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Original article
Kinematic alignment of current TKA implants does not restore the native trochlear anatomy

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Abstract:
Introduction: Preserving constitutional patellofemoral anatomy, and thus producing physiological patellofemoral kinematics, could prevent patellofemoral complications and improve clinical outcomes after kinematically aligned TKA (KA TKA). Our study aims 1) to compare the native and prosthetic trochleae (planned or implanted), and 2) to estimate the safety of implanting a larger Persona® femoral component size matching the proximal lateral trochlea facet height (flange area) in order to reduce the native articular surfaces understuffing generated by the prosthetic KA trochlea.
Methods: Persona® femoral component 3D model was virtually kinematically aligned on 3D bone-cartilage models of healthy knees by using a conventional KA technique (group 1, 36 models, planned KA TKA) or an alternative KA technique (AT KA TKA) aiming to match the proximal (flange area) lateral facet height (10 models, planned AT KA TKA). Also, 13 postoperative bone-implant (KA Persona®) models were co-registered to the same coordinate geometry as their preoperative bone-cartilage models (group 2 – implanted KA TKA). In-house analysis software was used to compare native and prosthetic trochlea articular surfaces and medio-lateral implant overhangs for every group.
Results: The planned and performed prosthetic trochleae were similar and valgus oriented (6.1° and 8.5°, respectively), substantially proximally understuffed compared to the native trochlea. The AT KA TKAs shows a high rate of native trochlea surface overstuffing (70%, 90%, and 100% for lateral facet, groove, medial facet) and mediolateral implant overhang (60%). There was no overstuffing with conventional KA TKAs having their anterior femoral cut flush.
Conclusion: We found that with both the planned and implanted femoral components, the KA Persona® trochlea was more valgus oriented and understuffed compared to the native trochlear anatomy. In addition, restoring the lateral trochlea facet height by increasing the femoral component size generated a high rate of trochlea overstuffing and mediolateral

implant overhang. While restoring a native trochlea with KA TKA is not possible, the clinical impact of this is low, especially on PF complications. In current practice it is better to undersize the implants even if it does not restore the native anatomy. Longer follow-up is needed for KA TKAs performed with current implant, and the debate of developing new, more anatomic, implants specifically designed for KA technique is now opened.

Level of evidence: II, Laboratory controlled study

Key words: knee replacement; kinematic alignment; Persona; native trochlea; prosthetic trochlea; trochlea groove

Introduction:

Mechanical alignment (MA) of total knee arthroplasty (TKA) can be qualified as a "systematic technique", as almost every patient has a similar implant positioning regardless of his or her constitutional lower limb and knee anatomy. This lack of anatomical restoration leads to poor prosthetic knee kinematics (from both femorotibial and patellofemoral joints) responsible for disappointing functional outcomes for MA TKA [1]. In order to solve this issue, a new more anatomical surgical technique for TKA, namely kinematic alignment (KA), has been recently promoted [2].

The KA technique has thus far focused on the femorotibial joint. Its rationale is that by restoring the individual femorotibial joint line level and 3D orientation, it is likely that the native physiological femorotibial laxity would be automatically restored (no soft tissue release), all improving the femorotibial kinematics [2]. However, by focusing on the femorotibial joint and by implanting components designed for mechanical alignment, the KA technique only partially improves clinical outcomes of TKA, as the deleterious effects of the poor patellofemoral kinematics has been show to persist (similar rate of patellofemoral complications between MA and KA TKAs) [3-5]. Therefore, it appears that restoration of the individual trochlea anatomy would probably also be beneficial to further improve the outcomes of KA TKA.

By way of a proximally extended, valgus oriented, understuffed, dysplastic shape (high sulcus angle) prosthetic trochlea, current TKA implants are specifically designed for mechanical positioning in order to achieve a biomechanical goal of early patella capture and low constrain of its tracking during knee flexion [6-8]. When modern implants are mechanically aligned, the individual trochlea anatomy is poorly restored [9]. By currently using those implants and by systematically performing an anterior femoral cut flush to the anterior femoral cortex, the current (conventional) KA technique does not restore the individual trochlea anatomy, but rather creates a prosthetic trochlea often excessively valgus oriented and massively proximally understuffed compared to native surfaces [9]. In turn, this is likely to prevent restoration of patellofemoral kinematics, therefore affecting clinical outcomes of KA TKA by preventing to solve the patellofemoral complications issue encountered with MA TKA [3].

