The Study of Anterior Cruciate Ligament Footprint in Thai Population: A Human Cadaveric Study

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Background: *Identification of the anterior cruciate ligament (ACL) footprint is critical for an anatomical ACL reconstruction. The osseous landmarks of the ACL footprint is one of the methods that can be used to determine the ACL insertion site. The size of ACL footprint on femur and tibia are also important for surgical decision. The purposes of the present study represent the existing of osseous landmarks and size of ACL footprint in Thai population.*

Objective: *Study the presence of the osseous landmarks and the size of ACL footprint both at femur and Tibia in Thai population.*

Material and Method: *77 knees from 39 cadavers (38 paired and 1 unpaired) from Department of Anatomy, Phramongkutklao College of Medicine were dissected to identify bony landmarks of ACL at both tibia and femoral attachment. The resident's ridge and lateral bifurcate ridge were identified. The metallic markers were then inserted into the defined anatomic footprint points and size of ACL footprint on tibia and femur were measured and recorded in length and width.*

Results: *The present study found resident's ridge in 75/77 knees (97.40%) and lateral bifurcate ridge (bony landmark between anteromedial and posterolateral bundle), 50/77 knees (64.94%).*

The average ACL length and width at the femoral attachment were 12.01 $\pm$ 1.66 mm and 9.52 $\pm$ 1.37 mm respectively. At the tibial attachment, the average length was 15.36 $\pm$ 2.33 mm and the width was 11.03 $\pm$ 1.77 mm. However, when performed an analysis between male and female footprint, there were significant difference in length and width of both Femoral and tibial attachment.

In male, the size of ACL at femoral attachment, average length was 12.68 $\pm$ 1.48 mm and average width was 9.99 $\pm$ 1.38 mm. At tibial attachment, average length was 16.84 $\pm$ 1.07 mm and width was 11.32 $\pm$ 1.43 mm.

In female, the size of ACL at right femur attachment, average length and width were 10.68 $\pm$ 1.1 mm, 8.64 $\pm$ 0.79 mm respectively. At tibial attachment, average length and width were 12.48 $\pm$ 1.08 mm and 10.1 $\pm$ 0.96 mm respectively.

Conclusion: *In femoral footprints of the ACL, the lateral bifurcate ridge can be found in 64.94% and resident's ridge can be found in 97.40% of the specimens. Then the authors can use the resident's ridge as a primary osseous landmark for anatomic ACL surgery in Thai patients, then locate the center of femoral tunnel at the lateral bifurcate ridge later in case of the authors could identify them. Gender has an effect on both femoral and tibial footprint size. The average size of ACL tibial footprint among Thai female are smaller than 14 mm, then the single anatomical ACL reconstruction may be preferred than double bundle technique. On the other hand, the average size of ACL femoral footprint in Thai male is greater than 14 mm. These findings alert the surgeon that double bundle technique could be performed in Thai male patients.*

Keywords: *Anterior cruciate ligament, ACL footprint, Resident's ridge*

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Arthroscopic ACL Reconstruction has improved steadily over the past 20 years. However, with the conventional clock-face reference technique, only 40% of patients reported their knees normal based on the International Knee Documentation Committee score[1]. Together with the increasing of the knowledge of native ACL footprint, these make the concept of an anatomic reconstruction to arise.

In the single bundle anatomical ACL reconstruction, both tibial and femoral tunnel were placed at the center of ACL footprint. Both lateral Intercondylar ridge (resident's ridge) and lateral bifurcate ridge were popularized and used as bony landmark for identifying the ACL footprint at the femoral side[2,3].

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The anatomic double bundle ACL reconstructions are also in fashion. The indications for choosing between single or double reconstruction are not yet clearly determined. The size of the ACL footprint is an important data for surgeon decision making, the tibial ACL insertion length more than 14 mm was postulated to be a prerequisite for double bundle reconstruction[4,5]. However, many literatures have reported the differences between the size of the ACL footprint. The differences in size among the races also have been in concerned[2,6,7]. The Asians, with smaller body, the footprints may be smaller than the Caucasians. Then knowing the size of the ACL footprint and the presence of osseous landmarks in Thai people will aid Thai orthopaedics surgeons in choosing the suitable technique for their patients.

To our knowledge, there is no study on the ACL footprint in Thai people. The present study the presence of femoral osseous landmark and the ACL footprint size in both femur and tibia.

