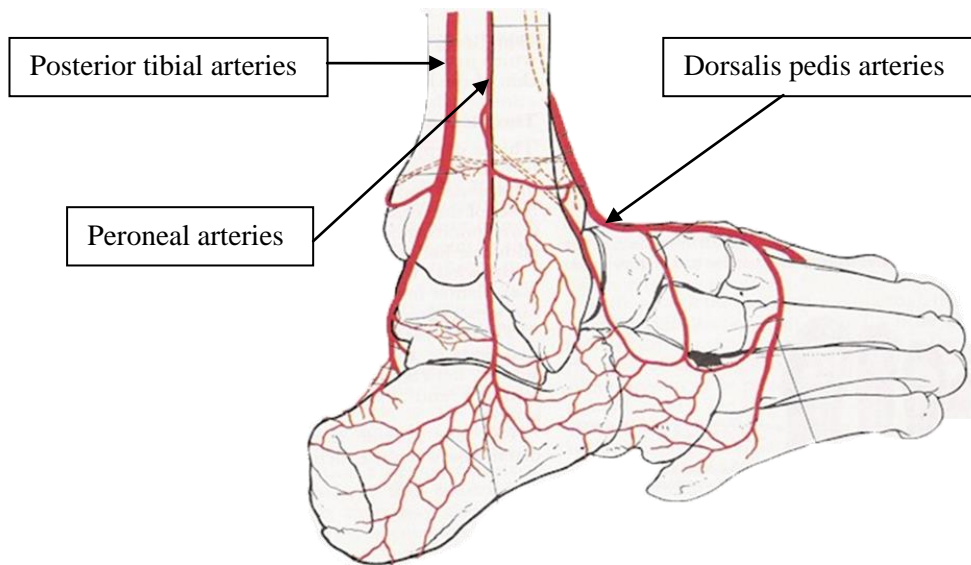


Figure 3.5: Three major arteries of subtalar joint.

(Adapted from: <http://www.myfootshop.com/article/arteries-of-the-ankle>)

The subtalar joint is innervated by the articular branches from the deep peroneal, posterior tibial and sural nerves.¹²(Figure 3.6)

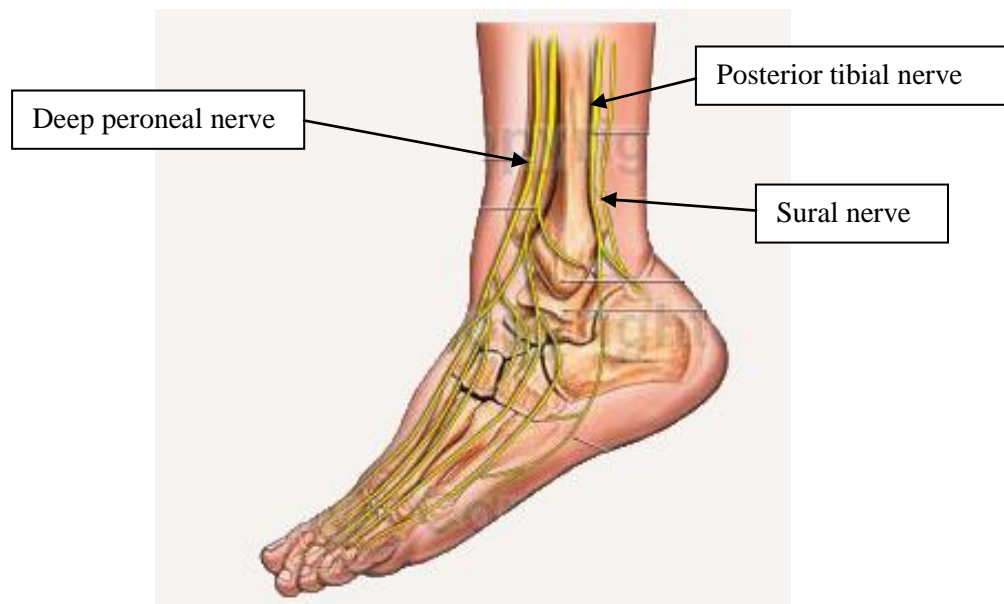


Figure 3.6: Nerve supply of subtalar joint. (Adapted from:

http://www.advocurenf2.org/livingwithnf2_ailments+care_dropfoot.php)

Movement of the subtalar joint is inversion and eversion. The movement occurs around an oblique axis which extends anteromedially from the neck of the talus to the posterolateral portion of the calcaneus.^{1,12}

3.2 Variation of articular facets of subtalar joint

Previous studies on calcaneal articular surface have been classified into several types according to the number of articular facet.

In 1965, Bunning⁶ divided the talar articular surface into three types; type A had three articular facet, type B had two articular facet and type C had one articular face. (Figure 3.7) They compared the talar articular facet between race and between ages. The result showed that the Europeans ethnic had type A more frequently than type B while the Indian and African ethnic were opposite and also the same in fetus bone.

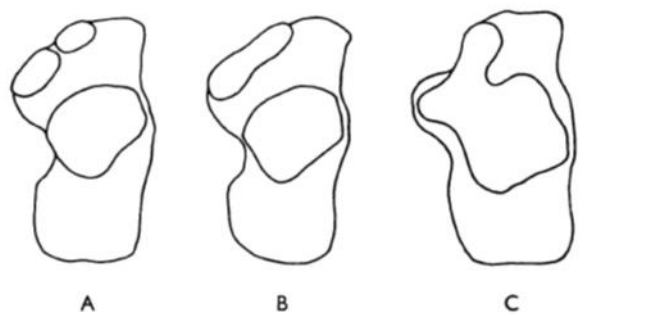


Figure 3.7: Variation of the calcaneal articular surface by Bunning PSC.et al.⁶

In 1977, Gupta¹³ studied in 401 calcaneus and classified into 4 types; type 1: the anterior and middle facets were continuous, type 2: three articular facets were separate, type 3: the anterior facet absent, type 4: the anterior, middle and posterior facets were continuous. In each type were found 67%, 26%, 5% and 2 %, respectively.

In 1987, Bruckner⁸ reported type of talar articular facet according to the number of facets as type A, B and C which were similar to Bunning⁶ study and final type D had 2 facets (anterior and posterior facets). They used only 32 dry adult

calcaneus and measured area of the articular surface as well as the angle of inclination to represent the arch of foot and joint mobility. The results showed that the joint with three articular facets had lesser articular surface area, high angle of inclination and diminished joint mobility.

In 1989, Campos¹⁴ studied in 176 human calcaneus in Spanish and classified as type A and C same as the previous study,^{6,8} furthermore they subdivided into subtype of the type A by using the distance between anterior and middle facets and subtype of the type B by the fusion configuration of anterior and middle facets. The results showed that type A had 46%, type B had 54% and absent in type C.

In 1993, Drayer-verhagen⁹ studied three types of anterior and middle talar articular facets; type 1 had fused facets, type 2 were separated facets and type 3 had only the medial facet. He studied in 191 calcaneus bones and found each type with 54.5%, 26.7% and 18.8 %, respectively. The study also reported the relationship between arthritis and type of the articular facet that the fused articular facet of calcaneal gave more arthritic lipping than the separated anterior and middle articular facets.

In 2003, Ragab¹⁵ and colleagues studied 1056 calcaneus bone in USA and divided into 5 types. Type 1,2 and 3 classification were similar to the studied of Bunning.⁶ Type 4 defined as between the anterior and middle facets showed a ridge or narrowing area while type 5 had no anterior facet. The distribution of each type was 36.9%, 45.54%, 0.19%, 11.58% and 5.79%, respectively. Moreover, they also reported type 1 facet was found mostly in the whites than the blacks.

In 2007, Shiraishi⁷ studied variation of anterior articular surface of subtalar joint and divided into 6 types. Type 1 anterior and middle articular facets dissociated as double ellipsoid with a smaller anterior articular facet, type 2 the two facets connected in a Gourd-form with smaller anterior facet, type 3 anterior and middle articular facets were separated as double ellipsoid which were touching each other, type 4 both facets were apparently to double ellipsoid with more or less equal sized, type 5 anterior and middle articular facets connected in cylinder-form and type 6 in another form such as having only anterior or middle articular facet. (Figure 3.8) They found the distribution of total 94 feet to each type as 8, 9, 8, 30, 34 and 5 feet, respectively.

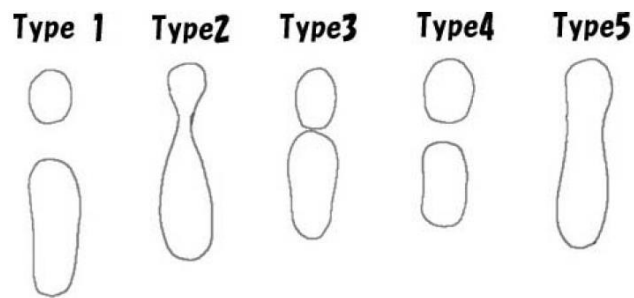


Figure 3.8: Classification of the anterior and medial talocalcaneal articular surface by Shiraishi et al. ⁷

In 2008, Madhavi¹⁶ studied 225 calcaneus in south Indian and classified into 5 types as following: type 1, the anterior and middle facets were fused; type 2, three facets were separated; type 3, absence of anterior facet; type 4, three facets were fused and type 5, absence of anterior facet with fused middle and posterior facets. There were 71.1%, 19.4%, 6.8%, 1.3% and 0.4 % of each type respectively. This study also reported the relationship between type of facets and arthritic changes that type 1 and 4 had more arthritic changes than other types.