There is substantial proximal trochlear understuffing when implants are kinematically aligned [9], resulting in a reduction in the quadriceps lever arm [10] thus potentially affecting clinical outcomes secondary to (1) quadriceps muscle overuse and

fatigue and (2) increased patellofemoral joint reaction force that might be responsible of patella component accelerated wear and loosening, and patella fracture. Also, whilst there is no evidence to support this assumption, trochlea understuffing could lead to an increased risk of patella instability secondary to excessively slack retinacular ligaments and low constraining trochlea, mainly in case of restoration of constitutional valgus of the limb or of abnormal femoro-tibial torsion. This prosthetic trochlea understuffing is the result of current implant design (wide trochlear groove radii) [7] and current surgical technique for replacing a knee (anterior femoral cut flush to the anterior femoral cortex). In order to cope with this prosthetic trochlea understuffing, surgeons performing KA TKA could restore the inter-individual variable native trochlea stuffing [11] by using a posterior referencing technique for femoral sizing. However, by doing this "alternative KA technique", where the femoral component size is increased to match the height of the lateral trochlear facet height, consequences such as the proximally extended flange lying at distance from the anterior cortex and mediolateral implant overhang might be generated and be clinically deleterious.
Our study aims 1) to compare the native and prosthetic trochleae (planned or implanted), and 2) to estimate the safety of implanting a bigger Persona® femoral component size matching the proximal lateral trochlea facet height (flange area) in order to reduce the native articular surfaces understuffing generated by the prosthetic KA trochlea. We tested the following null hypotheses: Kinematic positioning of the Persona® femoral component does not restore the native trochlear anatomy (trochlea offset and groove orientation) when the implant is planned (hypothesis 1) or implanted (hypothesis 2). Compared to the native articular surfaces, restoring the anterior lateral trochlea facet offset does not generate prosthetic trochlea overstuffing (hypothesis 3) or mediolateral implant overhang (hypothesis 4).

Methods:

Overview: Measurements of the anatomical parameters differences between native and prosthetic trochlear articular surfaces were performed on anonymised images of healthy (group 1) and osteoarthritic (group 2) knees. Because images were anonymised, their use was not subject to approval by our institutional review board. The methods flow-chart is illustrated in figure 1.
Group 1: Thirty-four magnetic resonance imaging scans (MRI) of healthy knees were randomly selected from the Osteoarthritis Initiative database. MRIs (0.7mm slice spacing) were segmented using Mimics® software (Materialise, Leuven, Belgium) to create 3D bone and cartilage models on which a 3D cruciate retaining Persona® femoral component model obtained by laser scanning (C-track 780 stereophotogrammetry laser scanner, Creaform 3D, Québec, Canada) was virtually kinematically aligned by using in-house planning software. The goal of this assessment was to measure the trochlear parameters differences between the native and the planned KA prosthetic trochleae.
Group 2: Thirteen preoperative MRIs of osteoarthritic knees (end-stage femorotibial arthritis without significant patellofemoral arthritis, that is ≤ Iwano stage 2 [12]) and postoperative (KA TKA with Persona® implant) computed tomography (CT) scans of implanted knees were segmented to create femoral 3D models including bone and cartilage for native knees and bone and implant for prosthetic knees. The procedure was performed by one of the authors (SH) who implanted the TKAs by using a manual

instrumentation for KA technique. The goal of this assessment was to measure the trochlear parameters differences between native and implanted KA prosthetic trochleae.

Method for group 1: Virtual femoral component positioning was performed on femur models using in-house planning software. Femoral component sizing and axial positioning was performed by using a virtual, measured resection, posterior referencing technique aiming an anterior cut flush to anterior femoral cortex. The frontal and axial femoral implant positioning were set parallel with the distal (frontal plane) and posterior (axial plane) femoral joint lines, and flush with the cartilage articular surfaces. The femoral flexion was set parallel, in the sagittal plane, to the distal anatomical axis of the femur, and the mediolateral positioning was adjusted in order to have the implant centred on the inter-condylar notch. Narrow component was selected when mediolateral overhang occurred with standard implant. In order to answer the question 2, ten randomly selected knees models, which had already been planned with the abovementioned technique (conventional KA technique – CT), were planned a second time with, as sole difference, the femoral implant sizing aiming at restoring the anterior offset of the lateral facet (alternative KA technique – AT) (figure 2).

Method for group 2 has been already described in a previously published article [13]. Briefly, knowing the femoral implant size that was implanted during surgery, the same size of implant model was overlaid on the postoperative femoral model to replicate, *in silico*, the performed implant positioning. This enabled the reproduction in the computer model of the implant features that were lost due to CT metal artefacts, and therefore improved the shape accuracy of the femoral component. Then, a section of the femoral shaft, which was unaffected by metal artefacts from the implants, was used to co-register the pre and postoperative 3D femoral models to the same coordinate geometry.

