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Estimation of the posterior tibial slope on magnetic resonance images in Serbian population

Procena veličine zadnjeg tibijalnog nagiba metodom magnetne rezonance u srpskoj populaciji

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Abstract

Background/Aim. Preservation of an adequate posterior tibial slope (PTS) during total knee arthroplasty is crucial for the biomechanical stability and function of the knee joint. Studies that investigated anatomical features of the tibial plateau found significant gender and inter-population differences in all components of the PTS. The aim of this study was to establish reference values of PTS in Serbian population and to explore if there is any difference in the tibial plateau inclination between genders. **Methods.** We retrospectively reviewed 161 magnetic resonance images (MRIs) of the knee of adult patients examined in Medical Military Academy in Belgrade, Serbia, in a period from November 2011 to September 2014. Measurements of PTS components: medial tibial slope (MTS), lateral tibial slope (LTS), and coronal tibial slope (CTS) were performed through several steps, according to the suggestions in the recent literature. Obtained values for each tibial slope were compared between gender subgroups using appropriate statistical tests. **Results.** Mean values of each component of the posterior tibial slope for male vs. female subgroups were as follows: MTS 3.7° ± 2.8° vs. 5.1° ± 2.9°, LTS 4.2° ± 2.8° vs. 4.3° ± 2.7°, and CTS 3.9° ± 2.4° vs. 3.3° ± 1.9° respectively. The medial tibial slope was significantly higher in females than in males ($p = 0.005$). The mean value of the coronal tibial slope was greater in males without statistically significant difference ($p = 0.105$). **Conclusion.** This study demonstrated significant difference in MTS of the tibial plateau between males and females, being higher in the female subgroup.

Key words:
knee joint; arthroplasty; magnetic resonance imaging; joint instability.

Apstrakt

Uvod/Cilj. Postizanje adekvatnog zadnjeg tibijalnog nagiba (PTS) tokom totalne artroplastike zgloba kolena doprinosi njegovoj biomehaničkoj stabilnosti i očuvanju funkcije zgloba. Studije koje su istraživale anatomske karakteristike tibijalnog platoa ukazuju na to da postoje značajne razlike među polovima i između populacija u svim komponentama PTS. Cilj ove studije bio je da se ustanove referentne vrednosti PTS u našoj populaciji i da se utvrdi da li postoje razlike u komponentama PTS među polovima. **Metode.** Snimci zgloba kolena 161 odraslog bolesnika načinjeni metodom magnetne rezonance (MR) u Vojnomedicinskoj akademiji u Beogradu (Srbija), retrospektivno su analizirani u periodu od novembra 2011. do septembra 2014. godine. Na snimcima su merene komponente zadnjeg tibijalnog nagiba [medijalni tibijalni nagib (MTS), lateralni tibijalni nagib (LTS), koronalni tibijalni nagib (CTS)] na način predložen u novijim publikacijama drugih autora. Dobijene vrednosti tibijalnih nagiba su upoređivane između polova korišćenjem odgovarajućih statističkih testova. **Rezultati.** Srednje vrednosti pojedinačnih komponenti zadnjeg tibijalnog nagiba za ispitanike muškog vs. ženskog pola bile su sledeće: MTS 3.7° ± 2.8° vs. 5.1° ± 2.9°, LTS 4.2° ± 2.8° vs. 4.3° ± 2.7°, i CTS 3.9° ± 2.4° vs. 3.3° ± 1.9°. Srednja vrednost medijalnog tibijalnog ugla bila je značajno veća kod žena nego kod muškaraca visoko statistički značajnu razliku ($p = 0.005$). Ispitanici muškog pola su imali veće srednje vrednosti koronalnog tibijlanog ugla od žena, iako statističkom analizom nije potvrđena značajnost razlike ($p = 0.105$). **Zaključak.** U radu je pokazano da postoji značajna razlika među polovima u vrednostima medijalnog tibijalnog nagiba koji je značajno veći kod žena.

Ključne reči:
koleni zglob; artroplastika; magnetna rezonanca, snimanje; zglob, nestabilnost.

