ID Design Press, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2019 Dec 30; 7(24):4362-4367.
https://doi.org/10.3889/oamjms.2019.836
eISSN: 1857-9655
Basic and Clinical Medical Researches in Vietnam

Anatomical Study of Femoral Condylar Index in Magnetic Resonance Imaging: Implication to Total Knee Replacement Surgery for Vietnamese People

Dung Tran Trung[1, 2], Phuong Nguyen Huy[2], Tung Pham Son[1], Thien Chu Dinh[3], Toi Chu Dinh[4*]

[1]Saint Paul University Hospital, Hanoi, Vietnam; [2]Hanoi Medical University, Hanoi, Vietnam; [3]Institute for Research and Development, Duy Tan University, 03 Quang Trung, Danang, Vietnam; [4]Department of Human and Animal Physiology, Faculty of Biology, Hanoi National University of Education, Hanoi, Vietnam

Citation: Tran Trung D, Huy PN, Son TP, Chu Dinh T, Chu Dinh T. Anatomical Study of Femoral Condylar Index in Magnetic Resonance Imaging: Implication to Total Knee Replacement Surgery for Vietnamese People. Open Access Maced J Med Sci. 2019 Dec 30; 7(24):4362-4367. https://doi.org/10.3889/oamjms.2019.836

Keywords: Femoral rotation angle; Magnetic resonance imaging of knee joint; Total knee replacement

***Correspondence:** Toi Chu Dinh. Department of Human and Animal Physiology, Faculty of Biology, Hanoi National University of Education, Hanoi, Vietnam. E-mail: chudinhtoi.hnue@gmail.com

Received: 11-Sep-2019; **Revised:** 20-Nov-2019; **Accepted:** 21-Nov-2019; **Online first:** 20-Dec-2019

Funding: This research did not receive any financial support

Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: The femoral rotation angle is important element in total knee replacement (TKR).

AIM: To measure this angle, we determine through the axes: the transepicondylar axis (cTEA and sTEA), the posterior condylar axis (PCA), the anteroposterior axis (APA – Whiteside axis).

METHODS: Measuring the angles created by the four axes: cTEA, sTEA, PCA and APA in magnetic resonance imaging (MRI); determining the femoral rotation angle and application TKR.

RESULTS: the angle between APA and cTEA: 90.41° ± 3.35°, the angle between APA and sTEA: 94.47° ± 3.31°, the angle between APA and PCA: 96.40° ± 4.59°, the angle between cTEA and sTEA: 4.00° ± 1.02°, the angle between cTEA and PCA: 6.53° ± 2.55°, the angle between sTEA and PCA: 3.48° ± 1.91°.

CONCLUSION: The angle between sTEA and PCA is the angle that best represents the femoral rotation angle. However, in case of sTEA or PCA is difficult to identify, it can be measure via the APA or cTEA. These angles don't differ by age, gender and place of knee joint.

Introduction

Knee osteoarthritis is a very common disease and one of the biggest causes of disability in the elderly. According to many epidemiology researches, approximately 13% of people over 60 years old has symptom of knee osteoarthritis [4]. There are many treatments for knee osteoarthritis: medicine treatment in combination with rehabilitation, weight reduction, joint arthroscopy, hight tibial osteotomy. Finally, when all the above methods fail, patient suffers severe pain, articular cartilage is destroyed, joint is deformed, mechanical axis is misaligned and knee osteoarthritis is shown clearly on the X-ray scan, then the decision to perform knee replacement is made.

Total knee replacement (TKR) is the surgery method of cutting the damaged articular cartilage and replacing it with artificial joint. The aim of TKR is to repair and to restore the mechanical axis of leg and reduce pain and improve the function of knee joint thanks to the precise placement of artificial joint and balance of soft tissues surrounding knee joint. To do this, the suitable surgical technique is very crucial and the access to well-designed artificial joint is available. The structure of an artificial knee joint set includes femur, tibia and patella, in which the femoral rotation angle is an important element that directly affect the result of the TKR. Many researches show that incorrect femoral rotation angle can lead to complications such as femur and patella pain after surgery, limitation in knee function, wear increment of artificial joint material and so forth. Although clinical reports of TKR usually show good results, the optimal femoral rotation angleis only 75% of cases [9].