Material and Method

The present study the cadaveric knees at the Department of Anatomy, Phramongkutklao College of Medicine, Phramongkutklao Army Hospital. Inclusion criteria were the entired knee at Department of Anatomy. Exclusion criteria were the knee with previous history of trauma or surgery. Of the 39 cadavers (78 knees) recruited, 77 cadaveric knees were included in the present study. One knee was excluded due to the previous history of the knee surgery. The genders were 26 male and 13 female. The total average age was 75.2 years (range from 56-95 years). The average ages for male and female cadaver were 75.3 and 75 years respectively, as shown in Table 1.

The 77 selected knees were dissected deep to the ACL site. Then the femur was cut to isolate the lateral femoral condyle from the medial femoral condyle with oscillating saw. The ACL, both femur and tibia, was cut from its footprints. Some fibers of the ACL at the border were left to aid in identify the footprint. After the footprints were identified, the bony landmarks at femur (resident's ridge and lateral bifurcate ridge) were identified and recorded (Fig. 1, 2).

The entired borders of ACL footprint were outlined with magic pen. The first 2 metallic markers were planted at the most longest points, represent the length of the footprint. For the width of the footprint, the rest two metallic markers were planted at the most widest points (Fig. 3, 4). Then the footprint in length and width (sizes) were measured using the vernier caliper.

Results

The authors' data showed the presence of the lateral intercondylar ridge (resident's ridge) in 75 of 77 knees (97.40%). While the lateral bifurcate ridge were found in 50 of 77 knee (64.94%) (Table 2).

There were no significant difference of size of

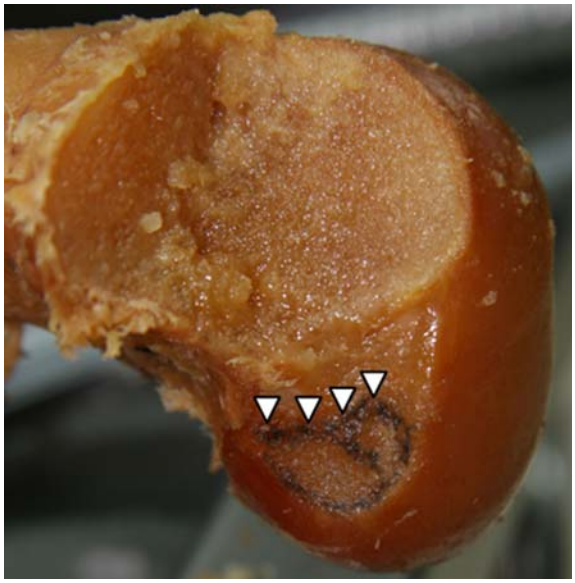

Fig. 1 Resident's ridge (white triangle)

Table 1. Demographic data

	Data
Number of cadaveric knees	77 knees (Rt knee = 37, Lt knee = 38)
Male	51 knees (Rt knee = 25, Lt knee = 26)
Female	26 knees (Rt knee = 13, Lt knee = 13)
Mean age	75.2 (range from 56-95) years
Mean age for Male	75.3 years
Mean age for Female	75 years

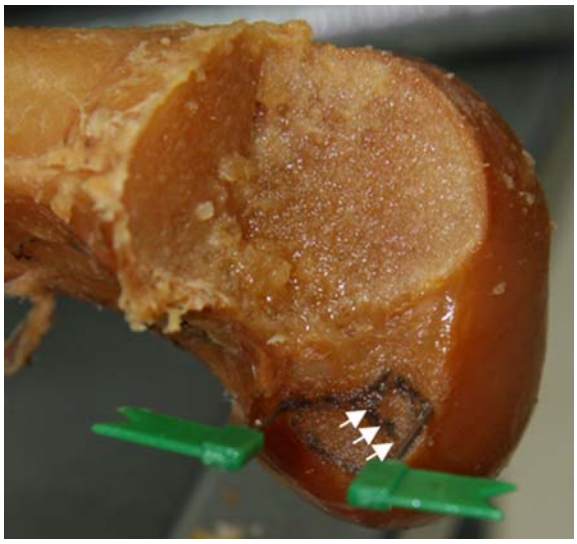

Fig. 2 Lateral bifurcate ridge (white arrow)

Fig. 3 Tibial footprint

Fig. 4 Length of ACL at tibial footprint

ACL footprint between right and left knee. The average ACL length and width at the femoral attachment were 12.01 ± 1.66 mm and 9.52 ± 1.37 mm respectively. At the tibial attachment, the average length was 15.36 ± 2.33 mm and the width was 11.03 ± 1.77 mm. However, when performed an analysis between male and female footprint, there were significant difference in length and width of both femoral and tibial attachment.