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Introduction

Total knee arthroplasty is widely used surgical procedure for the treatment of degenerative and rheumatologic diseases and certain fractures of the knee joint. Recent epidemiological studies that collected the data from eighteen countries reported 234 total knee replacements/100,000 population per year with the annual increase in incidence from 5.3% to 17%, depending on the country [1]. The long-term outcome of the total knee arthroplasty is highly dependent on the knee joint anatomy, particularly the posterior tibial slope (PTS) [2]. This anatomical feature represents the degree of posterior inclination of the tibial plateau in relation to the line perpendicular to the mid-diaphysis of the tibia [3]. Preservation of an adequate PTS during total and unicondylar knee replacement contributes to the overall biomechanical stability and function of the knee joint including maximal flexion and its resting position [4].

Values of the PTS that has to be set in implanted knee endoprosthesis are the subject of debate among surgeons. Great number of authors emphasize that there are no significant differences in the postoperative range of motion among patients whose tibial cuts were intraoperativly set from 0° up to 5° degrees during the implantation of the posterior cruciate ligament-sacrificed prosthesis model [5, 6]. Concerning cruciate retaining endoprosthesis, other authors argue that a greater extent of flexion can be achieved with cutting the tibia at an inclination of 5° to 7° [7–9].

Studies that investigated anatomical features of the tibial plateau found significant gender and inter-population differences in all components of the PTS [3, 10–12]. Females in general had greater medial (MTS) and lateral tibial slope (LTS) than males [3, 10, 12], while the mean values of the same parameters showed large variability depending on the study population. Furthermore, the lowest values of both MTS and LTS were found in White race [10], whereas Asian race showed the greatest inclination of the tibial plateau [10, 13, 14]. Recent studies suggest that higher values of the PTS may contribute to the anterior cruciate ligament injuries [15–18] and development of meniscal tear [19].

The aim of this study was to establish reference values of the PTS in Serbian population as well as to explore if there is any difference in the tibial plateau inclination between genders. Although the measurement of the PTS in Serbian population was recently performed on cadavers [20], we are unaware of any study that estimates value of the posterior tibial slope in clinical settings.

Methods

We retrospectively reviewed 207 knee magnetic resonance images (MRIs) of adult patients examined in the Medical Military Academy in Belgrade (Serbia), in a period from November 2011 to September 2014 year. Patients with tumors, bony cists, osteoarthritis, fractures of tibial plateaus, and previous knee surgery were excluded from the study. A final study sample consisted of 161 patients: 116 (72%) males aged between 21–53 (average 35.2), 45 (28%) females aged between 21–63 (average 41.8).

Measurement of the PTS components [medial tibial slope, lateral tibial slope, and coronal tibial slope (CTS)] was performed through several steps, according to Hashemi et al. [3]. Representative MRIs for the PTS measurement were selected using Merge e-film 3.4 freeware program. The orientation of the proximal tibial anatomic axis (PTAA) was established on sagittal and coronal section images respectively according to the mid-point method [3, 13]. Sagittal PTAA was determined on the mid-sagittal section that passed through the tibia at the level of the intercondylar notch (Figure 1a). This axis was reproduced on the two adjacent sagittal section images passing through the center of the medial and lateral articular surfaces of the tibial plateau, respectively (Figures 1b and 1c). On these images, a line perpendicular to the PTAA was constructed as well as the line that connected the most superior point of the anterior and posterior half of the tibial plateau. An angle between these two lines represented medial and lateral tibial slope, respectively (Figures 1b and 1c). A similar approach was used for the measurement of the coronal tibial slope. The PTAA in coronal plane was constructed on the section image that passed through the most lateral points of medial and lateral half of the tibial plateau (Figure 2a). Two additional lines were constructed (one perpendicular to the coronal PTAA and another that connected the most superior point on the lateral and medial portion of tibial plateau) and the angle between them was measured (Figure 2b). Corel DRAW X6 program was used for the line construction and angle measurement.

In order to avoid bias in the PTS assessment, the same observer repeated all measurements in randomly selected 50

