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ORIGINAL STUDY

Current fit of medial and lateral unicompartmental knee arthroplasty

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Whether failure in unicompartmental knee arthroplasty (UKA) is related to implant design remains unclear. We hypothesize that current available UKAs fit within 2 mm. Forty-eight CTs of cadaveric knees were compared to current available UKA brands. Overall no-fit compared to at least one component within 2 mm is high (91.7%) and worse for males (100%) compared to females (83.3%). Good fit was observed for the medial but not for the lateral tibia plateau. Seven males (29.2%) had larger dimensions of more than 2 mm. For the widest UKA brand, 12 (57%) males and 2 females (8. 3%) had lateral femoral condyles 3 mm larger. Current UKA's in our sample population fit less on the lateral tibia and on femoral condyles.

Keywords : knee arthroplasty ; component fit ; condylar dimensions ; unicompartmental knee arthroplasty ; medial and lateral condyle.

INTRODUCTION

Unicompartmental knee arthroplasty (UKA) has good long-term survivorship and is gaining popularity (*15,17*). Despite excellent clinical results (*5,13, 14,17*), early failure rates of UKA remain in the 5% range (*6,8,11,18*). Whether this is related to surgical technique, patient selection or implant design needs clarification. Some cohorts, such as obese patients have shown higher failure rates with specific, narrow implants (*2*).

We wonder whether femoral condyles and tibial plateaus are sufficiently covered with current available UKA designs. We hypothesize all current available components of modern UKA fit within 2 or 3 mm medial and lateral femoral condyles and medial and lateral tibia plateaus.

MATERIALS AND METHODS

Height, weight, and knee dimension sizes of a sample of cadaveric subjects were measured (Table I). All measurements were made 5 mm below the deepest point of the articular surface of the medial and lateral tibial plateau. The sample was composed of 24 female and 24 male cadavers, showing no significant arthritic changes. No details on age or race were available. We computed the mean and standard deviation of sample

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Table I. — Sample description and comparison of male to female measures

	Total	Males	Females	P-Value Comparing Males to Females
Height (cm)	168.7 (10.3)	173.6 (9.1)	163.4 (8.9)	$p < 0.001$
Weight (kg)	73.8 (21.9)	74.9 (22.2)	72.6 (20.6)	$p = 0.715$
Medial Tibia AP Length	5.06 (0.46)	5.37 (0.38)	4.75 (0.29)	$p < 0.001$
Medial Tibia ML Width	3.04 (0.32)	3.27 (0.25)	2.82 (0.19)	$p < 0.001$
Lateral Tibia AP Length	4.74 (0.46)	5.03 (0.34)	4.45 (0.38)	$p < 0.001$
Lateral Tibia ML Width	3.21 (0.32)	3.41 (0.26)	3.01 (0.23)	$p < 0.001$
Medial Condyle AP Length	5.73 (0.45)	6.01 (0.33)	5.45 (0.37)	$p < 0.001$
Medial Condylar ML Width	2.61 (0.29)	2.80 (0.23)	2.43 (0.22)	$p < 0.001$
Lateral Condyle AP Length	6.23 (0.51)	6.55 (0.35)	5.92 (0.45)	$p < 0.001$
Lateral Condylar ML Width	2.85 (0.33)	3.09 (0.25)	2.61 (0.19)	$p < 0.001$
Med/Fem Art. Surface AP Length	4.84 (0.41)	5.04 (0.35)	4.65 (0.38)	$p < 0.001$
Lat/Fem Art. Surface AP Length	4.46 (0.47)	4.71 (0.41)	4.22 (0.41)	$p < 0.001$
Lateral Tibia AP/ML Ratio	1.48 (0.09)	1.48 (0.11)	1.48 (0.08)	$p = 0.869$
Medial Tibia AP/ML Ratio	1.67 (0.09)	1.64 (0.10)	1.69 (0.08)	$p = 0.093$
Lateral Condyle AP/ML Ratio	2.20 (0.17)	2.13 (0.17)	2.27 (0.12)	$p = 0.002$
Medial Condyle AP/ML Ratio	2.21 (0.18)	2.16 (0.19)	2.25 (0.18)	$p = 0.080$

characteristics and performed t-tests to test for differences between male and female subjects. Using paired t-tests we also compared lateral and medial knee dimensions and tested for differences in the whole sample, among males only, and among females only. To examine how well the component dimensions defined two cutoffs for determining whether components would adequately fit the subject knee, a 2 mm no-fit was defined as a UKA component dimension at least 2 mm smaller than the measured knee dimension. We computed the proportion of subjects with at least one knee dimension 2mm larger than at least one brand of UKA component.

