EFFECT OF DESIGN PARAMETERS IN FB & MB UKA BIOMECHANICS

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Background

Unicompartmental Knee Arthroplasty (UKA) is a valid and less invasive alternative to Total Knee Arthroplasty for well-selected patients presenting single-compartment knee degeneration. Knee after UKA can reproduce the motion of the intact knee [1], with excellent results at 10 years of follow-up with modern designs [2].

Nowadays both Fixed Bearing (FB) and Mobile Bearing (MB) UKAs are available on the market, and different meta-analysis have demonstrated that both prostheses provided excellent clinical outcomes and survivorship in patients with UNI knee OA [3].

The aims of this study are (1) to identify the main design parameters used to develop and implant FB and MB UKA and (2) to analyze the effects induced by these different parameters in a FB and in a MB UKA, using a sensitivity analysis coupled with a validated finite element model [4,5].

Methods

For both MB and FB UKA, five design parameters were considered: polyethylene insert thickness, tibial component material, friction coefficient, anteroposterior slope, and tibial bone cut thickness. Two control models were defined based on the conventional features for MB and FB implants. The UKA configurations were then implanted in a knee joint model, following the surgical indications as reported by the manufacturer. A total of 216 configurations were analyzed, both at 0° and 90° of flexion, considering different parameter combinations, with a Finite Element Analysis based on previously validated models [4,5]. In detail, the distal extremity of the tibia was constrained and a vertical force was applied, equal to three times the average body weight, proportionally split between the medial and lateral compartments [4]. The results of the analysis were evaluated in terms of the change in average Von Mises stress in the tibial bone (considering four different regions of interest (medial and lateral, proximal and distal), contact area and average Von Mises Stress in the polyethylene insert.

Results

Results demonstrate that any design parameters alteration induces a variation from the control configuration both in terms of poly and bone stress. Among the analyzed parameters, bearing thickness, tibial bone cut, and slope angle are the most sensitive parameters for both implants. Figure 1 and 2 reported, for 0° of flexion, the percentage change from the control values in the different outputs, induced by the different parameters for a FB and an MB UKA.

Due to the different polyethylene insert design (flat for the FB and congruent for the MB UKA), the change in the polyethylene insert outputs are more sensitive in the fix-bearing designs. Due to the different materials used for the tibial baseplate, titanium for the FB and CoCr for the MB, the change in bone stress is more sensitive in the mobile designs.

Conclusions

Any change in the design parameters induced a variation (in terms of insert and bone stress) in comparison with the control configuration. FB designs led to lower bone stress variations, while MB design guaranteed more constant values for the insert.

References

1. Heyse et al, KSSTA, 22:1902-10, 2014.
2. Wilson et al, BMJ, 364:I352, 2019.
3. Zhang et al, Scientific Report, 10:19705, 2020.
4. Innocenti, et al, JOA 31(12):2685-91, 2016.
5. Innocenti, et al, JOA 31(1):295-301, 2016.

Fixed Bearing – 0° Flexion

Parameters \ Outputs	Insert	Medial Proximal	Lateral Proximal	Medial Distal	Lateral Distal	Contact Area
Lower Thickness	15,1%	2,9%	0,0%	3,6%	1,7%	7,4%
Higher Thickness	16,7%	2,9%	1,3%	1,4%	3,2%	3,4%
Material	17,2%	5,9%	0,5%	2,0%	3,1%	3,8%
Friction Coefficient	19,1%	3,4%	0,2%	1,9%	3,2%	3,8%
+2 mm cut	16,7%	0,9%	0,2%	6,6%	1,3%	3,4%
-2 mm cut	18,8%	4,1%	0,7%	2,6%	8,2%	7,8%
Lower Slope	20,1%	4,0%	0,4%	0,3%	6,4%	6,5%
Higher Slope	19,7%	1,4%	1,7%	7,5%	2,5%	6,5%

WHITE	GREEN	YELLOW	ORANGE	LIGHT RED	RED
<2,5%	<5%	<7,5%	<10%	<20%	>=20%

Figure 1: Percentage change from the control values in the different outputs (listed in the first line) induced by the different parameters (reported in the first column) in a fixed bearing UKA at 0° of flexion.

Mobile Bearing – 0° Flexion

Parameters \ Outputs	Insert	Medial Proximal	Lateral Proximal	Medial Distal	Lateral Distal	Contact Area
Lower Thickness	14,7%	11,4%	3,5%	3,0%	8,9%	4,7%
Higher Thickness	11,2%	8,7%	2,1%	2,0%	9,1%	6,0%
Material	11,2%	8,4%	2,6%	2,1%	9,5%	0,4%
Friction Coefficient	20,3%	7,7%	2,9%	2,3%	9,3%	0,1%
+2 mm cut	10,7%	6,7%	3,9%	3,5%	9,7%	0,5%
-2 mm cut	11,8%	7,1%	0,1%	1,3%	7,2%	0,2%
Lower Slope	11,3%	9,0%	4,6%	5,8%	13,1%	0,5%
Higher Slope	11,3%	7,8%	4,3%	4,8%	13,3%	0,1%

WHITE	GREEN	YELLOW	ORANGE	LIGHT RED	RED
<2,5%	<5%	<7,5%	<10%	<20%	>=20%

Figure 2: Percentage change from the control values in the different outputs (listed in the first line) induced by the different parameters (reported in the first column) in a mobile bearing UKA at 0° of flexion.