Many surgery techniques can determine the femoral rotation angle and while each technique has its own theoretical basis, all of them rely on the anatomical landmarks of femoral condyle and related components. Today, to measure this angle, we determine through the axes: the transepicondylar axis (cTEA và sTEA) [11], the posterior condylar axis (PCA), the anteroposterior axis (APA – Whiteside axis) [2]. The TEA is considered to be the most accurate of the four in reflecting the folding axis of knee joint and it is perpendicular to the mechanical axis. It is difficult to be identified and mark during surgery, thus the PCA is more commonly used [16]. Many researches in Europe and America evaluated that the PCA has an femoral rotation angle of 3^o compared to the TEA, which mean the femoral component external rotation angle is about 3° compared to the knee transverse axis [7], [5]. Currently our country is using this 3° external rotation angle to cut the femoral condyle. However, several researches on Asian races such as Chinese, Korean, and Japanese indicate that this angle varies in a wide range, from 1.7° to 9.7° [15], [17] . Specifically, researches in Japan indicated that the external rotation angle is 5°. This may be due to difference in races, living and working habits in each region. The determination of the femoral rotation angle or the relationship between anatomical landmarks have been researched multiple times through analyzing and measuring on corpses, or using diagnostic imaging tools such as MRI and CT scanner of knee joint. However, there has not been any research on these anatomical axes in Vietnam, causing many difficulties for surgeons during TKR.

Therefore, we decided to conduct this research to measuring the angles created by the four axes: cTEA, sTEA, PCA and APA in MRI; determining the femoral rotation angle and appling in TKR**.**

Materials and Methods

Subjects

Inclusion criteria: All patients with MRI scans of knee taken, above 16 years old, and have all four axes (APA, cTEA, sTEA and PCA) identifiable on axial slices.

Exclusion criteria: Foreign patients, patients under 16-year-old, patients with bone damage or surgical intervention at distal femur detected on MRI scan, and patients with any of the four axes (APA, cTEA, sTEA and PCA) not identifiable on axial slices.

Sample size calculation formula

We use the sample size calculation formula to determine the average value

$N=Z_{(1-\alpha/2)}{}^2.\delta^2/d^2$ [3]

δ : Standard Deviation.

D: Confident limit around the point estimate.

$Z_{(1-\alpha/2):}$ score corresponds to the desired level of statistical significance, usually taken 95%-95% CI, 2-side test Z = 1.96.

So, totally we had 280 patients conform to the requirement for selection.

Method of research

Retrospective research and prospective research using the descriptive cross-sectional method.

Research variables

Age, gender, place of knee, average measurement of 6 angles (APA, cTEA), (APA, sTEA), (APA, PCA), (cTEA, sTEA), (cTEA, PCA), (sTEA, PCA) calculated by age, gender and place of knee.

Tools

GE Optima MR360 1.5 Tesla MRI Scanner, made in Florida, USA, November, 2009, serial code 037255, high definition, 1 mm slice, 256 rows.

Simple Angle Measurement software. It is written using C#, uses Visual Studio 2015 and is designed to measure the angle between predetermined lines, and measures to the nearest 0.01%. This software is completely accurate.

Methods

The angles are measured using the Simple Angle Measurement software, then the data is collected using a uniform research form.

Statistical analysis

STATA 12.0 software to calculate Kruskal Wallis test, T-test.

Reduce errors

For one measurement, taking an average of these three measurements as the result of final research will minimize mistakes, and I use the four-digit figures after the comma. I use the software fully on my machine; therefore, the probability of errors has been greatly reduced.

Results

General characteristics

The age range of most patients participating in the research is 16-45 years old (195/280 patients). The average age of researched patients is 39.78 ± 15.14 (Table 1).

Table 1: Characteristics of age

Age range	Number of patients	Average age of each team	Rate (%)
Age 16-45	195	31.40 ± 7.32	69.64
Age > 45	85	59,00 ± 10.02	30.36
Total	280		100
Average age		39.78 ± 15.14	

In the young patient team, most of them are male, with the ratio between male and female being 2.7/1. In the elderly patient team, the ratio between male and female is 1/2.4. The ratio between male and female ratio of the entire team is 1.5/1 (Figure 1).