We computed the proportion of the sample with knee dimensions at least 2 mm larger and compared measurements to current available UKA systems (Table II & III). We focused on the two largest models (DePuy HP and Zimmer HF). The DePuy HP have the longest and widest tibial and Zimmer HF have the widest femoral condyle dimensions. Of the subjects whose knees are at least 2 mm larger than the DePuy and Zimmer components we determined how often it was the medial or lateral condyle ML width which was too wide or how often the tibial AP medial and lateral lengths were too long, and how often the tibial ML medial and lateral widths were too wide (Table IV).

RESULTS

The sample was composed of 24 female and 24 male cadavers. Height, weight and dimensions for medial, lateral femoral and tibial plateau are displayed in Table I. Differences of each measurement are included. While AP/ML ratios were similar between males and females on the lateral tibial plateau, there were differences for the medial tibial plateau and lateral femoral condyle. Among the total sample, lateral femoral condyle AP length was significantly longer than the medial condyle. The same relationship was also true for ML condyle width. Tibial lateral AP length was significantly shorter than the medial length while the lateral tibia ML width was longer than medial tibia ML width. Medial and lateral femoral condyle AP/ML ratios were similar while the medial tibia AP/ML ratio

Table IIa. — Tibial implant dimensions (cm) of available UKAs

	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6
	AP - ML (Ratio)	AP - ML (Ratio)	AP - ML (Ratio)	AP - ML (Ratio)	AP - ML (Ratio)	AP - ML (Ratio)
[1] Stryker Triathlon	4.1-2.3 (1.78)	4.4-2.5 (1.76)	4.7-2.7 (1.74)	5.0-2.9 (1.72)	5.3-3.1 (1.71)	5.6-3.3 (1.70)
[2] DePuy Sigma® High Performance Partial Knee System	4.2-2.4 (1.75)	4.5-2.6 (1.73)	4.8-2.8 (1.71)	5.1-3.0 (1.70)	5.4-3.2 (1.69)	5.7-3.4 (1.68)
[3] Zimmer Unicompartmental High Flex Knee System	4.1-2.3 (1.78)	4.4-2.5 (1.76)	4.7-2.7 (1.74)	5.0-2.9 (1.72)	5.3-3.1 (1.71)	5.6-3.3 (1.70)
[4] Smith and Nephew *Journey*	3.8-2.4 (1.58)	4.2-2.5 (1.68)	4.6-2.7 (1.70)	4.9-2.9 (1.69)	5.2-3.0 (1.73)	5.5-3.2 (1.72)
[5] Biomet *Oxford*	3.8-2.6 (1.46)	4.1-2.6 (1.58)	4.4-2.8 (1.57)	4.7-3.0 (1.57)	5-3.2 (1.56)	5.3-3.4 (1.56)
[6] Wright *Advance*	4.0-2.4 (1.67)	4.4-2.6 (1.69)	4.9-2.9 (1.69)	5.4-3.3 (1.64)		

Table IIb. — Femoral implant dimensions of available UKAs

	Femoral ML Width	
	Min (cm)	Max (cm)
[1] Stryker Triathlon	1.9	2.4
[2] DePuy Sigma® High Performance Partial Knee System	1.8	2.5
[3] Zimmer Unicompartmental High Flex Knee System	2.1	2.6
[4] Smith and Nephew Journey	1.8	2.5
[5] Biomet Oxford	1.9	2.3
[6] Wright Advance	1.9	2.2

was significantly longer than the lateral ratio. The same relationships were true among males and females only.

Eighteen knees were measured by two observers describing observer agreement for the knee dimensions with means for coefficient of variation between 0.01 and 0.22. Our small coefficient of variations indicate low variability with respect to the size of the mean.