Assessments of trochlea parameters: The method has been already described in a previously published articles [9,14]. Briefly, custom analysis software was used to assess native and prosthetic articular surfaces through cutting planes rotating about the patellar axis across the length of the native groove. This analysis software automatically calculated eight parameters defining the trochlear geometry (figures 3 and 4). As we did not assess the stuffing of the proximal part of the prosthetic trochlea that extends more proximally than the native trochlea, results to the question 1 only stand for the prosthetic trochlea that is matching the native trochlear area. Based on the previously reported data [15,16], an ideal fit was defined as a difference value less than 2 mm. If the value was larger than 2 mm, overstuffing or under-stuffing was considered.

Assessment of implant medio-lateral overhang (figure 5): This was measured medially and laterally in five zones as described by Mahoney et al. [17]. As implant medio-lateral overhang has been shown to have a clinical impact when $\geq$ 3 mm, we took this value to define if our implant positioning generated or not an overhang [17].

Statistical analysis: To enable comparison of geometric parameters across different sized femora, radial heights were normalised to the mean groove radius, and mediolateral translation was normalised to the mean transepicondylar width. Mean, SD, and range were computed for all the variables. The data were determined to be normally distributed by a Shapiro-Wilk test ($p>0.05$), so the results were analysed with a repeated measures analysis of variance (ANOVA) and post-hoc paired T-tests. The frequency of trochlear overstuffing and of implant overhang were compared with the $\chi 2$-test. A Bonferoni correction for multiple comparisons was performed, and the significance level was set at $p<0.01$. The reliability of measurements was tested by measuring four variables (native and prosthetic groove height at 40°, native coronal groove orientation, and presence or absence of implant overhang) in four randomly selected knees (for each group) by two observers (intra- and inter-observer reliability) using the intraclass correlation coefficient (ICC). The ICC was calculated as a one-way random effects model of single measures for each variable, and resulting ICC indicated good agreement (0.71 to 0.88). SPSS for Windows version 22.0 (SPSS, Chicago, IL) was used for the statistical analysis.

Results:

Question 1: Results for trochlea stuffing, frontal and axial groove alignment, mediolateral groove location, and trochlear sulcus angles are illustrated in figures 6, 7, 8, and 9, and 10 respectively. The figure 11 illustrates the average difference between native and prosthetic articular surfaces for group 2.

Hypothesis 1: We found the planned prosthetic trochlea to significantly ($p<0.001$) understuff the proximal part of the native trochlea (figure 6). Compared to the native groove (1° valgus (SD 2.8°) and 1.8° externally rotated (SD 3.6°)), the planned groove was 6.1° more valgus (SD 3.7°) ($p<0.001$), 1° more internally rotated (SD 4.2°) ($p<0.001$) (figures 7 and 8), was more laterally located proximally and medially located distally ($p<0.004$) (figure 9), and had larger radii by 10.8mm (SD 3.1) ($p<0.001$).

Hypothesis 2: We found the performed prosthetic trochlea to significantly ($p<0.001$) understuff the proximal part of the native trochlea (figure 6). Compared to the native groove (1.1° valgus (SD 3.5°) and 1.8° externally rotated (SD 3°)), the prosthetic groove (implanted component) was 8.5° more valgus (SD 4.5°) ($p<0.001$) (figure 7) and had larger radii by 11.2mm (SD 3.2) ($p<0.001$). The prosthetic groove was also 1.7° more internally rotated, and was more laterally located proximally and more medially located distally, but this was not statistically significant (figures 8 and 9).

Question 2: The AT technique increased the component size by 1.9 on average and generated a massive overstuffing of the extended proximal prosthetic trochlea part relative to the anterior femoral cortex (figures 12 and 13). Results regarding native and prosthetic trochleae (AT and CT) stuffings are illustrated in figure 12.

Hypothesis 3: Compared to the CT KA technique, we found that AT KA technique generated a significant overstuffing of the groove (90% (9/10) vs 0%, $p<0.05$), medial facet (100% (10/10) vs 0%, $p<0.05$), and lateral facet (70% (7/10) vs 0%, $p<0.05$). Figure 14 illustrates a case with massive proximal trochlea understuffing resulting from CT technique. Figures 13 and 15 show the best and the worst fit between native and prosthetic trochlea with the AT KA technique.

Hypothesis 4: Compared to the CT KA technique, we found that AT KA technique generated a significant mediolateral overhang (60% vs 0%, $p<0.05$). Implant mediolateral overhangs were mainly located laterally in zones 3 & 5.

Discussion:

This study found that with both the planned and implanted femoral components, the KA Persona® trochlea was more valgus oriented and understuffed compared to the native trochlear anatomy. Also, restoring the lateral trochlea facet height by increasing the femoral component size generated a high rate of trochlea overstuffing and mediolateral implant overhang.