In 2009, Uygur et al.¹⁷ studied 221 calcaneus of the Turkish and classified to 3 major types as type A- separated anterior and middle facets, type B- connected anterior and middle facets and type C-fusion of anterior, middle and posterior. They also subdivided type A into A1, A2 and A3 by the distance between the anterior and middle facet which was less than 2, 2-5 and more than 5 mm. and subtype A4 had only anterior facet. Subdivision of type B was B1 (between anterior and middle facets was constricted) and B2 (no constriction between both facets). The study of Uygur and associates¹⁷ showed frequency of type A was 39.3%, type B was 58.3% and type C was 2.2%. For subtypes A1, A2, A3, A4 were 4%, 13%, 17% and 1.9 % respectively. Subtypes B1 was 25.3% and B2 33%

In 2011, Muthukumaravel et al. ¹⁸ studied 237 dry calcaneus bone in the Indian and the classification of articular facet was similar to Madhavi's study.¹⁶ Each type was 65.83%, 33.33%, 0%, 0.42 and 0.42%, respectively.

Shahabpour et al.¹⁹ studied magnetic resonance imaging of subtalar joint in 49 subjects and classified as type A and C similar to previous studies^{6,8,14} by classifying into type A and B and further subdivided into A1: three facets were clearly separated, A2: anterior and middle facets were intimate and presented with a ridge between the facets. Subtype B1: anterior and middle facets were fused with constriction, B2: both facets completely fused and B3 was absent anterior facet. The type A1 was the highest frequency 36.7%.

In 2012, Seema et al.²⁰ studied 300 dry calcaneus bones in North Indian population. Types of calcaneus were classified as same as the study of Uygun¹⁷ and the results showed type B was the most common type (56%). Frequency of subtypes A (A1, A2, A3, A4) was 6%, 13%, 16% and 7 % respectively. Subtypes B (B1, B2) were 24%, 32% while type C was 2%.

Nagar and coworker²¹ studies 529 adult human calcaneus bones in Spanish and classified articular facets into 5 types as following; type A, B and C were defined the same as above studies.⁶ Furthermore, type D was an absent anterior facet and type E had continuous middle and posterior facets with absence of anterior facet. Each type was consisted of 118 (22.3%), 404 (76.37%), 0, 6 (1.14%) and 1 (0.19%) respectively.

Sharada et al.²² studies in 300 adult dry calcaneus bones in Indian and classified similar to the previous study.¹³ The percentage of each type was 67%, 28.6%, 3% and 1.3% respectively.

In 2013, Garg et al.²³ studies 310 adult dry calcaneus bones in Indian and classified the same as previous studies^{16, 18} and the distribution was 72.26%, 24.52%, 1.3%, 1.6% and 0.32% respectively.

Recently Kullar and associated²⁴ studied the variation of talar articular facets related to calcaneal spurs in Indian. They divided the talar articular facets into 4 types similar to the study of Gupta¹³ and the distribution presented as 72.5%, 25.5%, 1.5% and 0.5% respectively.

3.3 Arch of foot

An arch of foot is the anatomic formation of tarsal bones and metatarsal bones which bind in a curved or arch. It plays an important role in absorbing and distributing forces from the body during standing and moving on different terrain.^{2,12} The arch of foot consists of transverse arch, medial longitudinal arch and lateral longitudinal arch.^{1, 2, 12} Transverse arch situates in the mid segment of foot which forms a half dome of each foot. The dome is formed by the tarsal and metatarsal bones of both feet. The longitudinal arch is higher on the medial than the lateral side. (Figure 3.9) The posterior part of the calcaneus forms a common posterior pillar for both longitudinal arches. The lower lateral arch passes from the pillar through the anterior part of calcaneus, cuboid, and lateral two metatarsal bones. The medial arch is much higher and more important. Head of talus forms the keystone of the arch at its summit between the sustentaculum tali and the navicular bone. The anterior pillar continues through the navicular to three cuneiforms and the medial three metatarsal bones.¹⁰

Stability of the arch comes from ligament, muscle and shape of foot bones. In order to hold together the arch and to provide stability, the foot muscles need to contract as well as the ligaments. Furthermore, The shape of foot bone looks like a wedge shape it help bone articulate is stronger.^{2, 10}

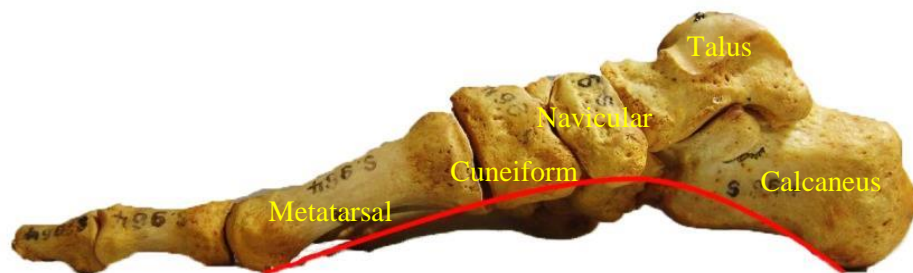


Figure 3.9 The Rt. medial arch of foot

3.4 Measurement of the medial longitudinal arch

Measurement of the medial longitudinal arch height can be done in several ways²⁵⁻²⁷ such as direct visualization by experienced observer, direct measurement of foot anthropometry and indirectly by using radiographic image.²⁸

Normalized navicular height (NNH) value is one of direct measurement using anthropometric method.²⁸ The normalized navicular height (NNH) is a ratio of navicular height (NH) relative to arch length (AL), where navicular height (NH) is the distance between the navicular tuberosity perpendicular to the floor and arch length (AL) is the distance between the posterior limit of calcaneus to anterior portion of head of first metatarsal bone.^{12, 28} The normalized navicular height (NNH) can be measured from the bony specimen or photograph. Study of Cobb SC. showed a photographic measurement was a valid and reliable for quantifying foot arch.²⁹

3.5 Foot type

Foot type is characterized by the height of foot arch, which can be divided into low, normal, and high arch.^{12, 27, 28} As mentioned above, there are several measurements to classify the arch height. Direct anthropometric measurement like arch index or normalized navicular height is the most favorable, reliable and valid method used recently.^{27,30-32} According to Murley, the breaking points of normalized navicular height (NNH) for low arch is less than 0.22, normal arch is 0.22-0.31 and high arch is greater than 0.31.³⁰

Foot type has relationship with injury of lower extremity and postural stability.^{11, 33-35} High arch found more incidence of lateral ankle injury and low arch reported a greater of medial knee injury.¹¹ Barton³⁵ present people with patellofemoral pain syndrome had more low arch.

CHAPTER IV

MATERIALS AND METHODS

4.1 Materials

4.1.1 Study designs

The present study is designed as descriptive study. This work was approved as exemption research by Siriraj Institutional Review Board (SIRB Protocol No.582/2556).

4.1.2 Cadaveric specimens

Three hundred and forty feet taken from one hundred and seventy Thai cadavers were used in this study. All cadavers were formalin embalmed that provided by the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University. There were 340 specimens which from 194 males and 146 females, the mean age of death was 68 years (range 36-102 years). Excluded criterion was pathologic changes on the subtalar articular surface.

4.1.3 Instrumentation

Dissection tools: Blade, forceps and probe.

Digital camera: All pictures were photographed by using the Sony DSC-F828 and camera stand board with lighting system.

4.1.4 Image analysis program

Arch height and area of articular surface of subtalar joint were analyzed by using CMEIAS© Advanced Image Analysis Software Custom Plug-ins operating in UTHSCSA ImageTool Ver. 1.27 is copyrighted by Michigan State University.

4.2 Methods and measurements

4.2.1 Specimens preparation

The specimens were obtained from the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University. One hundred and seventy Thai cadavers with known age, race, and gender were used. The demographic data were recorded and indicated as code number, personal data were covered.

The specimens were divided into 2 groups due to the mean and period of specimen collection. The first group was one hundred and forty-six feet taken from the dissection laboratory of the second year medical student in 2013 and were used for study the relation between the talar articular surfaces and arch of foot. The second group was one hundred and ninety-six feet were taken from the research laboratory during 2010-2012 used only for study the talar articular surfaces. Specimen preparation was done by removing all the skin, muscles and connective tissue and leaving only ligaments of foot. Later, medial aspect of the foot was photograph for further measurement.

Finally, the all talus bone has been removed to expose the subtalar articular surface on the calcaneus. Pattern of the articular surfaces were investigated, recorded and photographed.

