The Knee 23 (2016) 796–800

Contents lists available at ScienceDirect

The Knee

Anthropometric measurements of the femur change with component positioning in total knee arthroplasty

Emmanuel Thienpont [a,*], Massimiliano Bernardoni [b], Tyler Goldberg [c]

[a] Cliniques universitaires Saint Luc-UCL, Av. Hippocrate 10, 1200 Brussels, Belgium
[b] Medacta International SA, Strada Regina, 6874 Castel San Pietro, Switzerland
[c] Texas Orthopedics, 4700 Seton Center Parkway Suite 200, Austin, 78759 TX, USA

ARTICLE INFO

Article history:
Received 28 July 2015
Received in revised form 27 September 2015
Accepted 26 November 2015

Keywords:
Total knee arthroplasty
Gender
Sizing
Aspect ratio
Femur

ABSTRACT

Background: To analyze aspect ratio (AP size/ (ML) size) of osteoarthritic knees at four different areas of the femur and to observe if proximalization of the femoral cut would change the ML size as well as confirm that external rotation increases the measurements for the AP dimensions of the femur.
Method: From the available MyKnee database (Medacta International, Castel San Pietro, Switzerland) 1030 patients were randomly selected within 20° of deformity consisting of 400 men with a mean (SD) age of 67.5 (9) years and 630 women with a mean (SD) age of 69 (10) years ($p < 0.0001$).
A specific software program was developed to measure AP and ML dimensions of the femur on CT-scans for (3D) planning in four areas. The AP femoral size was measured with neutral axial rotation following the epicondylar axis and without accepting anterolateral notching.
Results: Proximalization of the femur resulted in no changes except for a larger ML3 area in men. Increased axial rotation increased the AP dimensions for the same femur by a mean (SD) 2.5 (1) mm for males and females.
Conclusions: The crucial area for overhang of the femoral component is the anterior region (ML1) with an aspect ratio of about ±, but with an important range. Proximalization of the femoral cut is not accompanied by narrowing of the anterior femur but ML widening of the more posterior femur in men. Increased external rotation leads to a measurement of bigger AP size leading to an AP versus ML mismatch and change in aspect ratio.

1. Introduction

The differences in anthropometric data and the concepts of sexual dimorphism in human knees, with anatomic variations among different races, are well known and supported by recent literature [1–7]. Total knee implants have traditionally been designed 'down the middle' based on the combined average size and shape of male and female knee anatomy [8,9]. Various studies have described anatomic differences in the hips and knees of men and women, including altered aspect ratios in the distal and proximal femur [10–12], different Q angles [8,13] and trochlear groove dimensions [14]. The result of these observations was the development of 'gender-specific' prostheses on the femoral side providing more sizes, differing aspect ratios with a narrower ML dimension and altered intertrochlear grooves [15–18]. In general, the distal femurs of females are not only smaller, but have different shapes with a narrower mediolateral (ML) diameter for any given anteroposterior (AP) distance than in males [2,6,11,15]. Anthropometric data has been collected utilizing various modalities such as radiographs, computed tomography/magnetic resonance imaging (CT/MRI), cadaveric measurements and finally by intra-operative observations [15, 19–21]. The mismatch between the AP and ML sizes has been attributed to posture, morphotype and race of the patient [3,22,23].

The AP dimension of the femur is widely used to select intraoperatively a suitable femoral component size for each patient during total knee replacement because of its importance in flexion gap kinematics. However, due to variance in AP/ML anatomy among different populations, some knee designs do not accurately reconstruct the femur due to ML mismatch [24]. Consequently, intra-operative problems such as overresection of the posterior femoral condyles, femoral notching, excessive femoral component flexion, or component overhang might all be caused when trying to match the native female anatomy with standard unisex components [15,25]. The consequences of ML overhang and soft tissue irritation have been well described [19, 26]. ML undersizing with uncovered bone could lead to more early blood loss, potential for subsidence, and increased osteolysis from wear debris on the longer term [6]. Several studies have failed to find any clinical advantages for the use of 'gender' components in female patients [27–31]. Other studies could not demonstrate inferior results for unisex components in the female population [32,33] despite preoperative functional differences in women compared to men [34,35].