Question 1: Our study shows KA TKA produces a proximally understuffed and excessively valgus prosthetic trochlea. Our results for the native and KA prosthetic trochlea parameters are in line with that of Iranpour et al. [18] (native groove orientation 1° valgus and externally rotated) and Riviere et al. [9], respectively.

Trochlea stuffing: The observed prosthetic trochlea proximal understuffing is the result of current implant design (wide trochlear groove radii) [7] and current surgical technique for replacing a knee (anterior femoral cut flush to the anterior femoral cortex). This prosthetic trochlea understuffing might increase the risk of patellar instability with KA TKA, notably in situations where constitutional valgus limb or excessive femoro-tibial torsion are restored, but this has not been reported [19-21]. In order to quantify its mechanical effect, we estimated roughly the decrease in the extensor moment of the quadriceps at 90° knee flexion. We based our calculations on the assumption that the centre of rotation of the native knee is the same as post-TKA, and used the values for moment arm and quadriceps force from the available literature [10,22] to make these calculations. We thus calculated a 5 Nm decrease in the extensor moment for 5 mm decrease in the lever arm, a decrease of 13%. A 8mm decrease in the lever arm would yield an extensor moment decrease of 25%. The implication of this would be that, although this understuffing is likely to prevent pain from retinacular ligaments stretching [15], the patient would have to generate more quadriceps force in order to extend their knee, potentially leading to inferior functional outcomes and patella component at risk of failure (loosening, wear) secondary to the increase of joint reaction force. While this might be concerning, it is interesting to note that mechanical alignment of TKA similarly understuffs the native proximal trochlea [9], and this has not led to catastrophic patellofemoral complications over the long-term.

Groove alignment and location: The observed excessive valgus orientation of the prosthetic groove might affect patellofemoral biomechanics at early knee flexion. As for the observed prosthetic understuffing, this could lead to patellofemoral complications such as instability, pain, and patella component failure. This is corroborated by the results of Ishikawa et al. [5] who found that the groove alignment generated by KA TKA affected the patellofemoral biomechanics with abnormal patella tilt/shift and increased peak stress at a very early knee flexion when the patella engaged the trochlea. To achieve a soft patella engagement, KA TKA should probably reproduce the individual (patient-specific) groove orientation, which has been shown to rarely be the case in our study (figures 7(B) and 8(B)). As shown in figures 7(B) and 8(B), there is a high inter-individual variability for native trochlear parameters, which makes unlikely a reliable restoration of the individual trochlear anatomy by current serial femoral implants.

General: The poor individual trochlear anatomy restoration observed in our study would potentially preclude KA TKA to avoid patellofemoral complications. Therefore, 4 randomised controlled clinical trials having compared MA and KA TKAs at early follow-up (1 to 2 years) found KA TKA generated less anterior knee pain but did not reduce (nor increased) other patellar complications [21]. One of the reasons to explain reduction in anterior knee pain after KA TKA could be the absence of overstuffing of the distal lateral prosthetic trochlea facet, which might clinically affect MA TKA by generating a lateral retinacular ligament stretching during knee flexion [14]. Other retrospective studies found

KA TKA to be affected by only 0.4% to 1.4% of patella instability with no influence of the postoperative limb alignment for this complication [19-21]. These overall good patellofemoral outcomes might be the consequence of a high tolerance of current trochlear designs, which seems to be able to compensate for the poor restoration of the individual trochlear anatomy, and also of the short follow up.

Question 2: We found that increasing the femoral component size to match the proximal lateral facet height would almost correct the understuffing of the lateral trochlea facet but would also result in a high rate of likely clinically deleterious mediolateral implant overhang [17] and trochlea overstuffing. This makes our AT KA technique not recommendable in clinical practice.

Trochlea overstuffing: With the AT KA technique, the individual analysis showed that every prosthetic trochlea overstuffed the native medial trochlea facet and/or groove articular surfaces. While this does not necessarily apply to KA TKA, millimeters of overstuffing of either the patella or the proximal trochlea (anterior condyles or flange area) in MA TKA has been shown to have little to no clinical and radiological impact [23,24], but affects patellofemoral kinetics (shear stress and contact force) [23]. In our simulation of AT KA TKA, distal trochlea overstuffing was frequent and this might generate a clinically deleterious retinacula ligaments stretching during knee flexion [25]. Also, AT KA TKA generated a massive prosthetic overstuffing of the proximally extended part of the flange, relative to the native anterior femoral cortex, which might also be clinically deleterious (soft tissue catching, retinacular stretching, etc.). Another AT KA TKA aiming at matching the proximal medial facet height would lead to smaller adjustment of the anterior femoral cut and would probably help at reducing risks related to prosthetic trochlear overstuffing and implant mediolateral overhang. However, this would not solve the issue of poor prosthetic groove alignment resulting from kinematic positioning of the femoral component [9].