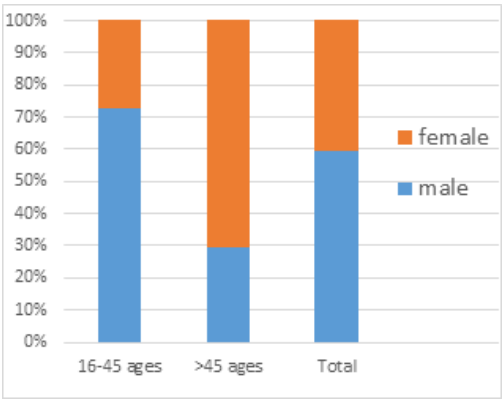

Figure 1: Characteristics of gender

The right knee/left knee ratio in the young patient team, elderly patient team and both teams combined are all approximately 1/1 (Figure 2).

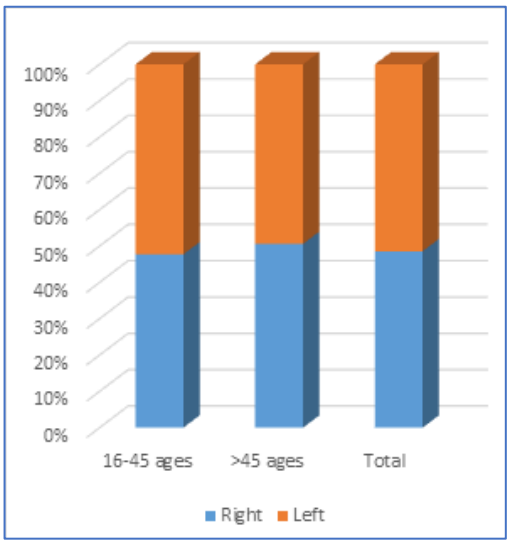

Figure 2: Characteristics of MRI scanning place

The APA and the cTEA are perpendicular to each other. The (sTEA, PCA) angle has an average measurement of 3.48° ± 1.91° (Table 2).

Table 2: Average measurement of anatomical angle (n = 280)

Angle	Average (°)	Smallest angle (°)	Biggest angle (°)
(APA, cTEA)	90.4 ± 3.35	78.68	103.14
(APA, sTEA)	94.47 ± 3.31	83.79	106.44
(APA, PCA)	96.40 ± 4.59	77.07	105.71
(cTEA, sTEA)	4.00 ± 1.02	1.11	7.38
(cTEA, PCA)	6.53 ± 2.55	0.01	13.74
(sTEA, PCA)	3.48 ± 1.91	0.08	13.36

Comparison of average measurement of angles created by 4 anatomical axes: APA, cTEA, sTEA and PCA between the young and the elderly patient teams

The result of analysis shows a relationship between anatomical axes of femoral condyle has no significant statistical difference in both the young and the elderly patient team ($p > 0.05$ in all 6 angles-Kruskal Wallis test) (Table 3).

Table 3: Comparison of average measurement of anatomical angles between the young and the elderly patient teams

Angle	Young patient team (n = 195)	Elderly patient team (n = 85)	p
(APA, cTEA)	90.33°	90.60°	0.21
(APA, sTEA)	94.34°	94.75°	0.13
(APA, PCA)	96.34°	96.54°	0.85
(cTEA, sTEA)	3.94°	4.15°	0.12
(cTEA, PCA)	6.60°	6.38°	0.45
(sTEA, PCA)	3.56°	3.29°	0.25

Discussion

In this research, we researched over 280 knee joints of patients from 16 to 88 years old, the most common age range was from 16 to 45 years old, the working age range. Perhaps because of that, there are many risk factors leading to knee disease such as injury, accident, soft tissue rheumatic syndromes, arthritis, and so forth. Thus, people in this age range should get MRI scanning more often. In the elderly patient team, the number risk factors decrease with the main factor being degeneration, so the patients go for examination less often.

Since this is a team of patients in working age, men often work harder, play more sports, and the male weight index is higher than that of women. Because of that the risk of men suffering from knee-related injuries is higher than that of women. In the elderly patient team, the male/female ratio is 1/2.4, which means women are the majority in this age team. This is reasonable because for women, after menopause, the estrogen level drops rapidly, which cause osteoporosis and osteoarthritis conditions to increase, especially in knee joint. This means more MRI scanning.