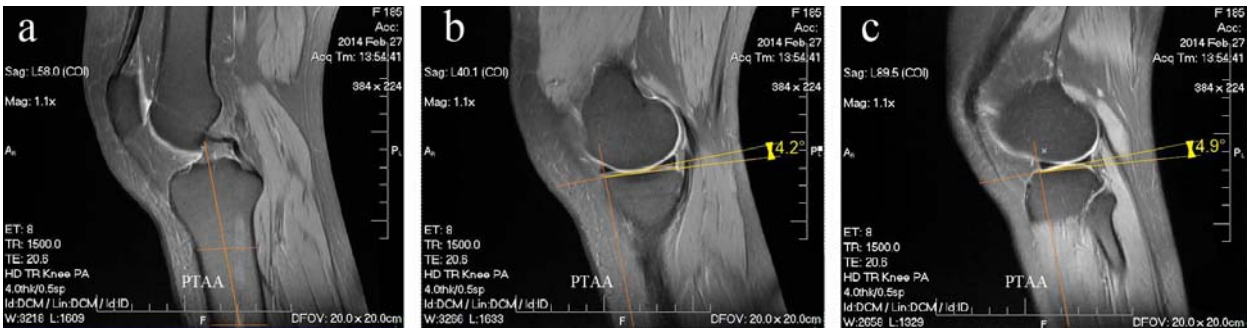

Fig. 1 – Reconstruction of the proximal tibial anatomic axis (PTAA) in the mid-sagittal plane (a) with the measurement of the medial (b) and lateral (c) tibial slope.

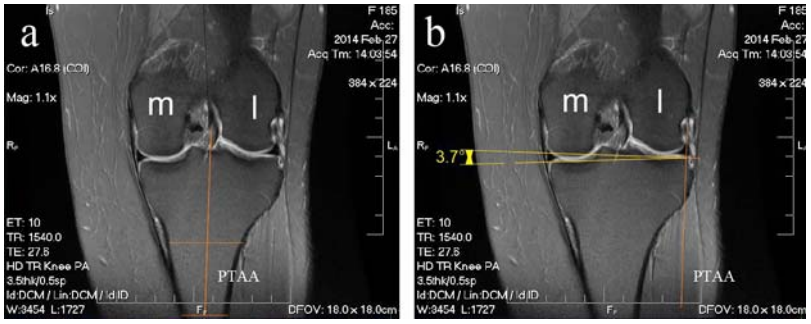

Fig. 2 – Reconstruction of the proximal tibial anatomic axis (PTAA) in the coronal plane (a) with the measurement of the coronal tibial slope (b).

patients after three months. Intraclass correlation analysis showed high reproducibility (Cronbah's alpha coefficient was 0.96 for MTS, and 0.94 for LTS and CTS).

The accuracy of measurement was limited to 0.1°.

Statistical analysis

The database was made in the statistical program SPSS, version 15.0. Analysis included descriptive and analytical statistical methods. Normality of data distribution was tested by Kolmogorov-Smirnov test. Mann-Whitney U tests was applied to compare the medial tibial slope, lateral tibial slope and coronal tibial slope between genders. Wilcoxon Signed Rank Test was performed to explore if there is any difference between medial and lateral tibial slope. The level of statistical significance was set at or below 0.05.

Results

The mean values of each component of the posterior tibial slope were as follows: medial tibial slope 4.1° ± 2.9°, lateral tibial slope 4.2° ± 2.8°, and coronal tibial slope 3.7° ± 2.3°. Angles of the each component of the posterior tibial slope measured in male and female subgroup are displayed in Table 1. The mean values of medial and lateral tibial slope were higher in female than in male subjects, with a significant difference ($p = 0.005$) detected in the former ones (Figure 3). Conversely, coronal tibial slope was greater in males than in females even though the difference was not statistically significant ($p = 0.105$) (Figure 3).

Comparative analysis of medial and lateral tibial slopes within gender subgroups showed the difference at the border of significance only in females ($p = 0.058$), while both angles differed non-significantly in males ($p = 0.128$) (Figure 4).

Table 1

Components of posterior tibial slope measured in male and female individuals (in degrees)

Tibial slope	Gender	Mean	Standard deviation
Medial	male	3.7	2.8
	female	5.1	2.9
Lateral	male	4.2	2.8
	female	4.3	2.7
Coronal	male	3.9	2.4
	female	3.6	1.9

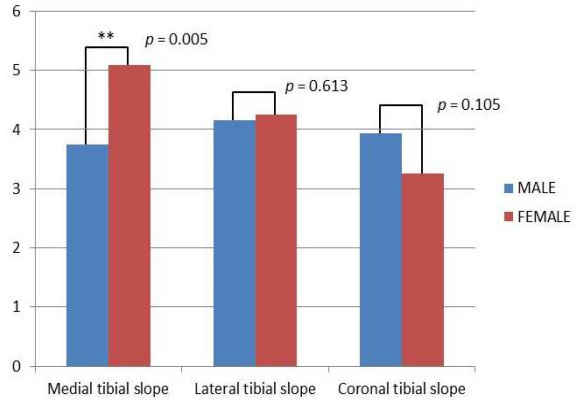

Fig. 3 – Gender differences in medial, lateral, and coronal tibial slope.