A few limitations should be discussed that might affect the generalisation of the findings. Firstly, sources of inaccuracies may occur at any of the stages of the methods, even if we have attempted to automate the process and follow a detailed protocol in order to minimise errors. However, we believe that we have successfully minimised this bias because our ICCs reflected good reliability and our results for the native groove orientation agree with those previously reported in the literature [18]. Secondly, regarding group 2, metal implant artefacts ('bloom') made the implant outlines less distinguishable thus affecting the accuracy of the overlay of the implant 3D model on the bone-implant 3D distal femur postoperative model. Nonetheless, because our results between planned (group 1) and implanted (group 2) knees are similar, it is likely that this bias was minimal. Thirdly, our results are implant-specific (Persona®) and should not be fully generalised to other implant designs. However, because most of current TKA implants follow a similar trochlea design rationale, it is likely that reproducing our study with different implants would lead to similar results. Fourthly, with only 13 knees and a significant level set at 0.01, our statistical tests regarding results from group 2 are lacking power thus explaining why some almost similar findings observed between groups 1 and 2 (groove axial rotation and mediolateral location) only reach statistical significance for group 1 (34 knees). Lastly, we used a library of healthy knee MRIs for group 1, which could differ in their trochlear geometry with that of arthritic knees, and therefore make irrelevant the results from the group 1. However, because our results were very close between groups 1 and 2, the trochlear anatomy of healthy knees (group 1) and osteoarthritic knees (group 2) are likely to be similar.

Conclusion:

This study found that with both the planned and implanted femoral components, the KA Persona® trochlea was more valgus oriented and understuffed compared to the native trochlear anatomy. In addition, restoring the lateral trochlea facet height by increasing the femoral component size generated a high rate of trochlea overstuffing and mediolateral implant overhang. While restoring a native trochlea with KA TKA is not possible, the clinical impact of this is low, especially on PF complications. In current practice it is better to undersize the implants even if it does not restore the native anatomy. Longer follow-up is needed for KA TKAs performed with current implant, and the debate of developing new, more anatomic, implants specifically designed for KA technique is now opened.

Conflict of interest: None of the authors has a conflict of interest regarding this study. Outside the current study Charles Riviere declares being consultant for Medacta, Stephen Howell declares being consultant for Medacta, Zimmer-Biomet and is the promotor of the kinematic alignment technique for knee replacement, and Justin Cobb declares being consultant for Biomet-Zimmer, Mathortho, and to perceive fee from Microport.
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Authors' contribution:
Charles Rivière, writing protocole and manuscript, data gathering and analysis
Fatima Dhaif, data gathering
Hemina Shah, data gathering
Edouard Auvinet, data analysis
Ali Adam, data gathering
Arash Aframian, data gathering, review manuscript
Justin Cobb, review manuscript
Stephen Howell, provided data (knee CT), review manuscript
Simon Harris, created softwares (planner and articular surface analysis) for study, review manuscript.

Figures legends:
Figure 1: methods' flow-chart
Figure 2: illustration of alternative and conventional techniques

Figure 3: this figure shows the analysis software for articular surfaces measurement via cutting planes revolving around the patellar axis. To account for the difference in angular sweep between trochleae, degrees of rotation were converted to a percentage rotation, and measurements were taken at 10% increments across the length of the groove, where 0% and 100% were defined as the most proximal and distal points on the native groove, respectively.

Figure 4: measured trochlear parameters. Axial (B) and frontal (C) groove rotations are assessed relative to the cylindrical axis. Lateral (b) and medial (c) facets heights, and groove height (a) are assessed relative to the patella axis. Medio-lateral groove translation (d), external groove rotation (ER), internal groove rotation (IR).

Figure 5: assessment of implant overhang (red arrows) using planning software. (A) Global view, (B) zoom-in on overhang and measurement of its size using scale of cutting plane (each box is 5mm wide). (C) Colour map with black area indicating implant overhang (red arrows).

Figure 6: medial facet (A), lateral facet (B), and groove (C) heights for native (blue line) and prosthetic (red line) trochleae for groups 1 and 2. Asterisk indicates statistical significant difference between native and prosthetic trochleae.

Figure 7: difference in frontal groove orientation (varus-valgus) between native and KA trochleae for groups 1 and 2. The mean difference and standard deviation (A) and difference for each case number (B) are presented for group 2.