Researches by international authors show that the ratio of male patients and female patients is

equal (Figure 1), according to Ye-Yeon Won [17] and Jai Gon Seo [15], or the ratio of male patients is lower than that of female patients, according to Grinffin [7] (Table 4).

Table 4: Characteristics based on gender according to several international authors

Author	Average age	Male ratio	Female ratio	Research sample (n)	References
Ye-Yeon Won	44.7	50%	50%	100	[17]
Jai Gon Seo	68	50%	50%	20	[15]
Griffin	42.8	40%	60%	104	[7]
Andrew Park	64	47%	53%	114	[13]

This is due to customs, practices and labor activities in each region. In Vietnam, men are predominantly heavy workers and most of them also participate in high intensity sport activities, so the risk of them having knee joint disease is higher than that of women. In foreign countries, women are more involved in social activities and the intensity of physical activities is higher than that of Vietnamese women, which means there are more factors that can lead to knee joint injuries. This is the reason leading to the difference of femoral condylar angles between Vietnamese and foreign countries people.

Looking at Figure 2, we see no difference between right knee position and left knee joint position in both young and elderly patient teams, similar to the research result of Anay R. Patel [14], Ye Ye-on Won [17] (right/left knee ratio is 1/1). In researches by international authors, the right/left ratio changes depending on the criteria for selecting patients. However, if patients are selected regardless of diagnosis or only patients with knee joint degeneration are selected, the right/left ratio is usually 1/1. This is due to the fact that joint degeneration usually happens on both knees and rarely on only one knee. The risk element of knee joint injuries for both knees are also the same.

During this research, we found that the APA is perpendicular to the cTEA and nearly perpendicular to the sTEA. Our result are similar to the results of international authors Kobayashi [10] and Adrew Park [13]. The cTEA and the sTEA are very difficult to accurately identify during surgery, as this is the attachment point of ligament lateral internes and is shielded by femoral muscles. Jerosch [8] proved that the change in position selected between surgeons was 22.3 mm at the medial and 13.8 mm at the lateral femoral condyle. When researching the accuracy in determining the femoral condyle in 74 cases of TKR, Kinzel [9] discovered that the TEA was only accurately determined within ± 3° in 75% of the cases when examined by CT scaner after surgery. The deviation stretches in a wide range: from 6° external rotation angle to 11° internal rotation angle, including the TEA not identified during surgery. Thus, determining the cTEA and the sTEA indirectly through the PCA and/or the APA gives higher accuracy and does not cause damage to the muscles in the knee.

In our researches, the (cTEA, sTEA) angle is 4.00° which is similar to the results of Victor J. [16] and Kumar [11]. This angle is mostly unnoticed by surgeons as well as authors, which is because it is made by two axes that are difficult to distinguish clinically. Many authors assume that the sTEA is the approximate axis of the transverse axis rather than the cTEA. Since the cTEA des not coincide with the sTEA and they also create a 4° angle together, this means that the two axes are significantly different in clinical practice, so accurately determining the cTEA is very important. Using the cTEA as the transverse axis of knee may cause mistake and directly affect the results of TKR. In researches by international authors, only 50%-80% of cases managed to identify the sTEA. For the remaining patients, since the sTEA was unidentifiable, they used the cTEA as the transverse axis of knee joint. In our research, the sTEA was only unidentifiable in 8 cases. Since the ratio was very small, we did not count them in this research. This is because we used a GE Optima MR360 1.5 Tesla with 1 mm slice cut so the scans were of high quality and we were able to get the slice we wanted.

