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# An Analysis of the Relationship between the Morphometry of the Distal Femur, and Total Knee Arthroplasty Implant Design

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## ABSTRACT

Current available implants for total knee replacement are based on the mormphometry of the Caucasian knee. We believe there are significant morphometric differences in the Asian knee that will be relevant in future implant designs. Sixty-nine consecutive patients (80 knees) underwent computer navigated primary total knee arthroplasty. The anterior-posterior (AP) length, and the medial-lateral (ML) width of the distal femur, were analyzed, with respect to the final sizing details of four implants (femoral component) commonly used locally. The mean AP length was 59.9 (SD 4.8) mm, and the mean ML width was 65.0 (SD 5.0) mm. The overall mean aspect ratio (ML/AP) was 1.09 (SD 0.07). The mean aspect ratio for females was 1.08 (SD 0.07). Both were smaller than the aspect ratio of the implants - which ranged from 1.11 to 1.13. All four implants tend to 'over-hang' at the medial-lateral width of the distal femur. This is more obvious in females. Future implant designs should provide more 'ML w›dth' sizes for a given 'AP length', in addition to gender differences, for th›s population.

Key Words:
*Computer Navigation, Morphometry Measurement, Malaysian Knees, Total Knee Arthroplasty*

## INTRODUCTION

The key factors to a long term success in total knee arthroplasty are accurate bone cut and appropriate implant size. These aim to achieve the best match between the prosthesis, and the resected bone surfaces. The two variables used to select the femoral implant size are the anterior-posterior (AP) length, and the medial-lateral (ML) width. The antero-posterior diameter is important in maintaining flexion-extension spacing and optimal tension in the quadriceps mechanism [1]. The medial-lateral diameter determines adequate coverage of the resected bone surfaces, which allows even stress distribution, tension-free wound closure, and smooth tracking of the patellar component in the trochlear groove during flexion [2].

Most of the available morphological data of normal knees are obtained from cadaveric studies, or radiographs of subjects not requiring surgery [3-6]. Osteoarthritic knees are usually deformed, and anatomically different from normal knees. Other morphological measurement methods are three-dimensional computed tomography [7] and manual slide calipers [8].

The objective of this study was to investigate the use of a computer navigation system for in vivo measurement of the AP lengths and ML widths of osteoarthritic knees in the Malaysian population and to compare these measurements to currently available implants in terms of differences according to gender and race. Our intent is to provide implant designers with morphometric information justifying the production of better fitting implants for the Malaysian population.

## MATERIALS AND METHODS

This is a singe centre observational cross sectional study, with all procedures performed by a single surgeon. The Scorpio® NGR PS knee was implanted, with the Stryker® Navigation Computer-Assisted Surgery System – eNact Knee (3.1) module. We adhered to standard surgical procedures. Sixty-nine patients (80 knees) underwent computer navigated primary total knee arthroplasty in the joint replacement unit of Kuala Lumpur Hospital. This study was conducted from 1st July 2007, until 31st June 2008. Patients with substantial bone loss and/or degeneration requiring augmentation, knee varus or valgus deformity of more than 15° and patients with an immature skeletal system were excluded from the study.

Digital mapping of the distal femur included the most proximal part of the junction between bone and articular surface, after the removal of osteophytes. The anterior - posterior (AP) length was then calculated by the Stryker® eNact Knee Software (3.1), based on the most anterior, and the most posterior points (Figure 1). The medial - lateral

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**Table I:** Number of knee-implant mismatches among four different brands of implants

| | SCOPIO | GENESIS | NEXGEN | PFC sigma |
|---|---|---|---|---|
| Unmatched | 46 (57.5%) | 48 (60%) | 49 (61.3%) | 42 (52.5%) |
| Matched | 34 (42.5%) | 32 (40%) | 31 (38.7%) | 38 (47.5%) |

**Table II:** Difference of distal femur measurements according to gender

| | Gender | N | Mean(mm) | |
|---|---|---|---|---|
| AP | Male | 11 | 64.55 | P<0.0001 |
| | Female | 69 | 59.14 | |
| ML | Male | 11 | 72.45 | P<0.0001 |
| | Female | 69 | 63.83 | |

**Table III:** Differences in distal femur measurements among races in Malaysia

| | Race | N | Mean(mm) | |
|---|---|---|---|---|
| AP | Malay | 24 | 59.88 | p>0.05 |
| | Chinese | 44 | 59.45 | |
| | Indian | 12 | 61.50 | |
| | Total | 80 | | |
| ML | Malay | 24 | 65.46 | p>0.05 |
| | Chinese | 44 | 64.68 | |
| | Indian | 12 | 65.33 | |
| | Total | 80 | | |

(ML) width was measured from the most medial and the most lateral point of the resected femur, along the trans-epicondylar axis.