4.2.2 Specimen Photography

4.2.2.1 Medial longitudinal arch

Medial longitudinal arch was photographed by placing the foot bone in anatomical position, with the medial side facing towards the digital camera. The camera was fixed on tripod and the lens was perpendicularly away from medial aspect of foot bone at between distances of 15 centimeter. (Figure 4.1 and 4.2)



Figure 4.1: The camera setting for taking photograph of medial longitudinal arch; front view.

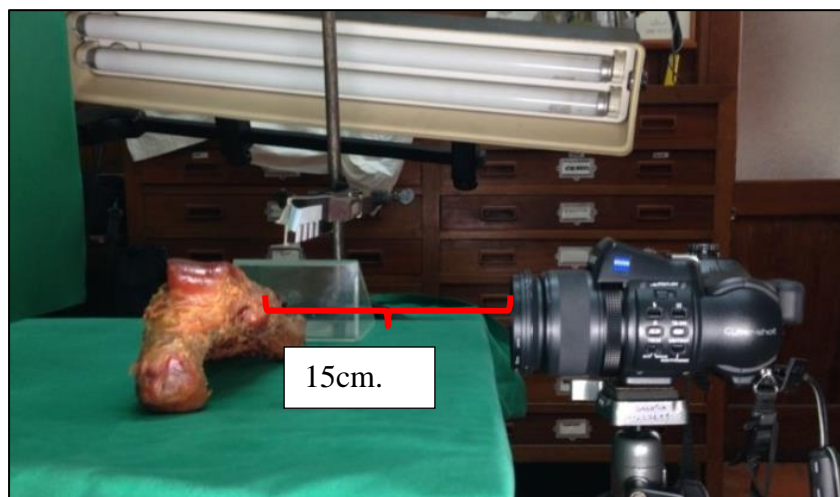


Figure 4.2: The camera setting for taking photograph of medial longitudinal arches; lateral view.

4.2.2.2 Articular surface

After the articular surfaces were scrutinizing and its pattern was classified and recorded, the photograph was taken for area estimation. The foot bone was placed in anatomical position with superior view faced towards the digital camera. The camera was set on standing board with constant perpendicular distance from foot bone 10 centimeter. (Figure 4.3)

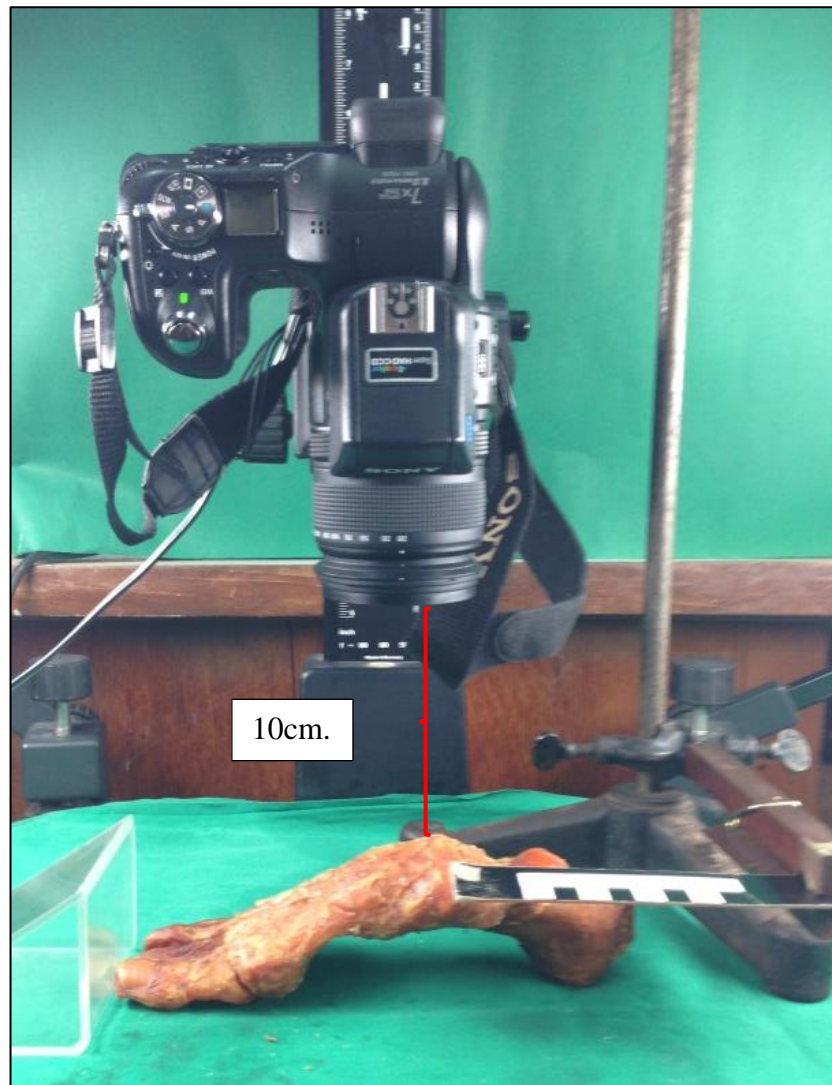


Figure 4.3: The camera setting for photography of articular surface.

4.2.3 Measurement

4.2.3.1 Medial arch height

This study chose the normalized navicular height¹³ to define the medial arch height of the foot. Then, the measurement was navicular height and arch length. (Figure 4.4) After importing the picture to the image tool program, the arch length was measure from the distance between the 1st tarsometatarsal joint to most posterior limit of the calcaneus and the navicular height was taken from the perpendicular distance from the navicular tubercle to the base line. Thus, medial arch height was estimated from ratio of navicular height (NH) and arch length (AL) as normalized navicular height (NNH). Intra-class correlation coefficient was used to analyses the repeatability and consistency of each measurement (appendix)

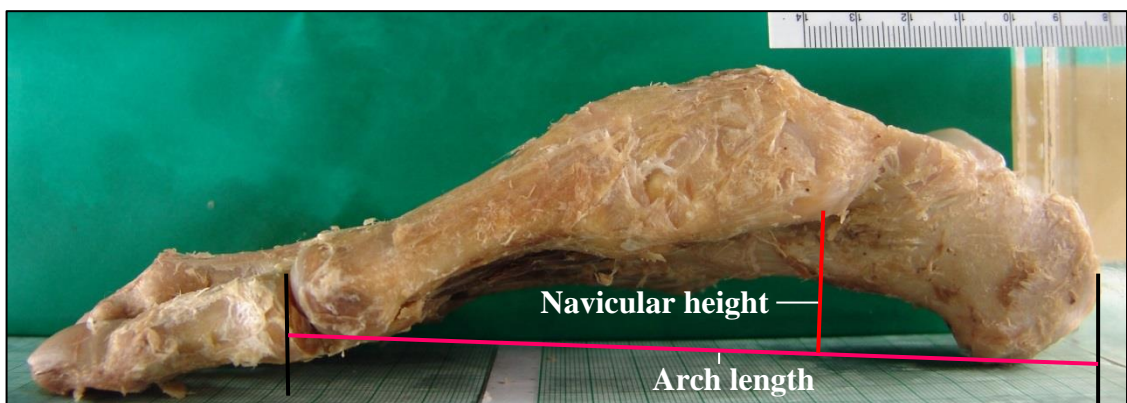


Figure 4.4: Normalized navicular height was taken from navicular height and arch length

4.2.3.2 Area of articular surface

Similarly, the area of articular surface was measured by using image tool program. (Figure 4.5)