* Corresponding author. Tel.: +3227642963.
E-mail address: emmanuel.thienpont@uclouvain.be (E. Thienpont).

http://dx.doi.org/10.1016/j.knee.2015.11.010
0968-0160/

The influence of external rotation on flexion gap kinematics and ligament release has been frequently studied [36,37]. Koninckx et al. showed in vivo that external rotation of the femur induced oversizing of the femur because the AP size measurement increases with more external rotation of the femur. They have shown that more external rotation brings the lateral pin hole down and therefore anterolateral notching would result, except if a bigger size of femur is utilized [31]. Other technical aspects of the surgery have not been linked to sizing of the femur until very recently when Nakahara et al. showed that the AP size of the femur changed depending on the flexion or extension position of the femur [38]. It is also common knowledge that in patients with hyperextension less distal femur is resected and in case of flexion contracture more proximal resection is performed [39]. Consequently, moving the femoral component for kinematic reasons intra-operatively may directly affect the size of the implant chosen.

The clinical question that the authors tried to answer with this study was whether a more proximal position of the femur to correct an extension deficit would lead to aspect ratio changes (Table 3). The same question was asked for axial rotation, whether changes in femoral rotation, for flexion gap balancing or patellofemoral tracking, would also influence the aspect ratio. The answer on both such questions can only be found in a simulated situation where different levels of femoral cut and rotation can be compared on the same patient.

The MyKnee database (Medacta International, Castel San Pietro, Switzerland) is a CT-based lower-extremity databank of over 20,000 patients from around the world scheduled to have total knee arthroplasty (TKA) utilizing patient-specific instrumentation. The creation of this databank allows for a new, extremely accurate modality to study femoral sizing, dimensions, and aspect ratios among large populations.

The hypotheses of this study were: (1) that the aspect ratio is variable for different zones of the distal femur; (2) that proximalization or distalization of the femur influences the observed width of the distal femur and changes the aspect ratio during surgery; (3) that external rotation influences AP size measurement if anterolateral notching wants to be avoided.

2. Materials and methods

From the available MyKnee database (Medacta International, Castel San Pietro, Switzerland) a Medacta engineer (MB) randomly selected patients. Inclusion criteria were patients awaiting primary TKA without history of fracture, infection or osteotomy and with a preoperative alignment within 20° of mechanical axis deformity. The study group consisted of 400 male patients with a mean (standard deviation (SD)) age of 67.5 (9) years and 630 female patients with a mean (SD) age of 69 (10) years ($p = 0.01$). This proportion was chosen because it represents the male/female representation of the total knee population.

Table 1
Mean (SD) values of mediolateral (ML) diameter of the femur at four different levels and the aspect ratio (AP/ML) per gender at the four levels.

Gender	Item	Mean (SD) [mm]	Range [mm]
Male	ML1	55 (5)	42–76
	ML2	72.5 (5.5)	54–92
	ML3	83 (5.5)	64–97
	ML4	83 (5)	65.5–98
	AP/ML1	1.01 (0.09)	0.70–1.32
	AP/ML2	0.76 (0.06)	0.62–0.95
	AP/ML3	0.67 (0.04)	0.56–0.85
	AP/ML4	0.66 (0.04)	0.67–0.84
Female	ML1	50 (4.0)	35.5–77.5
	ML2	64.5 (5)	48–85
	ML3	74 (5)	35–88
	ML4	74 (5)	36–91
	AP/ML1	0.99 (0.08)	0.59–1.25
	AP/ML2	0.76 (0.07)	0.47–0.93
	AP/ML3	0.67 (0.05)	0.44–1.41
	AP/ML4	0.66 (0.05)	0.45–1.36

Table 2
Mediolateral (ML) size per gender at different levels and in relation to the femoral cut. Distalization is represented by minus values and proximalization by plus values.