The angle created by the cTEA and the sTEA with the PCA is the highest concern of surgeons, in which the sTEA is the approximate axis with the transverse axis of knee. Accurately identifying this axis and using it as a landmark is very important in TKR surgery. Surgeons have tried to find another axis that is more easily identified clinically and has the most accuracy when using it to identify the sTEA. Many authors agree to take the PCA as an indirect axis to determine the sTEA. Many international authors have published the measurement results between these two angles as follows: Victor J. [16] measured of (cTEA, PCA) angle = 6.4°, (sTEA, PCA) angle = 3.1°; Nobuyuki Yoshinno [18] measured the (cTEA, PCA) angle = 6.4°, (sTEA, PCA) angle = 3°; and Jai Gon Seo [7] measured the (cTEA, PCA) angle = 5.3°, (sTEA, PCA) angle = 2.2°, and many others show similar results. In our research, by analyzing 280 MRI scans of knee joint, we found that the (cTEA, PCA) angle = 6.53° ± 2.55° and the (sTEA, PCA) angle = 3.48° ± 1. 91°. The results are quite similar to those of Asian and European authors [6], [13], [1]. This shows that although there are differences in anthropometric indicators, regions and living habits, the PCA always spins about 3° compared to the transverse axis of knee joint, or in other words, the posterior condylar angle is about 3° and the condylar twist angle is about 6°. This has a very important application in TKR, specifically in the cutting of the front and back of the distal extremity of femur, we let the cross-section rotate about 3° apart from the PCA, the transverse axis of knee will ensure the most physiological similarity. However, since the deviation of the (sTEA, PCA) angle between individuals is quite large, from 0.08° to 13.36°, we should evaluate this angle before surgery by using MRI scan of knee to optimize the femoral rotation angle, the femoral rotation angle of each patient will be different.

The measurement results of anatomical angles of young patients are equal to the results of the corresponding anatomical angles of elderly patients ($p > 0.05$ in all 6 angles-Kruskal Wallis test), which is shown in table 3. We found that the APA is perpendicular to the cTEA in both teams and the APA is not perpendicular to the sTEA but creates with that axis an angle of 94°. In 2000, Griffin [7] researched 104 knee joints, in which he also divided the team of patients into young and elderly teams, and his results were exactly the same as the results of our research. This means that the PCA rotated about 3° with the transverse axis and there is no difference between the young and the elderly. In TKR surgery, the PCA will be an important landmark to determine the transverse axis of knee.

Currently, other than the posterior condylar angle, the remaining angles are rarely researched. This is because on one hand these angles have little clinical significance, on the other hand they are also difficult to measure, their values are not high. According to Olcott [12], after comparing four methods of TKR, he determined that the method of using the sTEA is the most accurate, but since it is difficult to be identified during operation, he suggested using the PCA to determine the transverse axis of knee joint. According to Anay R. Patel [14], his research also shows that the relationship between the APA and the TEA is more volatile than the relationship between the TEA and the PCA, he also confirms that the anatomical angle is not affected by age. Therefore, authors focus on researching the angle created by the PCA with the cTEA and the sTEA, while the remaining angles are less researched. We researched all angles created by four anatomical axes of femoral condyle, which are APA, cTEA, sTEA and PCA, and use the result as reference data for research on Vietnamese people to serve the research of later Vietnamese authors.

Through the above analysis, in each team of patients, we found no difference between male and female, as well as right knee and left knee. When comparing the young and elderly patient team, the results of anatomical angles were not different ($p > 0.05$-Kruskal Wallis test), this result is consistent with the research results of European and Asian authors.

In conclusion, the angle between sTEA and PCA is the angle that best represents the femoral rotation angle. However, in cases sTEA or PCA is dificults to identify, it can be measure via the APA or cTEA. The value of the femoral rotation angle is about angle between sTEA and PCA, (sTEA, PCA) angle = 3.48° ± 1.91°. These angles don't differ by age, gender and place of knee joint.

Recommendation: The aim of TKR surgery is to restore the mechanical axis of leg, thus reduce pain and improve function of knee joint. In order to accomplish this, the precise placement of artificial knee joint and balance of the soft tissues surrounding knee joint is required. However, the relationship of anatomical axes of each patient is different. Therefore, through this research as well as researches of other authors around the world, we believe surgeons should evaluate the anatomical values on MRI scans before operation and identify the suitable femoral component external rotation for each patient, at the same time use multiple axes together to achieve the best surgery result.

Ethical approval

Approved by the Ethics Committee of Hanoi Medical University on June 30th, 2016.

Informed consent

The consent and commitment were signed by the patients.