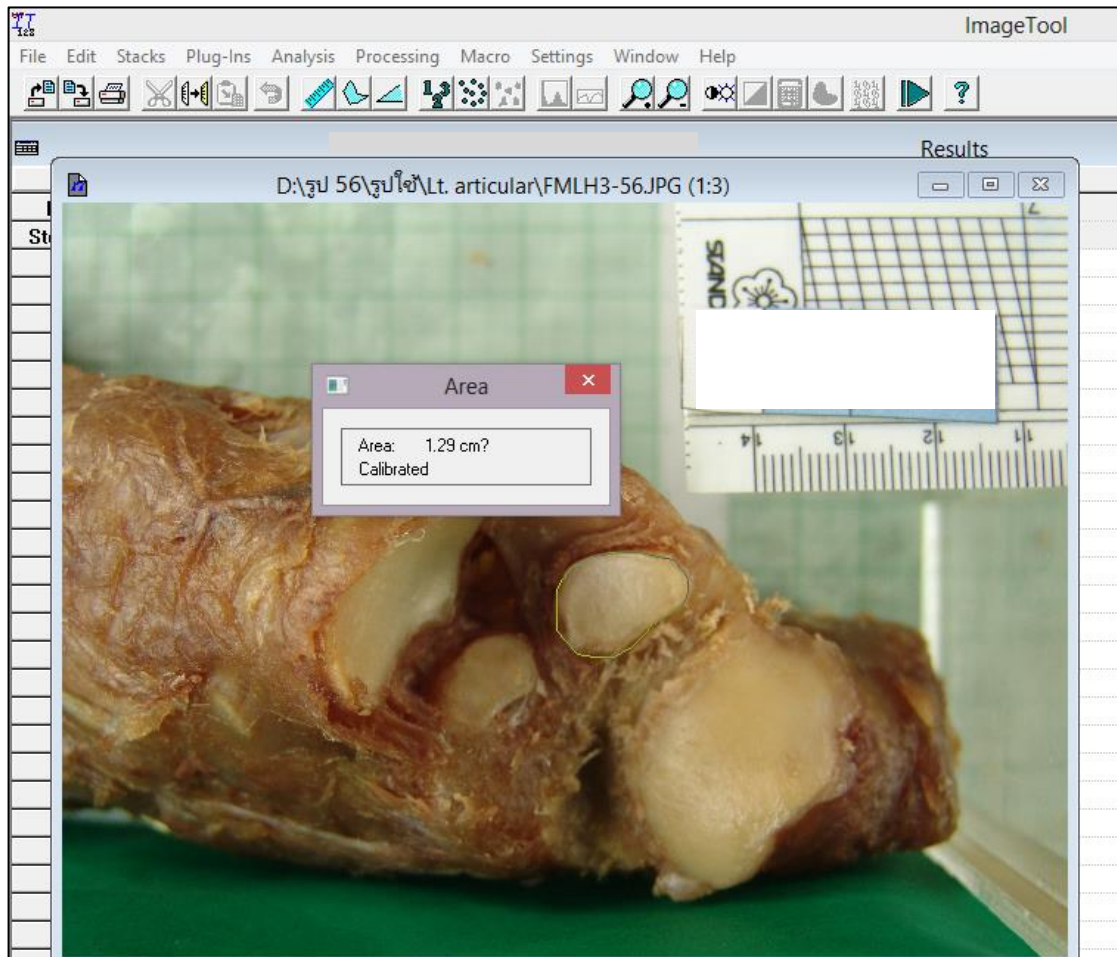


Figure 4.5: Area of articular surface was measured by using image tool program.

4.3 Classification of articular surface

The articular surface was normally classified by the number of articular facet and the pattern of in anterior and middle articular facets of calcaneus. The present study classified talar articular surface into 6 types which is similar to that of Shiraishi et al. ⁷. (Figure 4.6)

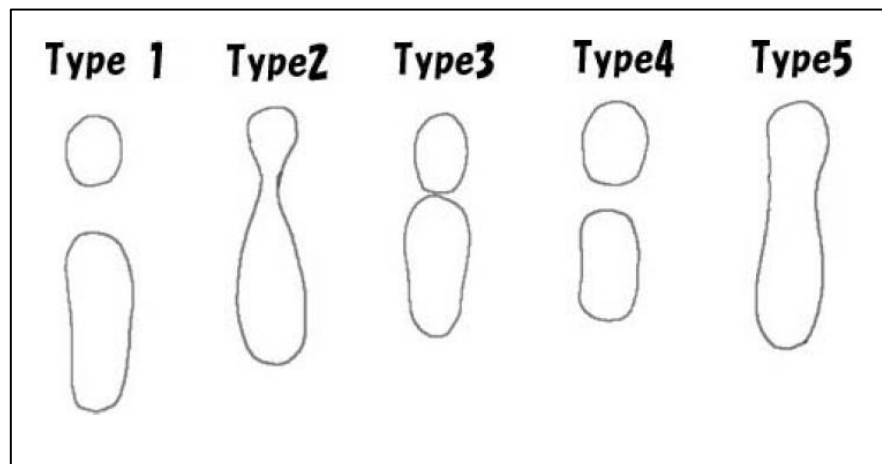


Figure 4.6: The anterior and medial talocalcaneal articular surface classified by Shiraishi et al.⁷ .

4.4 The accuracy of measurement

The accuracy of all measurements was assigned by measuring each parameter 3 times by the same observer and the result was averaged. The reliability of measurements was indicated as Intra-class Correlation Coefficient (ICC).

4.5 Data analysis

The statistical analysis will be performed by using the SPSS program. The results were presented as Mean \pm SD. Student's t-test and One-way ANOVA were used in order to compare the difference of the mean values of parameters between left and right sides and female and male. The statistical significance for all analysis was set at $p < 0.05$.

CHAPTER V

RESULTS

5.1 Anatomy of subtalar joint

Total of 340 feet were used in this study. The mean age was 68 years and ranges between 36-103 years. The total specimens were studied for the pattern of talar articular facet. One hundred and forty six complete feet from the dissection laboratory lab for second year medical student during 2011-2013 were studied the arch height and its relation to the articular facets. (Figure 5.1)



Figure 5.1 Medial aspect of the complete left foot for medial arch study.

The other 194 feet were without metatarsal and phalangeal bones from the research laboratory during 2010-2012 used only for study the talar articular surfaces. (Figure 5.2)



Figure 5.2 Medial aspect of the left foot without metatarsal and phalangeal for talar articular facet study.

The articular surfaces of subtalar joint were composed of talar articular surface on the calcaneus and calcaneal articular surface on the talus. The proximal calcaneal surface showed a large oblique concave surface on posterior aspect, anteriorly was anterior and middle facets which intervene by a groove for interosseous ligament. The talar articular surface was only found on the middle and anterior third of superior surface of calcaneus bone. Its large posterior facet was situated on the middle and present with convexity from anterior to posterior. Anterior and middle facets located at antero-medial surface of anterior third of calcaneus bone and have slightly concave facets. Between the former and latter facets were separated by canalis tarsi and sinus tarsi. The canalis tarsus was separated between posterior and middle facets where a talocalcaneal interosseous ligament and inferior extensor retinaculum were attached. The sinus tarsi located on the anterior of superior calcaneal surface and gave attachment of the extensor digitorum brevis muscle, cervical ligament and inferior extensor retinaculum. Morphology and pattern of talar articular facets were varied, particularly the anterior and middle facets. This study found fusion of the anterior and middle facets in various forms and also found only one specimen had a single fused facet and lacking of interosseous ligaments. The anterior and middle facets showed variation of shape and can be finally summarized into fused and non-fused of the facets. The detail variation of facet pattern was described below. The non-fused facets were occasionally found a superomedial calcaneonavicular ligament entwined between anterior and middle facets.

5.2 Pattern of talar articular facet of subtalar joint.

The variation of talar articular facet was found and classified into 7 types according to number of facet and shape of both facets. They were as followings and showed in Figure 5.3

Subtype 1, the anterior and middle facets apparently separated and anterior facet was smaller.

Subtype 2, both were fused and joined together with a small constriction between facets.

Subtype 3, the anterior and middle facets apparent separated and each adjacent rim nearly contacted.

Subtype 4, the anterior and middle facets clearly separated and the facets had similar size.

Subtype 5, the anterior and middle articular facets connected and formed a cylindrical facet.

Subtype 6, the anterior articular facet was missing.

Subtype 7, showed as a single confluent facet which was the fusion anterior, middle and posterior.