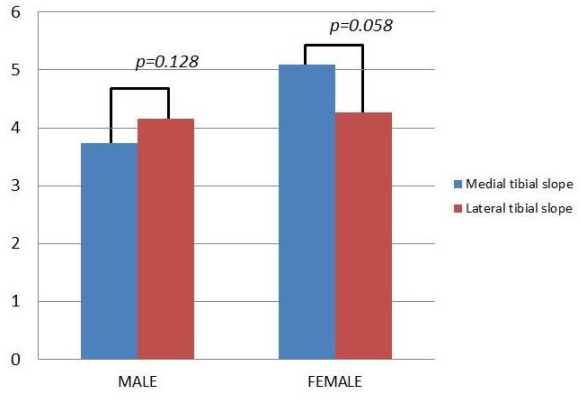

Fig. 4 – Comparative analysis of medial and lateral tibial slopes in gender subgroups.

Discussion

The posterior tibial slope range from zero to fifteen degrees is considered normal in healthy subjects [13, 14]. However, recently published studies reported inter-population differences in each component of the PTS. In European population, Hudek et al. [12] found the mean MTS around 3°, while the same slope was around 15° in Chinese population [13]. Our results of the PTS in both genders were consistent with values detected in Europeans. Additionally, tibial plateau morphology in Asians is characterized by significantly lager posterior slope then in White race [10]. This finding could be interpreted by the real presence of the race-related differences in proximal tibial morphology, but it could be also a consequence of various radiological methods applied for the measurement of the PTS [3, 10, 13, 17, 21, 22]. The plain radiography is the most commonly used imaging technique for this purpose [11, 22–24]. However, it is not considered reliable enough for the PTS assessment due to the superimposition of the medial and lateral slopes on the lateral radiographs. Study by Utzschneider et al. [22] showed that computed tomography (CT) and MR methods are more accurate in evaluation of the inclination of the tibial plateau. These techniques eliminate errors resulting from superimposition, patient position and knee rotation during an examination, and allow multiplanar reconstruction and selection of the most representative section images [16]. In general, authors prefer to use the MR examination for the measurement of the PTS in order to avoid unnecessary exposure of the patient to high radiation doses during CT scanning.

Considering gender differences in tibial plateau inclination, many authors reported that females often have higher MTS than males [3, 10, 14]. In addition, Hashemi et al. [3] described that in their population sample CTS angle was greater in males. Values that we registered in Serbian population showed the same tendency, but statistical significance was confirmed only for the gender difference in the MTS.

Results that we obtained are similar with findings of Haddad et al. [10], who also measured the same parameters of the PTS on MR of the White race European population [10]. In this study, the mean value of the MTS and the LTS for the whole study sample was 4.2° and 4.4° respectively, which is slightly greater than in our population (MTS 4.1°, LTS 4.2°, CTS 3.7°). When compared MTS and LTS values in gender subgroups between studies, we observed that males and females from the UK had higher MTS than Serbian population. In the case of the LTS, greater mean values than our results were reported only for the UK females. We also compared our findings with the study that was conducted among the USA population [3]. The mean value of the PTS in the USA population was slightly different from our findings. In their population sample the mean MTS was 5.02° and the mean LTS was 6.38°, while the mean CTS value was not reported [3]. Values of MTS were similar between genders in both studies. The LTS was greater in the USA study sample for both genders, but CTS was higher just in female subgroup.

Our study is potentially limited by the fact that determination of the tibial shaft axis would seem more reliable on the image of the entire lower leg then on the proximal part of the tibia. However, authors that measured tibial slopes on MR or CT images that included different lengths of the tibia (from proximal part to the entire bone) reported that length of the tibia did not significantly influence the measurement results [22, 25]. These authors were consistent in suggestions that determination of bone axis on proximal 10 cm of the tibial shaft could be accepted as reliable.

Conclusion

The mean value of the medial tibial slope was significantly higher in females than in males. Conversely, the mean value of the coronal tibial slope was greater in males, but without statistically significant difference. Clinicians should be aware about the exact value of each component of the tibial plateau inclination in order to achieve the best surgical outcome during arthroplasty. Additionally, the posterior tibial plateau values are important for anatomical and anthropometrical studies.

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