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## INFLUENCE OF FEMUR'S MORPHOLOGY AND LOWER LIMB MISALIGNMENT ON KNEE MEDIAL INTRA-ARTICULAR SPACE REDUCTION

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### SUMMARY

Several factors can change lower limb alignment, including femur morphology. A large misalignment may increase joint stress, decrease intra-articular space and contribute for the development and progression of knee osteoarthritis. Thus, the aim of this study was to determine the influence of femur's morphological land markers and lower limb misalignment on the intra-articular space (IAS) of the knee medial compartment. Results: Association of the 0.91 and 82% multiple influences between femur's morphology and IAS were observed. A negative correlation was observed between the femur neck length (FNL) and the angle between femur anatomical and mechanical axes ( $\Theta_{FM-FA}$ ) with IAS. A positive correlation was observed for condylar hip angle ( $\Theta_{CH}$ ) and femoral neck angle ( $\Theta_{FN}$ ) with IAS. Limb misalignment showed a 0.93 association of hip-knee-ankle angle ( $\Theta_{HKA}$ ) and condylar plateau angle ( $\Theta_{CP}$ ) with IAS. Also an 86.6% multiple influences were observed with IAS variation. Conclusion: Strong association and multiple influences were observed between femur's morphology and lower limb misalignment with narrowing of the IAS.

### INTRODUCTION

The knee mechanical stress generated by lower limb varus misalignment seems to have strong worldwide prevalence [1]. Approximately 60% of the body weight crosses the medial knee compartment in normal subjects [2]. However, different bone morphology and lower limb misalignment may increase the amount of body weight crossing the knee medial compartment, reducing the intra-articular space and increasing the risk of joint degeneration. The load bearing axis (LBA) is a line originated at the center of the femoral head that crosses the knee joint and ends at the talus [1-3]. Morphological changes in the femoral neck angle ( $\Theta_{FN}$ ), femoral neck length (FNL), physiologic femoral valgus and condylar hip angle ( $\Theta_{CH}$ ) may also have an influence on the LBA position with respect to the knee, increasing the misalignment and, consequently, decreasing the IAS. However, apparently there has been no study aimed at identifying a possible association and/or influence of the femur's anatomical structure with the IAS. Therefore, the purpose of this study was to determine the degree of association and the specific influence of the femur's

dimensions in lower limb misalignment and reduction of intra-articular space in knees varus.

### METHODS

#### Lower limb radiographic imaging

A digital radiographic panoramic image was obtained at an antero-posterior view for each patient. Collection procedures involved: (1) positioning of the transducer at 90° between the central X-rays beamer and the floor; (2) standardization of the focal-transducer distance (FTD); (3) patient barefoot with the tibial tubercle facing forward and body weight distributed equally between the two limbs; (4) demarcation of the central X-rays beam entrance area at the transducer; (5) measurement of the thigh's thickness and the distance between the thigh and the transducer, to determine the object-transducer distance (OTD); (6) lower limb alignment with the focal point plan and with the transducer, to minimize the segment rotational effects and image distortion; (7) peak kilo-voltage (kVp) was set between 80 and 90, with a current of the 100-300 milliamperes (mA) and a 5-sec exposure time; (8) images were obtained in the "Digital Image Communications in Medicine" (DICOM) format; (9) a correction factor was applied to anatomical regions of interest; (10) calibration of images for subsequent data analysis was performed by a semiautomatic interface data analysis script developed in Matlab ® 7.0

#### Determination of femur's morphology

A group of femoral morphological characteristics were selected to answer the questions of this study [1-3].

$\Theta_{FM-FA}$ : the "physiologic valgus" was determined as the angle between the femoral anatomical (FA) axis and femoral mechanical (FM) axis.

FNL: "femoral neck length" was determined by a line passing from the center of the femoral head, going from the femur neck to the femoral diaphysis.

$\Theta_{FN}$ : "femoral neck angle" was determined as the angle between the line of the FNL and the femur anatomical axis.

$\Theta_{CH}$ : "condylar hip angle" was the angle between the femoral mechanical axis and the femoral condyle plateau.

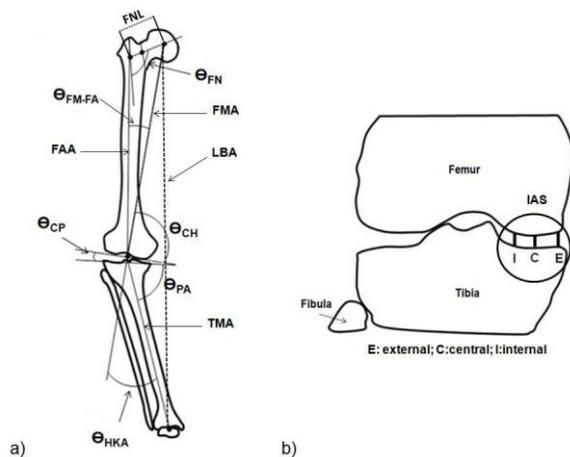
$\Theta_{PA}$ : "tibial plateau angle" was the angle between the tibial mechanical axis and the tibial plateau.