Figure 8: difference in axial groove orientation between native and KA trochleae for groups 1 (left) and 2 (right). The mean difference and standard deviation (A) and difference for each case number (B) are presented for group 2. Negative value indicates external rotation.

Figure 9: difference in medio-lateral groove translation between native and KA trochleae for groups 1 and 2. Negative value indicates medial translation. Asterisk indicates statistical significant difference between native and prosthetic grooves.

Figure 10: difference in sulcus angle between native and KA trochleae for groups 1 and 2. For the group 1, the mean sulcus angle is illustrated at every 10% of the revolving process. Asterisk indicates statistical significant difference between native and prosthetic grooves. For the group 2, difference are shown at 30° and 45° of the groove. The upper graph illustrates difference for each case, the lower graph shows mean and standard deviation.

Figure 11: colour map with anterior (left) and axial (right) views showing the average trochlear height differences for group 2. The colour maps represent colour coded surface differences between the native and prosthetic trochleae, quantified by the error scale. Blue indicates the prosthesis and is not related to the colour mapping.

Figure 12: mean differences and SD for facets and groove heights between native (green line) and prosthetic trochleae (AT in red, CT in blue). The proximally extended prosthetic part is not considered in this graph.

Figure 13: illustration of the best case with the AT technique. The extended flange massively overstuffs proximally (black central area on top right image). There is still overstuffing in the distal part of facets and groove (red arrows).

Figure 14: illustration of the massive trochlea understuffing resulting from the CT technique. (A) anterior and inferior views, (B) lateral views.

Figure 15: illustration of the worst case with the AT technique. While most of overstuffing occurred on medial facet and groove, the worst case was a massive overstuffing of the distal lateral facet (red arrows). There is also a massive overstuffing of the proximal flange (yellow arrow) and mediolateral overhang (white arrow).