Current available UKA brands have different dimensions, different AP/ML ratios and vary between sizes. Tibial components AP lengths ranged from 3.8 cm to 5.7 cm and tibia ML width ranged from 2.3 cm to 3.4 cm, corresponding to AP/ML ratios ranging between 1.46 and 1.78 (Table III). Femoral ML width ranged from 1.8 cm to 2.6 cm. DePuy HP had the largest tibial component (AP length = 5.7 cm, ML width = 3.4 cm) while Zimmer HF had the largest femoral ML width (2.6 cm). All female tibial knee dimensions fall within +/- 2 mm of the range of UKA component dimensions for all UKA brands. Two knees exceeded the ML width dimensional range for all brands of UKA components while one exceeded all AP length dimensional ranges.

UKA dimensions are smaller than measured sizes and overall no-fit compared to any component within 2 mm is high (91.7%) and worse for males (100%) compared to females (83.3%) (Table IV). Comparing the UKA brand with the longest AP dimensions good fit was observed for the medial tibial plateau (Table IV) : two male knees (8.3%) had longer AP dimension of 2 mm. For the widest ML UKA brand three male knees (12.5%) had wider ML dimensions of 2 mm. For the lateral tibial plateau, AP fit

Table III. — Proportion of sample with 2 mm-fits of components[1] to knee dimensions

	Total		Males		Females	
	2 mm-Fit N (%)	2 mm-No Fit N (%)	2 mm-Fit N (%)	2 mm-No Fit N (%)	2 mm-Fit N (%)	2 mm-No Fit N (%)
Any component[2]	4 (8.3)	44 (91.7)	0 (0.0)	24 (100)	4 (16.7)	20 (83.3)
DePuy[3]	13 (27.1)	35 (72.9)	0 (0.0)	24 (100)	13 (54.2)	11 (45.8)
Zimmer[4]	20 (41.7)	28 (58.3)	2 (8.3)	22 (91.7)	18 (75.0)	6 (25.0)

[1] 2 mm-Fit defined as subject knee dimension lies within +/- 2 mm of component dimension, 2 mm-No Fit defined as subject knee dimension larger than component dimension +2 mm.
[2] Any component displays number and proportion of sample with at least one knee dimension larger than at least one of the available component sizes.
[3] DePuy has longest Tibial AP Length and widest Tibial ML Width.
[4] Zimmer has widest Femoral condylar ML Width.

Table IV. — Dimensions where DePuy and Zimmer components are 2 mm smaller than subject measures

	DePuy dimensions 2 mm larger than subject measure[1]		Zimmer dimensions 2 mm larger than subject measure[2]	
	Males N (%)	Females N (%)	Males N (%)	Females N (%)
Total	24 (100.0)	11 (45.8)	22 (91.7)	6 (25.0)
Femoral condyle[3] ML Width				
Medial	17 (70.8)	4 (16.7)	16 (66.7)	2 (8.3)
Lateral	23 (95.8)	10 (41.7)	21 (87.5)	5 (20.8)
Tibia AP Length				
Medial	2 (8.3)	0 (0.0)	3 (12.5)	0 (0.0)
Lateral	0 (0.0)	0 (0.0)	1 (4.2)	0 (0.0)
Tibia ML Width				
Medial	3 (12.5)	0 (0.0)	6 (25.0)	0 (0.0)
Lateral	7 (29.2)	0 (0.0)	12 (50.0)	1 (4.2)

[1] DePuy has longest Tibial AP Length and Tibial ML Width.
[2] Zimmer has widest Femoral Condylar ML Width.
[3] AP length of condylar component part not published – sole comparison for this part of the UKA component is the ML width.

within 2 mm was good and only 1 male knee (4.6%) exceeded 2 mm. The ML fit for the widest UKA brand showed 7 male knees (29.2%) had larger dimensions of more than 2 mm.

Coverage of the medial and lateral femoral condyle is worse. Femoral condyle ML widths were at least 2 mm longer than the widest femoral component for 16 (66.7%) of male medial condyles, 21 (87.5%) of male lateral condyles, 2 (8.3%) of female medial condyles, and 5 (20.8%) of female lateral condyles.