The final implanted size was that which most closely approximated the anterior-posterior dimensions of the patient's knee. Since the AP size is determined from the procedure of anterior or posterior referencing, we attempted to compare ML dimensions of three other implants (Genesis II, NexGen and PFC sigma) which all had similar AP dimensions.

For every AP length, the ML width of four implants was compared with the patient's ML width. The 'matched' category was cases with no over-hang, and any differences within 5mm. The 'unmatched' category was cases with over-hang, or no over-hang, but differences exceeding 5mm [13]. The percentage of matched and unmatched was determined for the four types of implants.

The AP measurements were then plotted against the ML measurements in a scatter gram. A best fit line was calculated by least square regression. This was compared with the dimensions of the femoral components of the four most commonly used implants in this country: Scorpio NGR, Genesis II and NexGen and PFC sigma.

Gender and racial differences were analysed. The relationship between femur aspect ratio (ML/AP), and the anterior-posterior measurements were evaluated. These were compared with the four implant designs for both sexes. The dimensions were given as means and standard deviations. Comparisons of dimensions and gender differences were done with the Independent Sample t-test and the Mann Whitney U-test, since the ML data was not of normal distribution. A p value of <0.05 indicated a significant outcome. Comparisons of dimensions and racial differences were made with the One-Way ANOVA test.

## RESULTS

There were 69 patients (60 females, and 9 males), with a mean age of 64.5 (SD 8.68, and range 48 to 82) years old. The racial makeup was Chinese (55%), Malay (29%), and Indian (16%). Eleven patients had bilateral total knee arthroplasty.

The overall mean AP length of the femur surface was 59.9 (SD 4.8) mm, and the overall mean ML width was 65.0 (SD 5.0) mm. In terms of ML mismatch, more than 50% of the subjects had ML mismatch with all four implants, with the highest number occurring in the NexGen implant (Table I). There was a close correlation between the morphological data and the dimension of implants, but all four implants tended to over-hang at the resected femur surface, especially with the larger sizes (Figure 2).

The mean AP length for female patients was 59.14 (SD 4.23) mm, and the mean ML width was 63.83 (SD 3.78) mm. For male patients, the mean AP length was 64.55 (SD 6.06), and the ML width of 72.45 (SD 5.61) mm. Resected femur surfaces of female subjects were significantly smaller than male subjects, with p<0.0001 in both the t-test and the Mann Whitney U-test (Table II). The femoral components for women tended to be too large for given AP measurements, with the most over-hang occurring in the larger sizes. This over-hang was more obvious in females (Figure 3).

Analysis by race showed that Indians with the largest knee dimensions, with a mean AP length of 61.50 (SD 5.62) mm, and a mean ML width of 65.33 (SD 4.56) mm. This was followed by the Malays, with a mean AP length of 59.88 (SD 5.37) mm, and a ML width of 65.46 (SD 6.23) mm. The Chinese had the smallest knee dimensions with an AP length of 59.45 (SD 4.33) mm, and a ML width of 64.68 (SD 4.47) mm. However, the One Way ANOVA test failed to show any significant differences (Table III).

The overall mean aspect ratio (ML/AP) was 1.09 (SD 0.07). The mean aspect ratio for females was 1.08 (SD 0.07). These were smaller than the aspect ratios of the implants, which range from 1.11 to 1.13. The males had a mean aspect ratio of 1.13 (SD 0.06); this was within the range of the four implants. The femoral aspect ratio, from the morphological data showed a higher ratio for smaller knees, and a proportionally lower ratio for larger knees. The four designs showed little change in the relationship between aspect ratio, and the anterior-posterior dimension (Figure 4).