$\Theta_{CP}$  : “condylar plateau angle” was the angle between the femoral condylar plateau and the tibial plateau.

$\Theta_{HKA}$ : “hip-knee-ankle angle” was calculated by equation 1.

$$\Theta_{HKA} = (\Theta_{CH} + \Theta_{PA}) + \Theta_{CP} \quad \text{equation 1.}$$

Figure 1 shows the medial compartment of the intra-articular space (IAS): 1) the outer compartment region (E) 2) central compartment region (C), 3) the inner compartment region (I). All areas are points between the distal femur and the proximal tibia. Of these three measures, the lowest value was selected and considered the knee medial compartment minimum IAS.



**Figure 1.** Antero-posterior view of the main anatomical structures for lower limb morphology characterization and alignment. a) lower limb with varus alignment: FMA: femoral mechanical axis; TMA: tibial mechanical axis; LBA: load bearing axis;  $\Theta_{FN}$ : femoral neck angle; FNL: femoral neck length;  $\Theta_{FM-FA}$ : angle between the femoral anatomical axis and femoral mechanical axis “physiological valgus”;  $\Theta_{CH}$ : condylar hip angle;  $\Theta_{PA}$ : tibial plateau angle;  $\Theta_{CP}$ : condylar plateau angle;  $\Theta_{HKA}$ : hip-knee-ankle angle. b) Determination of the minimal medial knee joint compartment space: E: external; C: central; I: internal. IAS: intra-articular space.

### Statistical Procedures

A multivariate regression test (Stepwise Regression) was performed in order to determine which parameters were

associated with changes in the IAS. Two groups of predictor variables for a predicted variable were established: Predictor variables of lower limb misalignment:  $\Theta_{CP}$ ;  $\Theta_{HKA}$ . Predictor variables for segment morphology:  $\Theta_{FM-FA}$ , FNL,  $\Theta_{FN}$ ,  $\Theta_{CH}$ , and  $\Theta_{PA}$ . Predicted variable: IAS.

### RESULTS

A 0.91 association and an 82% multiple influence between the femur’s morphology and IAS was observed ( $F(4.79) = 95.961$ ;  $p < 0.001$ ). A negative correlation was observed between FNL and  $\Theta_{FM-FA}$  with IAS. With one SD increase in FNL there was a -0.31 SD reduction in IAS. Similarly, one SD increase in  $\Theta_{FM-FA}$  determined a -0.24 SD reduction in IAS. For  $\Theta_{CH}$  and  $\Theta_{FN}$  we observed a positive correlation with IAS, where one SD increase in  $\Theta_{CH}$  determined a 0.25 SD increase in IAS, and one SD increase in  $\Theta_{FN}$  determined a 0.25 SD increase in IAS. Limb misalignment: A 0.93 association was observed between  $\Theta_{HKA}$  and  $\Theta_{CP}$  with IAS, with 86.6% multiple influence of the variation in IAS ( $F(2.81) = 262.555$ ;  $p < 0.001$ ). One SD increase in  $\Theta_{HKA}$  determined a -0.79 SD reduction in IAS. As for  $\Theta_{CP}$ , one SD increase in this variable determined a -0.17 SD reduction in IAS.

### CONCLUSIONS

A strong association and multiple influences of femur’s morphology and of lower limb misalignment with a reduction in the IAS were observed. These findings are evidence that anatomical bone structure and lower limb misalignment significantly contribute for the appearance and progress in knee joint degeneration. These results may help health professionals to better understand the influence of morphological and functional factors in the development of knee osteoarthritis, and show the relevance of a good biomechanical lower limb evaluation for the proper limb realignment if surgery is needed to correct the alignment.

### REFERENCES

1. Cooke T.D.V, et al. The Journal of Rheumatology. v 34, N 9: 844-845, 2007b.
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3. Kettelkamp D. B, et al. Clinical Orthopedics and Related Research . N 83: 202-213, 1972.

**Table 1.** Morphological factors associated with reduced IAS: multivariate analysis (n = 85).

	Variable	Regression Coefficient (beta)	Standard error (beta)	t	p	Z Score
Morphologic	Coefficient	3.55	2.84	21.24	0.016	
	FNL	-0.08	0.02	-3.67	0.000	-0.31
	$\Theta_{FM-FA}$	-0.32	0.11	-2.96	0.004	-0.24
	$\Theta_{CH}$	0.26	0.06	4.14	0.000	0.25
	$\Theta_{FN}$	0.05	0.01	3.21	0.002	0.23
Geometric	Coefficient	5.50	0.10	50.32	0.000	
	$\Theta_{HKA}$	-0.39	0.02	-13.36	0.000	-0.79
	$\Theta_{CP}$	-0.12	0.04	-2.88	0.005	-0.17

FNL: femoral neck length;  $\Theta_{FM-FA}$ : physiologic valgus;  $\Theta_{CH}$ : condylar hip angle;  $\Theta_{FN}$ : femoral neck angle.  $p < 0.05$ .