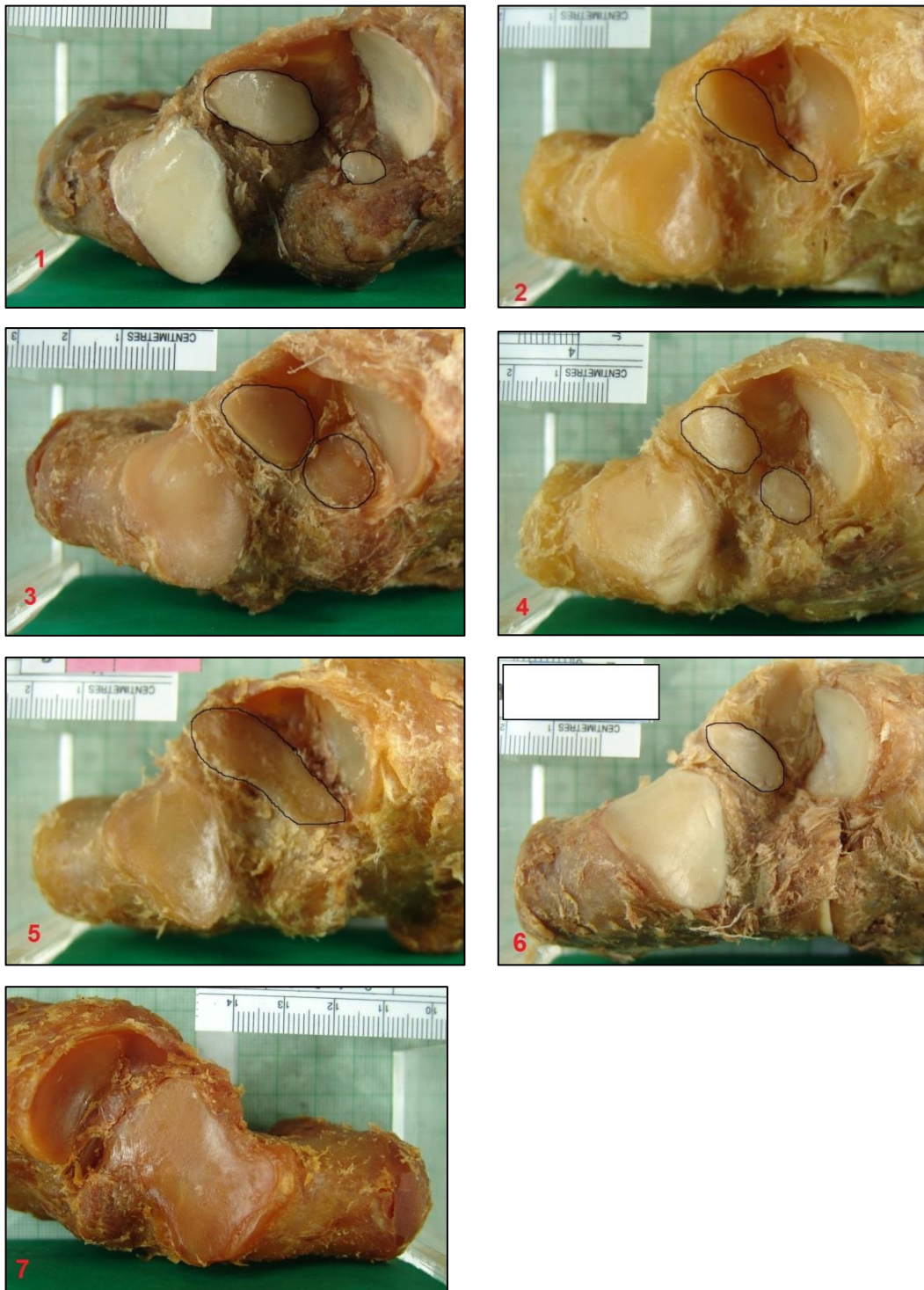


Figure 5.3 Classification of the anterior talocalcaneal articular surface.

1= Subtype 1, 2= Subtype 2, 3= Subtype 3, 4= Subtype 4, 5= Subtype 5, 6= Subtype 6, 7= Subtype 7

The distribution of various pattern of articular facet was shown in table 5.1. The mostly found pattern of talar articular facets on the calcaneus in Thai was type 5, followed with type 1 and 2 and the least found was type 7 and 6. The latter was found only one. (Table 5.1 and Figure 5.4)

Table 5.1 Distribution of the articular facet pattern in 7 subtypes.

Type of anterior subtalar joint (Total 340)	n	%
Subtype 1	83	24.4
Subtype 2	71	20.9
Subtype 3	29	8.5
Subtype 4	20	5.9
Subtype 5	134	39.4
Subtype 6	2	0.6
Subtype 7	1	0.3

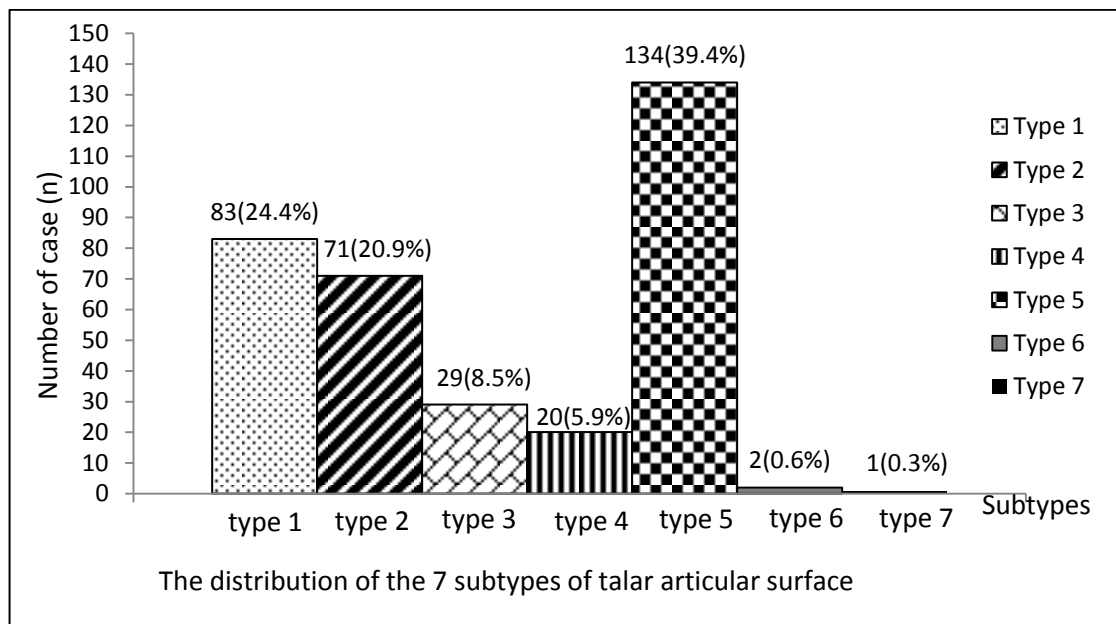


Figure 5.4 Histograms of the 7 subtypes of talar articular surface of the subtalar joint (N=340).

5.3 Area of talar articular surface of subtalar joint.

To study the relationship of pattern of articular surface and articular surface area, the talar articular facets were grouped into 2 major types. Fused and non-fused of anterior and middle facets as type A: the anterior and middle facets apparently separated and type B: showed the fusions of both facets. (Figure 5.5)

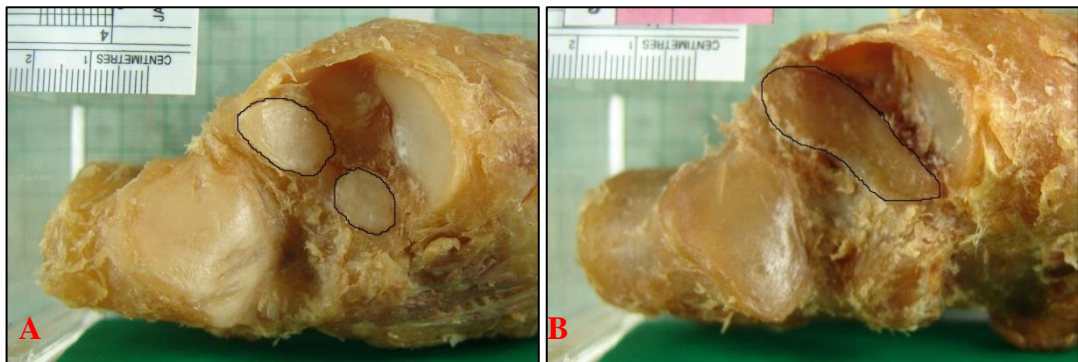


Figure 5.5 (A) Type A as non-fused facets; (B) Type B as fused facets.

Total three hundred and thirty six feet, type A articular facets was found in 132 feet (39.3%) and type B was in 204 feet (60.7%). (Table 5.2 and Figure 5.6)

Table 5.2 Percentage of 2 major articular facet of anterior subtalar joint.

Type of anterior subtalar facets	n	%
(Total 336)		
Non-fused	132	39.3
Fused	204	60.7

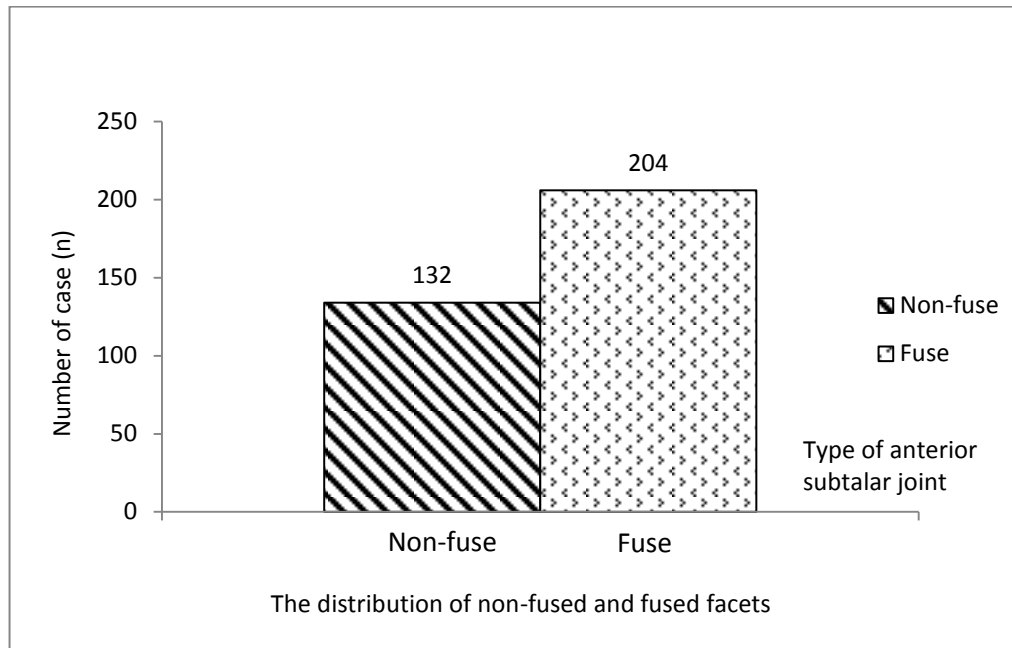


Figure 5.6 Histograms of the distribution of non-fused and fused facets.