In male, the size of ACL at femoral attachment, average length was 12.68 ± 1.48 mm and average width was 9.99 ± 1.38 mm. At tibial attachment, average length was 16.84 ± 1.07 mm and width was 11.32 ± 1.43 mm.

In female, the size of ACL at femur attachment, average length and width were 10.68 ± 1.1 mm, 8.64 ± 0.79 mm respectively. At tibial attachment, average length and width were 12.48 ± 1.08 mm and 10.1 ± 0.96 mm respectively. The data were shown in Table 3.

Discussion

One of the purposes of the present study is to identify the existing of two osseous landmarks on the medial wall of lateral femoral condyle, the resident's ridge and the lateral bifurcate ridge. The lateral intercondylar ridge or resident's ridge is a thick bony ridge running from a proximal to distal direction in fully extended knee position. The important of this bony landmark is none of ACL fibers attach anterior to these ridges, which have been first described by William Jr Clancy, MD[2]. The lateral bifurcate ridge is a bony ridge that runs from anterior to posterior and separated AM and PL bundles attachment site which was first proposed by Ferretti et al[2]. Then, identification of the both ridge may assist surgeons to perform ACL surgery in a more anatomic fashion.

The present study found a presence of resident's ridge in 75 of 77 knees (97.4%), which is comparable with the previous studies by Farrow et al[8], Hutchinson and Ash[9], Steiner M[10]. They found this osseous ridge 97%, 90%, 100% respectively. No significant difference was found between male and female, also right and left knee. The lateral bifurcate ridge were presented in 50 of 77 knees (64.94%). The present data also showed lower percentage of lateral bifurcate ridge when compare with resident's ridge that were similar to other studies. Van Eck et al[11] found the presence of the lateral bifurcate ridge and resident's ridge 48% and 88% respectively. Ferretti et al[2] reported 82% of lateral bifurcate ridge and 100% of resident's ridge.

For the lateral bifurcate ridge, the data further showed the difference of existing between side in 5

Table 2. Presence of osseous landmarks

	Total average	Male	Female	Side to side difference
Resident's ridge	75/77 knees 97.4%	49/51 knees 96.08%	26/26 knees 100%	None
Lateral bifurcate ridge	50/77 knees 64.94%	32/51 knees 62.75%	16/26 knees 61.54%	Yes, found in 5 cadavers

Table 3. Length and Width of Femoral and Tibial footprint

	Length (mm)	Width (mm)
Femoral footprint		
Total Average	12.01 ± 1.66	9.52 ± 1.37
Rt Knee	12.11 ± 1.49	9.55 ± 1.18
Lt Knee	11.91 ± 1.83	9.49 ± 1.55
Male		
Rt Knee	12.77 ± 1.27	10.03 ± 1.10
Lt Knee	12.60 ± 1.69	9.94 ± 1.63
Total Rt & Lt Knee	12.68 ± 1.48	9.99 ± 1.38
Female		
RT knee	10.82 ± 0.99	8.63 ± 0.69
Lt knee	10.54 ± 1.26	8.59 ± 0.9
Total Rt &Lt knee	10.68 ± 1.1	8.64 ± 0.79
Tibial Footprint		
Total Average	15.36 ± 2.33	11.03 ± 1.77
Rt Knee	15.60 ± 2.44	11.01 ± 1.29
Lt Knee	15.14 ± 2.23	11.05 ± 1.05
Male		
Rt Knee	17.16 ± 1.00	11.48 ± 1.30
Lt Knee	16.52 ± 1.07	11.16 ± 1.56
Total Rt & Lt Knee	16.84 ± 1.07	11.32 ± 1.43
Female		
Rt Knee	12.00 ± 1.21	10.11 ± 0.62
Lt Knee	12.37 ± 0.98	10.09 ± 1.23
Total Rt & Lt Knee	12.48 ± 1.08	10.10 ± 0.96

paired of knees (Table 2). These findings may be interpreted that the lateral bifurcate ridge has more variation than the resident's ridge.