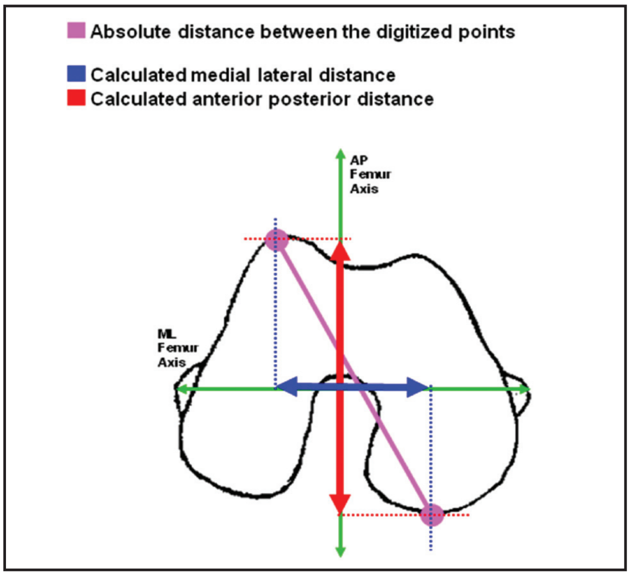


**Fig. 1:** Calculation of anterior-posterior length and medial-lateral width.

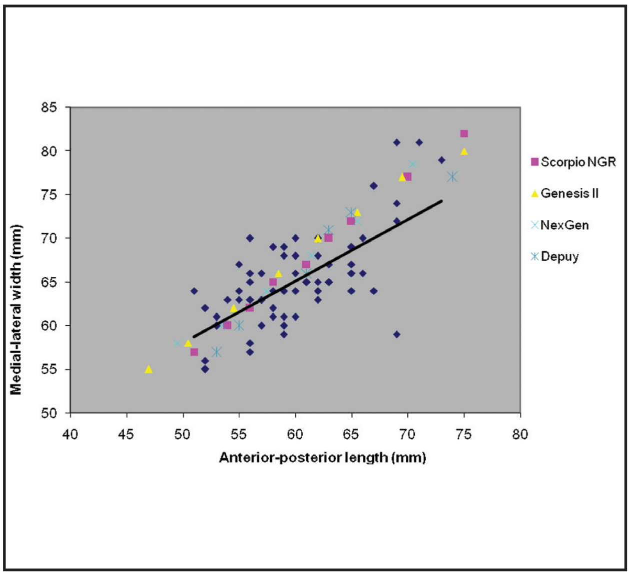


**Fig. 2:** Femoral Medial-Lateral (ML) Measurements vs. Anterior-Posterior measurements for eighty knees, showing ML overhang increases as the implant size increases.

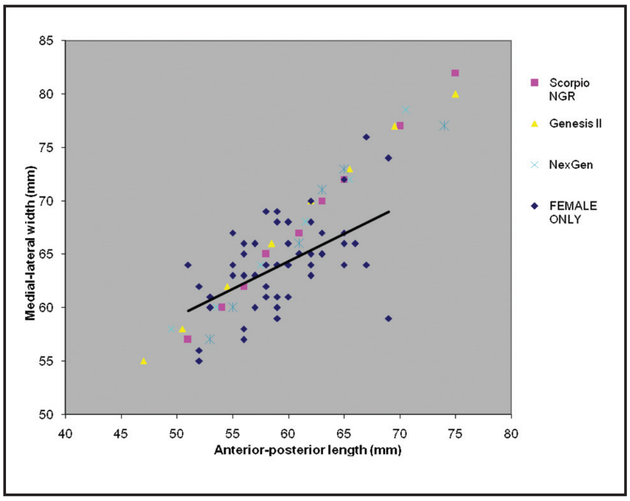


**Fig. 3:** Femoral medial-lateral (ML) measurements vs. anterior-posterior measurements for female patients only, showing ML overhang more prominent than male patients.