The area of articular facets measurement was done by using Image tool program. Individual articular facet of 336 feet (except the four feet with confluent facet) was measured for a surface area according to its existing articular facets which categorized into 4 areas. (Table 5.3 and Figure 5.7)

1. The anterior facet.
2. The middle facet.
3. The posterior facet. (posterior part of subtalar joint)
4. The fused anterior- middle facet.

Later, the summation of anterior and middle facets of the non-fused type was done to yield the articular area of anterior part of subtalar joint.

The mean total articular area of talar articular surface was $6.76 \pm 1.20 \text{ cm}^2$ and the posterior facet was $4.59 \pm 0.85 \text{ cm}^2$. The mean area of anterior facet was $0.656 \pm 0.24 \text{ cm}^2$ smaller than middle facet which was $1.39 \pm 0.38 \text{ cm}^2$. The fused anterior facets was $2.25 \pm 0.54 \text{ cm}^2$ with larger than the summation of anterior and middle facet. ($2.04 \pm 0.51 \text{ cm}^2$)

Table 5.3 The mean area of talar articular surface of subtalar joint.

	Number of case	Mean area (cm ²)	SD (cm ²)
Anterior facet	132	0.656	0.240
Middle facet	132	1.390	0.382
Posterior facet (Posterior part)	336	4.599	0.857
Fused anterior and middle facets	204	2.256	0.546
Summation of Anterior part (anterior and middle facets)	132	2.046	0.511
Total area	336	6.767	1.205

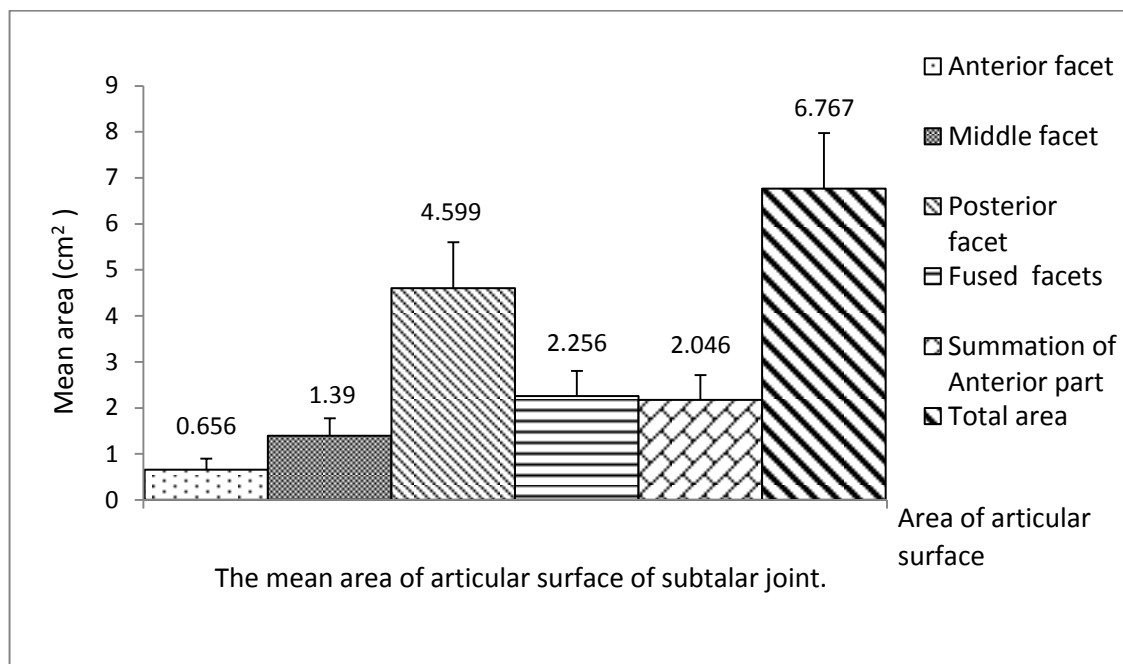


Figure 5.7 Histograms showed the mean area of articular surface of subtalar joint.

The mean area of talar articular surface according to facet pattern (type A and B) in relation to sides, age groups and genders were showed in Table 5.4. The articular surface areas were considered mainly as anterior subtalar (anterior and middle facets), posterior subtalar (posterior facet) and the total area.

The mean total area of talar articular surface in male was $7.30 \pm 1.15 \text{ cm}^2$, significantly larger ($p < 0.0001$) than female. ($6.06 \pm 0.81 \text{ cm}^2$)

The mean area of the anterior talar articular surface showed significantly larger in the male ($p < 0.0001$) and type B facets ($p < 0.0001$) which was fused facet.

The mean area of the posterior talar articular also showed significantly larger in the male ($p < 0.0001$), in type A facets ($p < 0.04$), and also in the younger age group. (≤ 60 years) ($p < 0.01$)

Table 5.4 The mean articular area of subtalar joint between articular patterns (type A and B), sides, age groups and genders. (* significantly different at p -value < 0.05)

	Total area (cm^2) (mean \pmSD)	Anterior subtalar joint (cm^2) (mean \pmSD)	Posterior subtalar joint (cm^2) (mean \pmSD)
<u>Articular pattern</u>			
Type A (n=132)	6.756 ± 1.108	$2.046 \pm 0.511^*$	$4.709 \pm 0.780^*$
Type B (n=204)	6.773 ± 1.266	$2.256 \pm 0.546^*$	$4.527 \pm 0.898^*$
<u>Side of foot</u>			
Left (n=168)	6.828 ± 1.241	2.187 ± 0.560	4.652 ± 0.892
Right (n=168)	6.705 ± 1.165	2.160 ± 0.523	4.545 ± 0.819
<u>Age group</u>			
>60 (n=224)	6.680 ± 1.151	2.163 ± 0.546	$4.517 \pm 0.821^*$
≤ 60 (n=112)	6.939 ± 1.294	2.219 ± 0.533	$4.763 \pm 0.905^*$
<u>Gender</u>			
Male (n=190)	$7.307 \pm 1.153^*$	$2.296 \pm 0.544^*$	$5.011 \pm 0.813^*$
Female (n=146)	$6.063 \pm 0.861^*$	$2.014 \pm 0.495^*$	$4.062 \pm 0.567^*$

The total specimen (Table 5.4) showed that articular surface of the male was significantly larger in total articular area as well as in each facet which could be the gender effect on the bone. There was no difference between sides. For the age group showed significantly larger of the posterior facet in the younger group. (≤ 60 years) Despite the similarity of the total articular area between type A and B, there was

significantly larger area of posterior facet in type A and significantly larger area of anterior facets in type B.

Consideration only the anterior (anterior and middle facets) and posterior portions of subtalar joint, the articular area from male specimen was showed in Table 5.5 There was no significant difference between sides and age group in all categorized areas except only the anterior subtalar joint of type B (fused facets) was significantly greater than type A. (p<0.0001)

Table 5.5 The mean articular area of of subtalar joint in the male, compared between articular pattern (type A and B), sides and age group in 3 categories of articular areas. (* significantly different at p-value<0.05)

	Total area (cm²) (mean ±SD)	Anterior subtalar joint (cm²) (mean ±SD)	Posterior subtalar joint (cm²) (mean ±SD)
<u>Articular pattern</u>			
Type A (n=88)	7.167 ± 1.022	2.146 ± 0.535*	5.020± 0.692
Type B (n=102)	7.429 ± 1.247	2.425 ± 0.520*	5.003 ± 0.908
<u>Side of foot</u>			
Left (n=95)	7.408 ± 1.140	2.319 ± 0.523	5.088 ± 0.837
Right (n=95)	7.207 ± 1.162	2.273 ± 0.566	4.934 ± 0.785
<u>Age group</u>			
>60 (n=118)	7.200 ± 1.112	2.265 ± 0.537	4.934 ± 0.787
≤60 (n=72)	7.484 ± 1.203	2.347 ± 0.556	5.136 ± 0.845

It was similar in the female group (Table 5.6), there was no significant difference of all categories of articular area between sides and age groups except the articular pattern of anterior subtalar joint. Type B (fused facets) showed the significant greater anterior articular area. (p<0.004)

Table 5.6 The mean articular area of female subtalar joint, compared between articular pattern (type A and B), sides and age groups. (* significantly different at p-value<0.05)

	Total area (cm²) (mean ±SD)	Anterior subtalar joint (cm²) (mean ±SD)	Posterior subtalar joint (cm²) (mean ±SD)
<u>Articular pattern</u>			
Type A (n=45)	5.929 ± 0.763	1.854 ± 0.391 *	4.074± 0.570
Type B (n=101)	6.122 ± 0.898	2.085 ± 0.521 *	4.057 ± 0.581
<u>Side of foot</u>			
Left (n=73)	6.073 ± 0.923	2.014 ± 0.564	4.085± 0.594
Right (n=73)	6.052 ± 0.800	2.013 ± 0.420	4.039 ± 0.542
<u>Age group</u>			
>60 (n=106)	6.102 ± 0.891	2.050 ± 0.536	4.052 ± 0.574
≤60 (n=40)	5.959 ± 0.775	1.918 ± 0.355	4.090 ± 0.555

Summary, the articular areas in male were significant larger than female in all categories. For the age groups, the younger age group showed significant larger only posterior facet. Between the articular patterns, type B showed significant greater area in anterior facets and type A showed significant greater area in posterior facet.