According to most commonly found of resident's ridge and less vary than lateral bifurcate ridge, the authors can use the resident's ridge as a primary osseous landmark for anatomic ACL surgery in Thai patients, then locate the center of femoral tunnel at the lateral bifurcate ridge later in case of we could identify them.

The other purpose of the present study was to compare the size of both tibial and femoral footprint of ACL with other previous studies. The hypothesis was ACL footprint in Thai people may be smaller than Caucasian.

The present found femoral footprint length and width were 12.01 ± 1.66 and 9.52 ± 1.37 mm respectively. The authors femoral footprint length seems to be smaller than studies by Ferretti et al[2], Colombet et al[12] and Odensten et al[7]. Nevertheless, the authors' femoral footprint widths were similar to thoses studies. This difference will alert the surgeon for the ethnic difference.

Femoral footprint length and width in our study were found smaller than tibial footprint. These findings agreed with the previous studies[2,7,12,13]. Harner et al reported. The tibial insertion site is the broadest part of the ligament and is 120% greater than its femoral footprint[13].

The previous studies reported the tibial footprint 14-20 mm in length and 9-13 mm in width[7-17]. The authors data were also comparable with the previous literatures, 15.36 ± 2.33 mm in length and 11.03 ± 1.77 mm in width.

As mentioned before, the tibial footprint length more than 14 mm is the prerequisite for the double bundle reconstruction technique[11], the authors data seem to support the double bundle technique in all Thai populations. Interestingly, when the authors' performed a subgroup analysis between male and female gender. The tibial footprint length in male was significant bigger than female, 16.84 ± 1.07 mm and 12.48 ± 1.08 mm respectively (p = 0.05). To our knowledge, our study is the first study that reports female gender is a significant parameter that relate to ACL footprint size.

This is definitely important for clinical relevance; these data will alert the surgeon to perform arthroscopic direct measurement in all female patients in who decide to perform double bundle technique.

From the authors data, the double bundle reconstruction technique probably proper for the Thai male populations, while the single bundle reconstruction technique should be enough for the female populations.

Conclusion

In femoral footprints of the ACL, the lateral bifurcate ridge can be found in 64.94%, and resident's ridge can be found in 97.40% of the specimens. Then the authors can use the resident's ridge as a primary osseous landmark for anatomic ACL surgery in Thai patients, then locate the center of femoral tunnel at the lateral bifurcate ridge later in case of the authors could identify them. Gender has an effect on both femoral and tibial footprint size. The average size of ACL tibial footprint among Thai female are smaller than 14 mm, then the single anatomical ACL reconstruction may be preferred than double bundle technique. On the other hand, the average size of ACL femoral footprint in Thai male is greater 14 mm. These findings alert the orthopaedic surgeon that double bundle technique able to perform in Thai male patients. In the future, the trend of individualized ACL reconstruction may be in fasion.

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Potential conflicts of interest

None.

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การศึกษาจุดเกาะเอ็นไขว้หน้าของข้อเข่า ในคนไทย : ศึกษาจากศพ

ณัฏฐา กุลกำม์ธร, อรรถพล อรรคสีหยุทธ์, กรกฎ ชรากร, ปิยาณี ศรียา, มานพ ชัยมัติ, นิธิศ รีบุญลาภ

ภูมิหลัง: การระบุตำแหน่งจุดเกาะของเอ็นไขว้หน้าที่ถูกต้องแม่นยำมีความสำคัญต่อผลการผ่าตัดสร้างเอ็นไขว้หน้าเป็นอย่างมาก ในระหว่างการผ่าตัดส่องกล้องนั้นจำเป็นต้องใช้ลักษณะพื้นผิวของปุ่มกระดูกที่เป็นจุดเกาะดั้งเดิมของเอ็นไขว้หน้าทั้งบนกระดูก femur และ tibia นอกจากนี้ ขนาดของจุดเกาะที่กระดูก tibia ก็ส่งผลถึงการเลือกวิธีการผ่าตัดด้วย