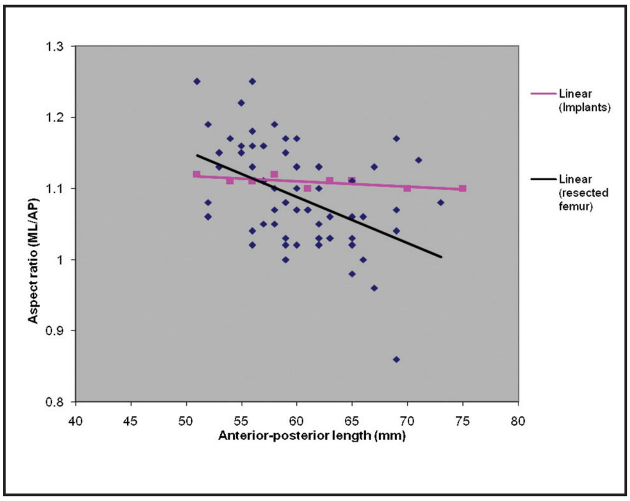


**Fig. 4:** Femoral aspect ratio (ML/AP) versus anterior-posterior (A/P) measurements (mm) for 80 knees, showing a higher aspect ratio for smaller knees and a proportionally lower ratio for larger knees. The four designs showed little change in the aspect ratio with the anterior-posterior dimension.

## DISCUSSION

It is well documented that the Asian knee dimensions are much smaller than their Western counterparts [6, 14]. In cadaveric studies, with non-arthritic knees, the mean AP length of the lateral femoral condyle was 63.3 (SD 4.7) mm for the Chinese [14], and 64.2 (SD 3.4) mm for the Singaporeans [15]. Intra-operative measurement of the osteo-arthritic knee in Taiwan was performed by W.P.Ho *et.al* [16] using manual calipers showed a mean AP of 63.7 (SD 5.1) mm, which was quite similar to the cadaveric studies. This is due to the fact that the lateral condyles of osteo-arthritic knees are usually unaffected [16].

The mean AP length in this study was 59.9 (SD 4.8) mm, which was comparatively smaller. The measurements in this study were more representative of the distal femur, as it took into consideration the distance between the most anterior and the most posterior points, in addition to the length of the lateral condyle.

The mean ML width in this study was 65.0 (SD 5.0) mm which was smaller than Urabe et al's study (70.6 (SD 4.5) mm) which used three-dimensional computed tomography to measure the resected femoral sections for Japanese patients [7]. These were also smaller than W.P.Ho et.al's study (70.2 (SD 5.4) mm) [16].

Our knee measurement results were not only comparatively smaller than the Caucasians, but also smaller than other Asian sub-populations. Therefore, the risk of implant over-hang, and its associated complications are significant in the Malaysian population. The need for a better 'fitting' implant is crucial to ensure the long term success in total knee arthroplasty.

It is impossible to expect a few implant sizes to fit well into patients with different knee dimensions. Problems occur especially when the knee dimensions fall into the in-between sizes. Most of the time, the surgeon needs to down or up-size depending on the site of referencing in order to avoid any obvious over-hang.

Down-sizing of implants, means the surgeon needs to cut more bone either from the anterior or posterior distal femur. Excessive anterior bone cuts will lead to anterior notching, while excessive posterior bone cuts will cause flexion laxity and reduced momentum. Down-sizing of components could also result in exposed cancellous bone, which could be a source of increased intra-articular bleeding during the immediate post-operative period, and may lead to increased osteolysis from wear debris, during longer follow-up. To avoid the above problems, one can cut less bone, i.e., up-size, but this will lead to patella-femoral joint over-stuffing, especially if the anterior distal femur is cut less. On the other hand, if the posterior is cut less, it will lead to tight flexion post-operatively.

A solution may be custom-fit implants such as The OtisKnee. However, at the present moment, these custom fit implants are not practical, and have been found to result in malalignment [17]. A better and more practical solution would be to design implants based on the morphological data of the local population, with several ML widths for one AP length to obtain a better anatomical fit [11].

Studies have shown distinctive shape differences in female and male distal femurs. Female femurs are more trapezoidal-shaped, and narrower in the ML dimension, when compared to the male femur of the same AP dimension [18]. This was also consistent in our study. Newer implants such as the Triathlon and Gender Solution, have taken these gender differences into consideration, but outcome results are still only preliminary. There is little, in the literature to suggest an inferior result when a TKA is performed for a female. Some authors believe that there is too much focus on the gender specific implant currently, and that there is little evidence to suggest that these sex-specific changes will translate into improved outcomes. Further research is needed to assess the impact of sex-specific design changes [19].

## CONCLUSION

We conclude that current implant designs of TKR are not optimal for Malaysian knees, which are generally smaller than Caucasian counterparts. The mean AP length was 59.9 mm, the mean ML width was 65.0 mm, and the overall mean aspect ratio (ML/AP) was 1.09. The results of this study can provide a guide for future implant design to help provide better fitting implants for the local population.

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