Between genders, the male group showed only significant larger in the anterior facets of type B. The same result was found in the female group that the anterior facets area was larger significantly in type B.

5.4 Arch of foot

This study used the normalized navicular height (NNH) to define the arch height. The mean of NNH of 146 complete feet from 73 Thais embalmed foot was 0.207 ± 0.048 (mean \pm SD). Arch types were classified as low, normal and high arch by setting at the first and third quartile of NNH which were 0.178 and 0.237 respectively. Later, the total 146 feet were classified into 35 low arches, 75 normal arches and 36 high arches as showed in Table 5.7 and Figure 5.8.

Table 5.7 Percentage of the arch type. (n=146)

Arch type and NNH range	Number of case (%)
Low arch < 0.178	35 (24%)
Normal arch 0.178- 0.237	75 (51.4%)
High arch > 0.237	36 (24.7%)

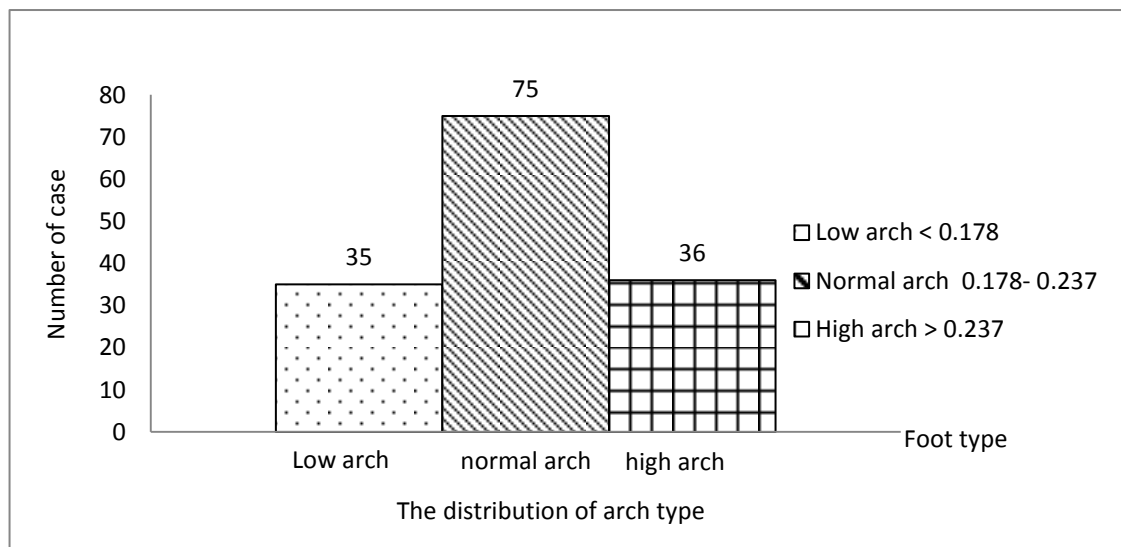


Figure 5.8 Histograms of the distribution of arch type.

In order to study the relationship of normalized navicular height and pattern of articular surface, the pattern was grouped into 2 major types as mention in the above (type A was separated anterior and middle facets and type B was fused facets). (Figure 5.5)

The mean NNH of type A was 0.218 ± 0.047 and type B was 0.198 ± 0.047 . It was significantly different between articular pattern type A and B with *p*-values at 0.016.

The mean NNH of left side was 0.209 ± 0.048 and right side was 0.204 ± 0.048 . It was no significant difference between sides.

The mean NNH between age group, the younger group less than or equal 60 years was 0.217 ± 0.48 and age more than 60 years was 0.203 ± 0.481 , respectively. However, there was no significantly different between age groups.

The mean NNH between male and female showed significantly different by male was 0.213 ± 0.052 greater than female 0.195 ± 0.038 , with *p* values < 0.032 . (Table 5.8)

Table 5.8 NNH between 2 major types of articular facet, sides, age groups and gender. (* significantly different)

	NNH (mean \pm SD)	<i>p</i> -values (Sig. $p < 0.05$)
<u>Articular pattern</u>		
Type A (n=62)	0.218 ± 0.047	0.016*
Type B (n=84)	0.198 ± 0.047	
<u>Side of foot</u>		
Left (n=73)	0.209 ± 0.048	0.574
Right (n=73)	0.204 ± 0.048	
<u>Age group</u>		
>60 (n=106)	0.203 ± 0.481	0.110
≤ 60 (n=40)	0.217 ± 0.482	
<u>Gender</u>		
Male (n=94)	0.213 ± 0.052	0.032*
Female (n=52)	0.195 ± 0.038	

The distribution of each talar articular surface pattern in relation to each arch height was showed in table 5.9 and figure 5.9. The result indicated that both types (A and B) were mostly allocated in the normal arch height while type B tended to shift to the low arch and type A inclined to the high arch. (Table 5.9and Figure 5.9)

Table 5.9 Allocation of two foot articular facet patterns into each arch type. (n=146)

Arch type	Non-fused facet(n=62)		Fused facet(n=84)	
	Number of case	%	Number of case	%
Low (n=35)	9	6.16	26	17.81
Normal (n=75)	34	23.29	41	28.09
High (n=36)	19	13.02	17	11.56

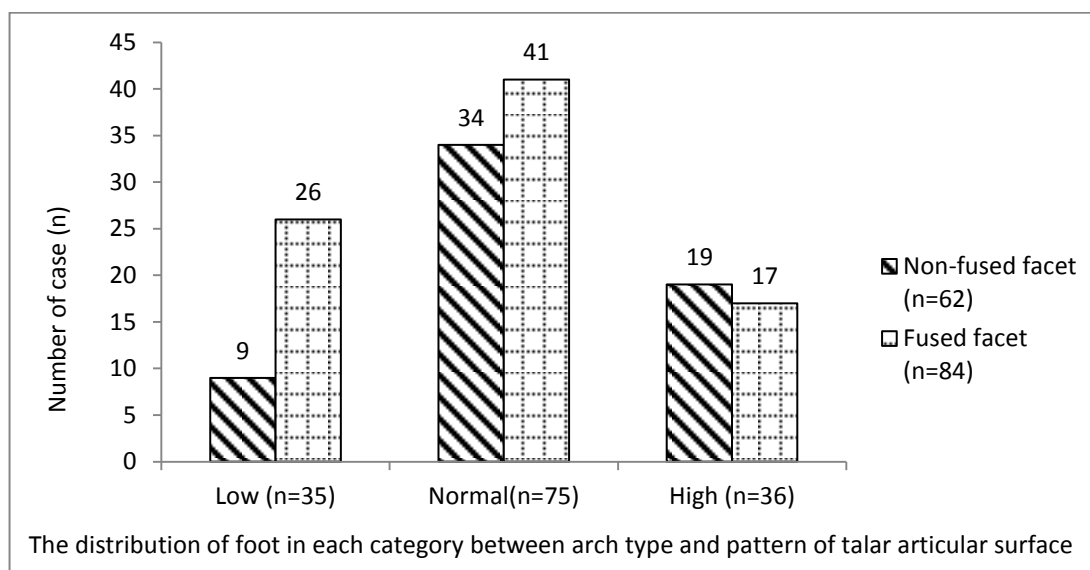


Figure 5.9 Distribution of different foot patterns in each arch height. (n=146)

According to arch types that classified by using the first and third quartile of NNH, the 146 feet were assigned into 3 groups: low (35 feet), normal (75 feet) and high arch (36 feet). The mean area of articular surface of subtalar joint was also estimated according to three categories as the above and showed in Table 5.10

The mean total area of subtalar facets was significant different ($p < 0.02$) in low and height arch. ($6.937 \pm 1.385 \text{ cm}^2$ and $7.607 \pm 1.123 \text{ cm}^2$ respectively)

The mean area of anterior subtalar joint was, significantly different between low ($2.303 \pm 0.751 \text{ cm}^2$) and high arch ($2.589 \pm 0.41 \text{ cm}^2$) at $p\text{-value} < 0.04$

and between normal ($2.341 \pm 0.559 \text{ cm}^2$) and high arch ($2.589 \pm 0.410 \text{ cm}^2$) at p-value < 0.03 .

The mean area of posterior subtalar joint had $4.620 \pm 1.025 \text{ cm}^2$, $4.782 \pm 0.930 \text{ cm}^2$, $4.982 \pm 0.870 \text{ cm}^2$, respectively. There were no significantly different between arch groups.

In summary, the mean area of total and anterior part of subtalar joint in high arch group was significantly greater than low arch group.