Gender	Item	−4 mm	−2 mm	0 mm	+2 mm	+4 mm
Male	ML1	56 (5)	55.5 (5)	55 (5)	55 (5)	54.5 (4.5)
	ML2	71.5 (7)	72.5 (7)	72.5 (5.5)	72.5 (5.5)	72 (5)
	ML3	77.5 (6)	80.5 (6)	83.0 (5.5)	84 (5)	84.5 (5.5)
	ML4	81 (7.5)	82.5 (5.0)	83 (5)	83 (5)	83 (5)
Female	ML1	50 (4)	50 (4)	50 (4)	49.5 (4)	49.5 (4)
	ML2	63.5 (7.5)	64.5 (6)	64.5 (5.5)	64.5 (5)	64.5 (4.5)
	ML3	69.5 (6.5)	72 (5)	74 (5)	74.5 (5)	74 (4.5)
	ML4	73 (5.5)	74 (4)	74 (4.5)	74 (4.5)	74 (4.5)

A specific software program was developed for this study to measure the AP and ML sizes of the femur on CT-scans. All measurements are based on CT data and therefore do not include the cartilage thickness at different levels.

The ML size was initially measured at the epicondylar axis level in between both epicondyles. Then the ML width was measured at four different regions of the femur that correspond to the different zones of the femoral bone cuts and the inside of any femoral component (Fig. 1). Zone ML1 corresponds with the transition zone of the anterior and distal femoral cut. Zone ML2 corresponds with the anterior chamfer region. Zone ML3 is the posterior chamfer region and finally ML4 is the ML width of the condyles at the posterior level of the femur. The AP size of the femur was measured with neutral axial rotation following the epicondylar axis without accepting any anterolateral notching and with a fixed three degrees of flexion compared to the anatomical sagittal axis of the femur.

After making all these different reference measurements, the aspect ratio (AP/ML) was calculated for the different levels of the femur (AP/ML1, AP/ML2, etc.) with as axial alignment reference, the epicondylar axis. Once these aspect ratios were known the study variables were introduced being either a change in femoral resection level or a change in external rotation. The two variables were never combined. The change in femoral resection level was a CT-based simulation with either two or four millimeters more distal or more proximal resection. After these CT-based simulations the aspect ratios were again compared.

Furthermore the AP size was compared within different ranges of rotation, from five degrees internal rotation over neutral rotation to five degrees external rotation referenced of the Posterior Condylar Line. The CT-simulation allows calculation of femoral component sizes both in internal and external rotation, which would be very difficult intra-operatively. It is well known that the transepicondylar axis can be easily identified on CT scans [40].

2.1. Statistics

Sample characteristics are presented as numbers, means, SDs, and ranges. The normal distribution of the data was assessed using the Kolmogorov–Smirnov test. The nonnormally distributed data were analyzed using the nonparametric statistical Mann–Whitney test for independent samples and Wilcoxon signed rank test for dependent samples. Comparison of observed proportions was performed using chi-square and Fisher's exact test. Statistical analysis was conducted using Stata 12.1 (Stata Corp, College Station, TX, USA) and significance was set at $p < 0.05$.

3. Results

Measurement accuracy for the specific software program was one degree and 0.5 mm. The mean (SD) preoperative Hip-Knee-Ankle (HKA) angle for male patients was 175° (4.5°) (range, 164.5° to 191.5°) and 176.5° (5°) (range, 160° to 192.5°) for female patients ($p < 0.0001$), both measured with CT scan in a non-weight bearing position [41].

The mean (SD) ML width at the epicondylar axis level (distance medial to lateral epicondyle) of the femur was 87.5 (5) mm (range, 73 to 101 mm) for males and 77.5 (4) mm (range, 67 to 93 mm) for female patients ($p < 0.0001$). The mean (SD) ML