วัตถุประสงค์: ศึกษาลักษณะพื้นผิวของปุ่มกระดูกบริเวณจุดเกาะของเอ็นไขว้หน้าที่กระดูก femur และขนาดของจุดเกาะของเอ็นไขว้หน้าทั้งที่กระดูก femur และ tibia ในซนไทย

วัสดุและวิธีการ: ทำการผ่าพิสูจน์จุดเกาะของเอ็นไขว้หน้าทั้งสองข้าง ทั้งที่กระดูก tibia และ femur ในศพ 39 ร่าง หรือ รวมทั้งหมด 77 เข่า โดยบันทึกขนาดความกว้างและยาว และ บันทึกการพบ Resident's ridge, Lateral bifurcate ridge

ผลการศึกษา: จากการศึกษาพบ Resident's ridge 75 ใน77 เข่า หรือ ร้อยละ 97.40 , พบ Lateral bifurcate ridge 50ใน 77 เข่า หรือ ร้อยละ 64.94% ขนาดความยาวและความกว้างเฉลี่ยของเอ็นไขว้หน้าที่กระดูก femur คือ 12.01๓1.66 มิลลิเมตร และ 9.52๓1.37 มิลลิเมตรตามลำดับ ที่กระดูก tibia จุดเกาะของเอ็นไขว้หน้ามีความยาวเฉลี่ย 15.36๓2.33 มิลลิเมตร และความกว้างเฉลี่ย 11.03๓1.77 มิลลิเมตร อย่างไรก็ตามพบว่าขนาดของจุดเกาะทั้งที่กระดูก femur และ tibiaในผู้ชายและผู้หญิงมีความแตกต่างกันอย่างมีนัยสำคัญกล่าวคือ ขนาดความยาวเฉลี่ยของเอ็นไขว้หน้าที่กระดูก femur ในผู้ชายยาวกว่าในผู้หญิง(12.68๓1.48 มิลลิเมตร และ 10.68๓1.1 มิลลิเมตร) ความกว้างเฉลี่ยผู้ชาย 9.99๓1.38 มิลลิเมตร ผู้หญิง 8.64๓0.79 มิลลิเมตร เช่นเดียวกับขนาดของจุดเกาะเอ็นไขว้หน้าที่กระดูก tibia ในผู้ชายมีความยาว 16.84๓1.07มิลลิเมตร แต่ผู้หญิงมีความยาว 12.48๓1.08 มิลลิเมตร ขนาดความกว้างเฉลี่ยของจุดเกาะเอ็นไขว้หน้าในผู้ชาย 11.32๓1.43 มิลลิเมตร ส่วนในผู้หญิง 10.1๓0.96 มิลลิเมตร

สรุป: พื้นผิวกระดูกบริเวณจุดเกาะของเอ็นไขว้หน้าในคนไทยสามารถพบ lateral bifurcate ridge ได้ 64.94% และ resident's ridge 97.40 % ซึ่งสามารถนำมาใช้เป็นจุดสังเกตและระบุตำแหน่งของจุดเกาะเอ็นไขว้หน้าบนกระดูก femur ในขณะส่องกล้องผ่าตัดได้ ดังนั้นเราสามารถเลือกใช้ resident's ridge เพื่อช่วยในการระบุตำแหน่งของจุดเกาะของเอ็นไขว้หน้าบริเวณกระดูก femur เป็นอันดับแรกก่อน จากนั้นจึงเลือกใช้ lateral bifurcate ridge ในรายที่พบ จะสามารถช่วยหาตำแหน่งจุดเกาะของเอ็นไขว้หน้าบนกระดูก femur ได้แม่นยำมากขึ้น นอกจากนี้ยังพบว่าจุดเกาะเอ็นไขว้หน้าบนกระดูก tibia ของเพศหญิง มีขนาดเล็กกว่า 14 มิลลิเมตร ดังนั้นการผ่าตัดด้วย Single-bundle น่าจะมีความเหมาะสมมากกว่า Double-bundle ในทางกลับกัน จุดเกาะเอ็นไขว้หน้าบนกระดูก tibia ของเพศชายมีขนาดใหญ่กว่า 14 มิลลิเมตร จากข้อมูลดังกล่าวสรุปได้ว่า ควรเลือกทำ double bundle technique ในผู้ป่วยบางกลุ่มเท่านั้น โดยในผู้ป่วยชาวไทย เพศชายน่าจะได้ประโยชน์ที่สุด