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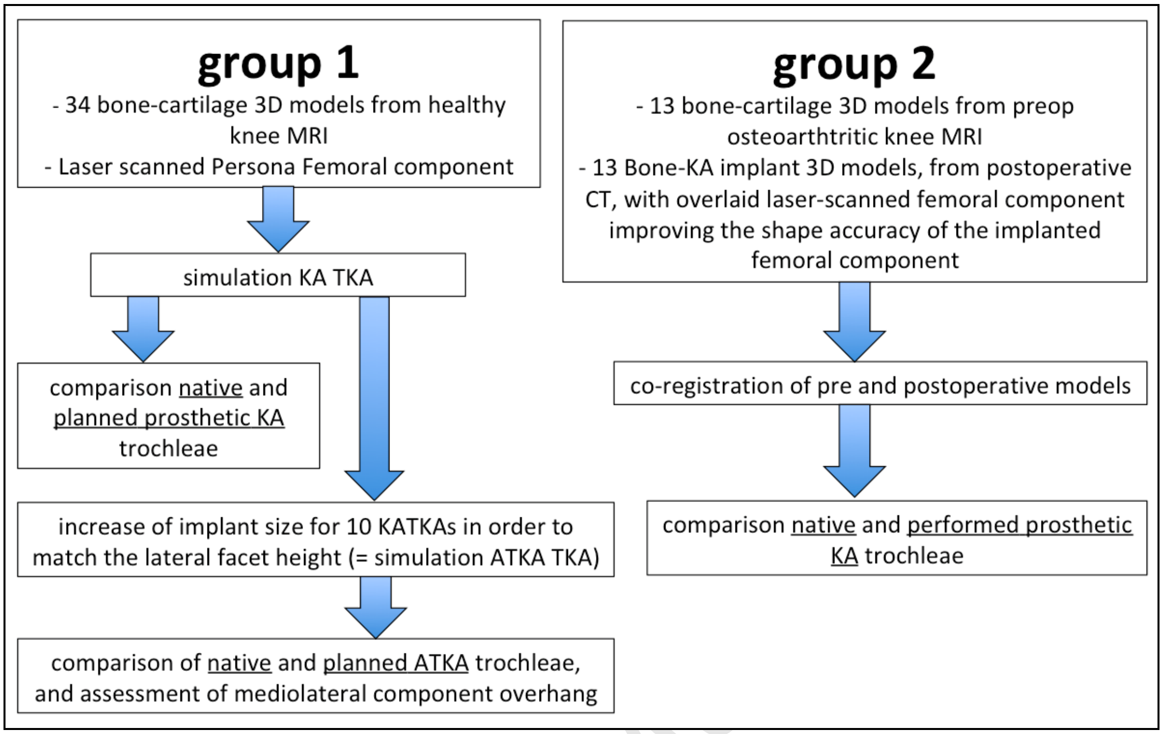
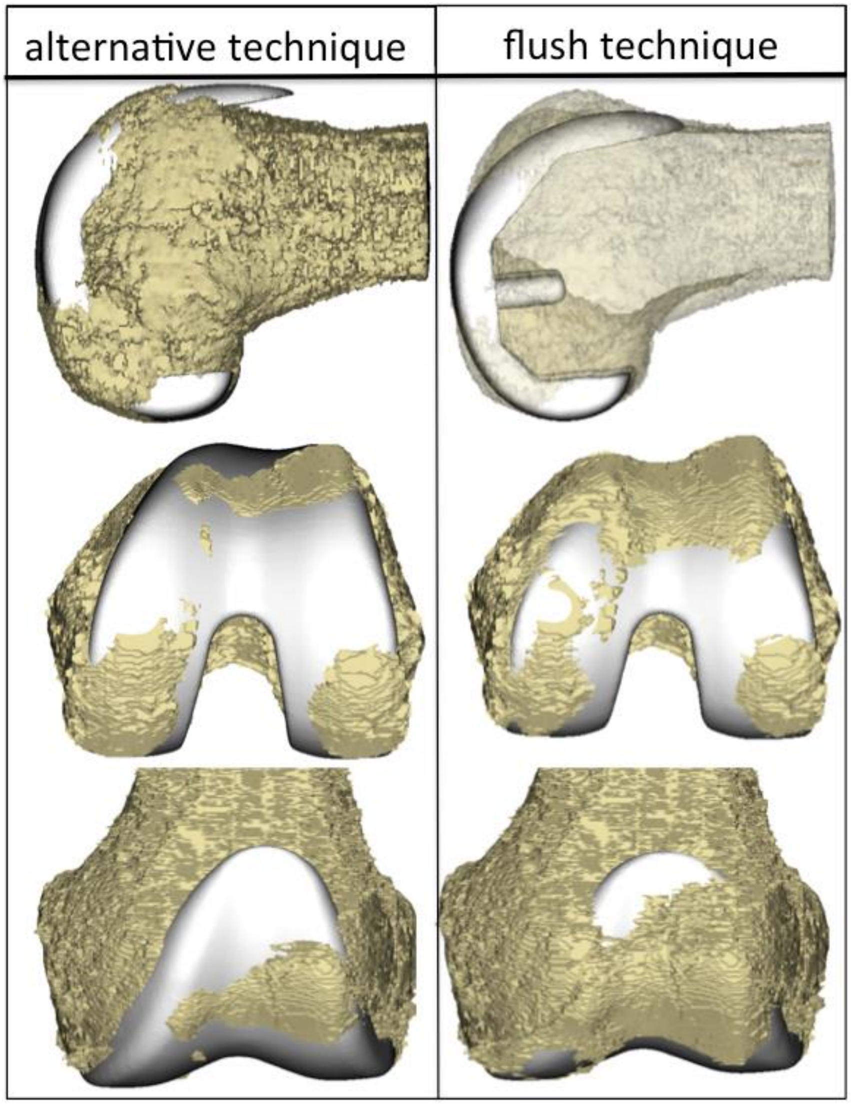