References

1. Chao TW, Geraghty L, Dimitriou P, Talbot S. Averaging rotational landmarks during total knee arthroplasty reduces component malrotation caused by femoral asymmetry. Journal of orthopaedic surgery and research. 2017; 12(1):74. https://doi.org/10.1186/s13018-017-0575-2 PMid:28499396 PMCid:PMC5429545

2. Cho Y, Lee MC. Rotational alignment in total knee arthroplasty. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology. 2014; 1(4):113-8. https://doi.org/10.1016/j.asmart.2014.08.001

3. Cochran WG. Sampling Techniques, John Wiley & Sons, ed. Edition, 3rd, New York, 1977.

4. Hung NV. Osteoarthritis. Medicine, Medical Publishing, 2012:188-196.

5. Berger RA, et al. Determining the rotational alignment of the femoral component in total knee arthroplasty using the epicondylar axis. Clin Orthop Relat Res. 1993; (286):40-7. https://doi.org/10.1097/00003086-199301000-00008

6. Franceschini V, Nodzo SR, Della Valle AG. Femoral Component Rotation in Total Knee Arthroplasty: A Comparison Between Transepicondylar Axis and Posterior Condylar Line Referencing. J Arthroplasty. 2016; 31(12):2917-2921. https://doi.org/10.1016/j.arth.2016.05.032 PMid:27374639

7. Griffin FM, et al. Anatomy of the epicondyles of the distal femur: MRI analysis of normal knees. J Arthroplasty. 2000; 15(3):354-9. https://doi.org/10.1016/S0883-5403(00)90739-3

8. Jerosch J, et al. Interindividual reproducibility in perioperative rotational alignment of femoral components in knee prosthetic surgery using the transepicondylar axis. Knee Surg Sports Traumatol Arthrosc. 2002; 10(3):194-7. https://doi.org/10.1007/s00167-001-0271-x PMid:12012038

9. Kinzel V, Ledger M, Shakespeare D. Can the epicondylar axis be defined accurately in total knee arthroplasty?. Knee. 2005; 12(4):293-6. https://doi.org/10.1016/j.knee.2004.09.003 PMid:16026698

10. Kobayashi H, et al. Reproducibility of condylar twist angle measurement using computed tomography and axial radiography of the distal femur. Orthop Traumatol Surg Res. 2014; 100(8):885-90. https://doi.org/10.1016/j.otsr.2014.07.025 PMid:25453922

11. Kumar K, Sharma D. A study of anatomy of distal femur pertaining to total knee replacement: an analysis, conclusions and recommendations. Musculoskelet Surg. 2018; 102(1):29-34. https://doi.org/10.1007/s12306-017-0489-5

12. Olcott CW, Scott RD. A comparison of 4 intraoperative methods to determine femoral component rotation during total knee arthroplasty. J Arthroplasty. 2000; 15(1):22-6. https://doi.org/10.1016/S0883-5403(00)91051-9

13. Park A, Nam D, Friedman MV, Duncan ST, Hillen TJ, Barrack RL. Inter-observer precision and physiologic variability of MRI landmarks used to determine rotational alignment in conventional and patient-specific TKA. The Journal of arthroplasty. 2015; 30(2):290-5. https://doi.org/10.1016/j.arth.2014.08.015 PMid:25267537 PMCid:PMC4323956

14. Patel AR, et al. Femoral component rotation in total knee arthroplasty: an MRI-based evaluation of our options. J Arthroplasty. 2014; 29(8):1666-70. https://doi.org/10.1016/j.arth.2014.02.033 PMid:24746490

15. Seo JG, et al. Relationship between mechanical axis-derived and anatomic landmark-derived femoral rotation in TKA: a three-dimensional CT study. J Arthroplasty. 2014; 29(12):2314-8. https://doi.org/10.1016/j.arth.2014.07.017 PMid:25138615

16. Victor J. Rotational alignment of the distal femur: a literature review. Orthop Traumatol Surg Res. 2009; 95(5):365-72. https://doi.org/10.1016/j.otsr.2009.04.011 PMid:19592323

17. Won YY, et al. An additional reference axis for determining rotational alignment of the femoral component in total knee arthroplasty. J Arthroplasty. 2007; 22(7):1049-53. https://doi.org/10.1016/j.arth.2007.02.005 PMid:17920480

18. Yoshino N, et al. Computed tomography measurement of the surgical and clinical transepicondylar axis of the distal femur in osteoarthritic knees. J Arthroplasty. 2001; 16(4):493-7. https://doi.org/10.1054/arth.2001.23621 PMid:11402414