Table 5.10 The mean area of talar articular surface of subtalar joint between arch types. (*, # significantly different)

Arch type	Total area (cm^2) (mean \pm SD)	Anterior subtalar joint (cm^2) (mean \pm SD)	Posterior subtalar joint (cm^2) (mean \pm SD)
Low arch (n=35)	$6.937 \pm 1.385^*$	$2.303 \pm 0.751^*$	4.620 ± 1.025
Normal arch (n=75)	7.136 ± 1.295	$2.341 \pm 0.559^\#$	4.782 ± 0.930
High arch (n=36)	$7.607 \pm 1.123^*$	$2.589 \pm 0.410^{*,\#}$	4.982 ± 0.870

CHAPTER VI

DISCUSSION

Subtalar joint is consist of the inferior surface of talus and superior surface of calcaneus. The superior surface of calcaneus is called talar articular surface and consist of anterior, middle and posterior facets. In the present study, the talar articular surface was corresponding to standard anatomy textbook^{1-3,10,12} and previous study^{6-9,13-16,18-20,22-24,36,37} that shown fused and non-fused of anterior and middle facets. The fused facet of talar articular surface was the most frequently found in this study and corresponding to the previous works which showed the fused articular facet in various ethnic groups like Indian, Japanese and African.^{6,7,13,16,18,20,22-24} Study of Bunning⁶ and coworker showed the variation of talar articular pattern in fetus which presumably supported the relationship between to the variation and nationalities difference. Furthermore, the anterior and middle facets in this study were classified into 7 subtypes according to number and shape of both facets, slightly different from previous study which solely investigated the number of facets. However, when came to comparative study of the articular facet area and the arch height, this study used only fused and non-fused pattern of the talar articular facet. It is showed that the fused type of subtalar articular facet is mostly found in Thai population.

The mean total area of talar articular surface in this study was $6.767 \pm 1.205 \text{ cm}^2$ and was lesser than the study of Wang³⁸, Ward³⁹ and Bruckner⁸. This was probably due to ethnic difference and also the dissimilarity of technical measurement. The present study used image tool program to determine the area of articular surface from the image directly taken from the articular surface while the studies of Wang³⁸ and Ward³⁹ used pressure-sensitive film inserted into the articular surface and measured the contact area with various loading. Bruckner⁸ studied by using the transparent tape placed over facet and drawing a mark of the facet border then measured the area by planimeter. The studies of Wang and Ward showed the far larger articular area partly because of the load applying. Comparison among the

western specimens the two former works gave larger articular area than that of Bruckner⁸ which carried out on the dry bone. Consideration of the articular area from cadaveric bone in present study and dry bone from Bruckner's work⁸ using the planimeter to obtain the total area showed the disparity. Bruckner claimed that the lesser number of articular facet or the fused facets had larger articular area while this study showed no significant difference for the total articular area. However, the total size of articular area was clearly demonstrated that the western talar articular surface area was larger than the eastern. When each talar articular facets was taken in to account; this study found that in the fused facet the anterior facet area was larger significantly while the non-fused facet showed the significant larger posterior facet.

In this study, the total talar articular area, anterior and posterior articular area were significantly larger in male which corresponded to most of the previous studies and other part of the body like knee joint⁴⁰, patella⁴¹. This also gets along with general concept of the larger masculine configuration which could be due to the more active and energize in male.

Comparison between age group, there was no significant difference of the total articular area and the anterior articular area except the posterior articular facet. The elder group had significant larger posterior articular area, this was presumably due to the ungainliness in the elderly that decrease the load to the bone particularly the posterior facet which can be the primary loading site. This study shown that among Thai population, approximately 60% of talar articular facet was type B which was fusion of the anterior and middle facets. Among the articular patterns, the total area of talar articular surface was no significant difference, while separately considered each part, the fused anterior facet (type B) has significantly larger area while the non-fused facet (type A) was significantly larger in posterior facet.

This study used NNH to represent the medial arch height of foot and the mean NNH was 0.207 ± 0.048 . The medial arch of foot can be separated into 3 types by using the first and third quartile of NNH which were 0.178 and 0.237 respectively. Since measurement of NNH was taken from the arch length and height, the studied specimen had to have the metatarsal bones attached. The total number of specimen

with intact metatarsal bones was 146 feet. All of this was classified according to NNH into 35 feet of low arch, 75 of normal arch and 36 of high arch. However, Murley³⁰ studied the breaking points of normalized navicular height (NNH) for low arch as less than 0.22, 0.22-0.31 for normal arch and greater than 0.31 was high arch. This can be implied that generally the western people have higher medial arch than the eastern.

The mean NNH between age group and side showed no significantly difference while the mean NNH in type A pattern and in male was significant greater however, the NNH index was in the normal range (0.178-0.237). It indicates that there is a tendency of increasing arch height in male and non-fused facet, this also is in line with the articular facet pattern allocation study (Table 5.4.3) shows that the non-fused pattern is mostly found in normal and high arch. Perhaps this could be the differences physiology between male and female that resulted from an androgen difference. As a consequence, male would have larger bone and bigger articular surface than women⁴² as well as the higher arch foot. The type B (fused facet) mostly found in normal and low arch was corresponding to Bruckner study.⁸

The study of articular area according to arch height showed that the low arch had significant lesser total articular area while the height arch group had significant greater area. Posterior facet had no different in all arch groups while anterior facet in high arch height was significant difference from the rest. The largest anterior facet was found in the high arch group and the low arch group showed smallest anterior facet area which contradicted to Bruckner⁸ study. This could be due to the difference method of measure the arch height and also the articular area, apart from the smaller sample size of the previous work. This is the new insight of the subtalar configuration according to the arch height because this study was carried out in two parts. First was the articular facet type and articular areas which is corresponding to the previous works that the fused facet represented the greater area. Second was scrutinized into the arch height and articular area which showed the difference only on the total area and anterior facet which meant that the arch height closely related to the anterior facet. Thus the further study on arch height related to mobility of the foot need to be clarified. It was possible that in high arch the subtalar joint was usually in supination or inversion position and this constrained position needed more contact area.³⁹

Pattern of talar articular facet has been reported in relation to the stability of arch of foot. Bruckner⁸ claimed that talar articular surface of the fused facets had lower subtalar joint axis angle and had more joint mobility. Whilst Verhagen⁹ and Madhavi¹⁶ report fused facets showed arthritic change more than other facets pattern. Cowan and coworkers⁴³ reported the increasing risk of lower limb injury in the young army infantry trainee who had high arch of foot. Kaufman et al⁴⁴ reported that individual either with low arch or high arch was at increased risk for stress fracture foot. It agrees with recent study on arch structure and injury indicated that low arched runners involved in knee injury while high-arched exhibited ankle injury.¹¹ The arch of foot plays a crucial role in shock absorber; the variation of arch height can cause the malfunction of the entire foot. This study demonstrated that the greater arch height associated with larger articular area particularly the area of anterior facet. This could be the basis ground for biomechanics study and also the better understanding of etiology foot injury in various activities.

CHAPTER VII

CONCLUSION

This study revealed the morphometric information of talar articular surface in term of patterns of articular facets and surfaces area of the subtalar joint as well as the relation to arch of foot in Thais. Three hundred and forty specimens were taken from formalin embalmed cadavers in the Department of Anatomy, Faculty of Medicine Siriraj Hospital. The information of variable of articular patterns and size of the talar articular surface can be used to predict the foot arches and briefly the stability of the joint. Furthermore, prevention of foot injury can be pursued particularly in athlete group and also beneficial in biomechanical study. Following are the conclusion list from the present study.

1. The pattern of talar articular surface can be classified into 7 types. In Thai population, the most found is subtype 5 which represents the fusion of anterior and middle articular facets and formed as a cylindrical facet.

2. Consideration as fused and non-fused talar articular surface, the former is the mostly found in Thai population.

3. In comparison, the total talar articular area in Thai population is lesser than that reported in western subject.

4. The posterior facet shows more stable in term of pattern and surface area, however it constantly larger in male and in non-fused facet.

5. The anterior facet shows more variable in term of pattern and surface area as well as the relationship to the medial longitudinal arch height. The fused facet gives more articular area as well as in male shows larger anterior facet area.

6. Normalized navicular height in Thai population is generally lesser than the western subject. The normal arch height in this study is between 0.178- 0.237 while the lesser and greater is classified as low and high arch respectively.

7. The mean normalized navicular height is significantly greater in non-fused facet and in male group.

8. Relationship between arch height and the pattern of talar articular facet shows that fused and non-fused pattern are found in every arch type but there is a tendency of predominant fused pattern in low arch group.

9. Articular surface area in each arch type shows that the posterior facet do not show any difference. The total articular area is significant larger in the high arch while the anterior facet of the high arch group is significant larger than the others.

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APPENDIX

Intraclass Correlation Coefficient (ICC) of measurements.

Variable	Intraclass Correlation Coefficient (ICC)
Navicular height	0.995
Arch length	0.988
Normalized navicular height	0.996
Total area	0.989
Anterior subtalar joint	0.988
Posterior subtalar joint	0.987

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- A part of this study was publishing entitled Patterns of Subtalar Articular Surface Related to Medial Longitudinal Arch Height in Thais: in Siriraj Medical Journal, 2014(66):46–9

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