DISCUSSION

As more encouraging long-term results after UKA are published, indications are extended to younger and heavier patients. Weight and activity have been discussed controversially in the literature and some implants reported no higher failure rate in heavier patients in resurfacing Marmor implants (*4,5*). Similar results were published for the Miller-Gallante UKA (*1,9,15,16,22*) but not with inset all-poly tibiae or narrow implants in patients with a BMI above 32 (*2*). We wondered whether, besides implant design and surgical technique, the dimensions of femoral and tibial implants could play a role and how well current available implants fit.

We hypothesized that all currently available components of modern UKA fit within 2 mm.

For the medial tibial plateau overall implant fit was better for females. Looking at the implant with the largest ML width, 12.5% had wider tibial plateaus by 2 mm. This describes the best case scenario using the largest implant in respect to AP length and ML width. We did not compute the coverage for smaller implants, which would result in worse coverage and higher percentages of patients with larger medial or lateral tibial plateaus. However, these numbers show that specifically for larger males, improvement of tibial coverage is desirable for both tibial plateaus but even more so on the lateral side.

The poor fit of femoral components should be cautiously interpreted. Both condyles have a different geometry with the medial femoral condyle being more curved and the lateral condyle being more straight. Given these geometric differences the implants have to be narrower, otherwise surgeons would not be able to rotate and place the components along the specific curvature of both condyles. Asymmetric components fit better on the medial side and worse laterally. A symmetric femoral component fits better onto the lateral condyle. No femoral component is designed for the lateral condyle with an anterior radius twice that of the medial side and being shorter anteriorly compared to the medial condyle (*12,20*).

Our measurements are comparable to other publications which studied tibial fit. Servien *et al* (*19*) measured tibial CT after 17 medial and 18 lateral UKA's. Average AP length was 50.8 mm for the medial and 47.2 mm for lateral plateau with a ML width of 28.8 medially and 29.3 on the lateral side. They calculated an AP/ML ratio of 1.8 medial and 1.6 lateral. Our measurements are similar, but our ML widths are wider. We measured CTs of normal non-arthritic knees 5 mm below the lowest point of medial and lateral tibial plateau, which may be slightly higher compared to Servien *et al* (*19*) measurements, since they measured the dimension just below the implant of CT. Servien *et al* sample was not well balanced, since 31 of 37 subjects were females (*19*). Servien *et al* observed that some tibial components matched the medial tibial plateau better than others and vice versa the lateral tibial condyle. Authors felt that better coverage could be a success factor. Surgeons tend to avoid medial overhang and therefore downsize the tibial implant by compromising anteroposterior coverage.

For the Korean population, smaller values are described in one publication for the medial tibia only : 47.1 mm for AP dimension (male 49.8 mm and female 47.1 mm) and 24.8 mm for ML dimension (26.1 mm for male and 23.5 mm for females) (*21*). Our measurements are similar for the female AP lengths, but not for the rest : our male AP measurements are 6 mm longer and our ML dimensions 6 mm wider (males 7 mm wider and females 5 mm). Surendan *et al* (*21*) concluded that for the Korean population UKA brands tend to oversize in the ML dimension. Fitzpatrick *et al* concluded that even theoretical optimized implants could not cover more than 76% of the exposed cortical rim (*7*). Insufficient tibial coverage may induce tibial plateau collapse (*3,10*) if forces are transmitted to cancellous bone. The described differences of various components are important and surgeons may benefit from knowing specific sizes in regard to AP length and ML width for medial, lateral femoral and tibial condyles.

Our study describes limitations of current available unicompartmental implants for both, medial and lateral, femoral and tibial condyles. The worst fit was observed for the lateral tibial plateau and for both femoral condyles. A different tibial implant, rounder with a lower AP/ML ratio would improve lateral tibial plateau fit. Design improvements for medial and lateral femoral condyles are difficult and limited due to the different geometry of medial and lateral femoral condyles. Surgeons should be aware of the consequences of using an asymmetric versus a symmetric femoral component for either medial or lateral femoral condyle and the consequences of poor fit. Surgeons should use implant sizes and their potential to improve implant fit for their different patients.

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