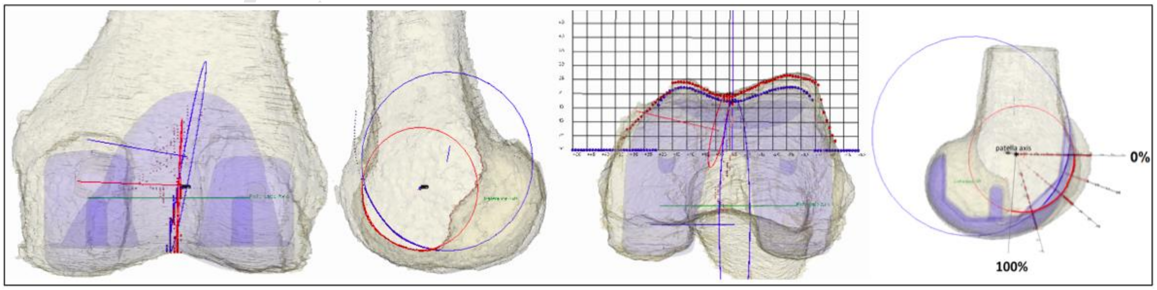
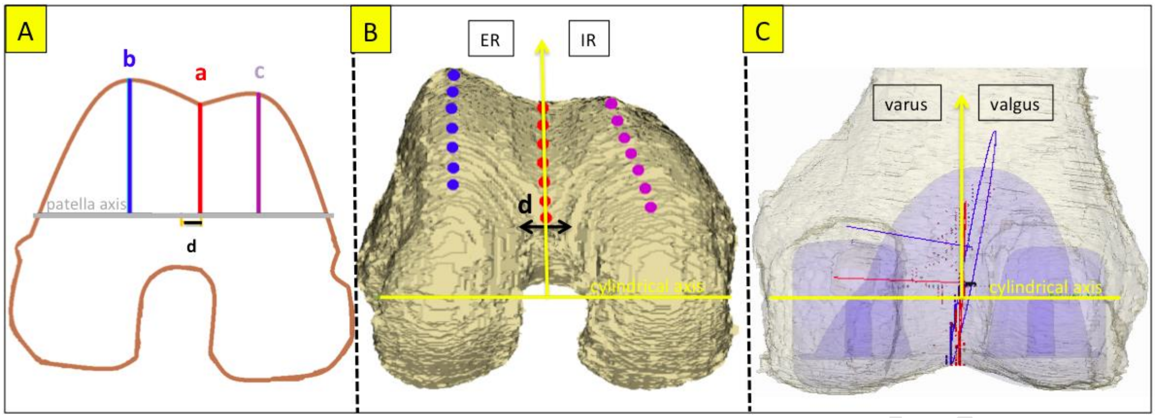
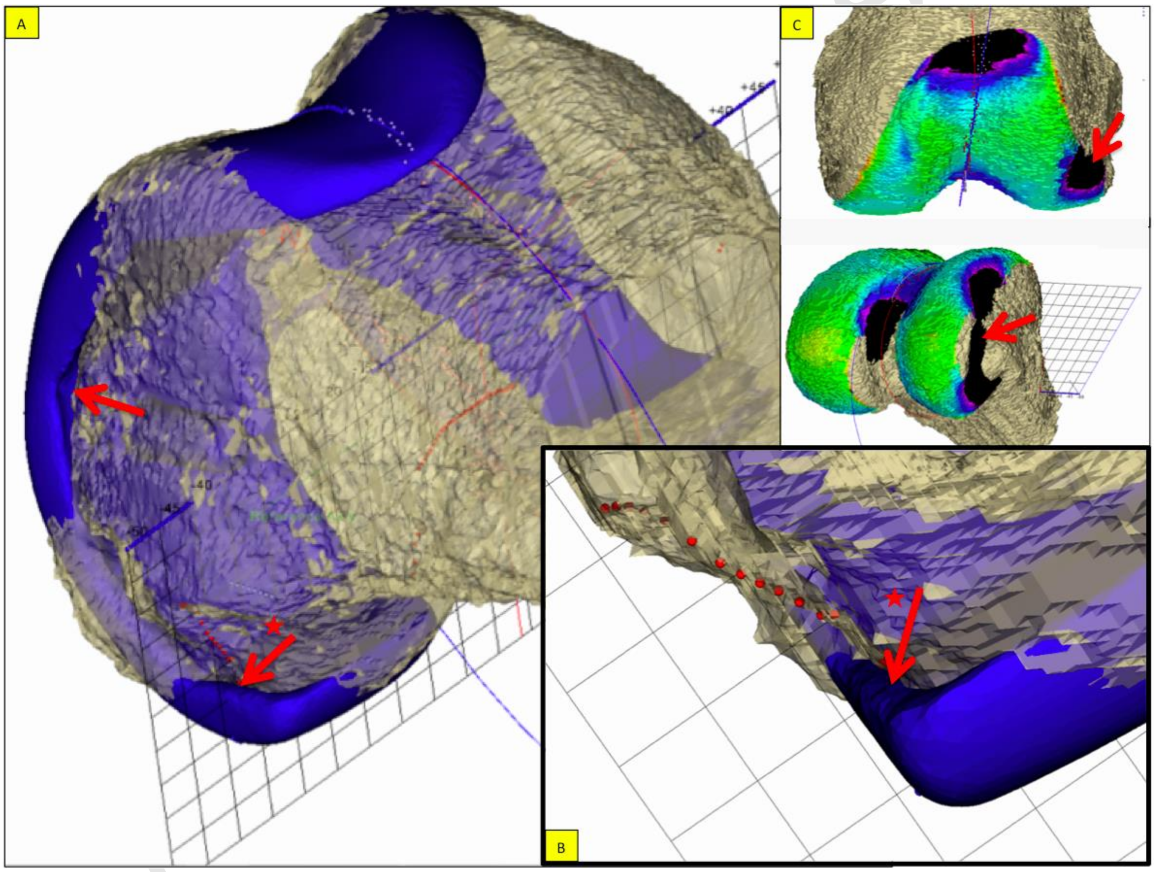
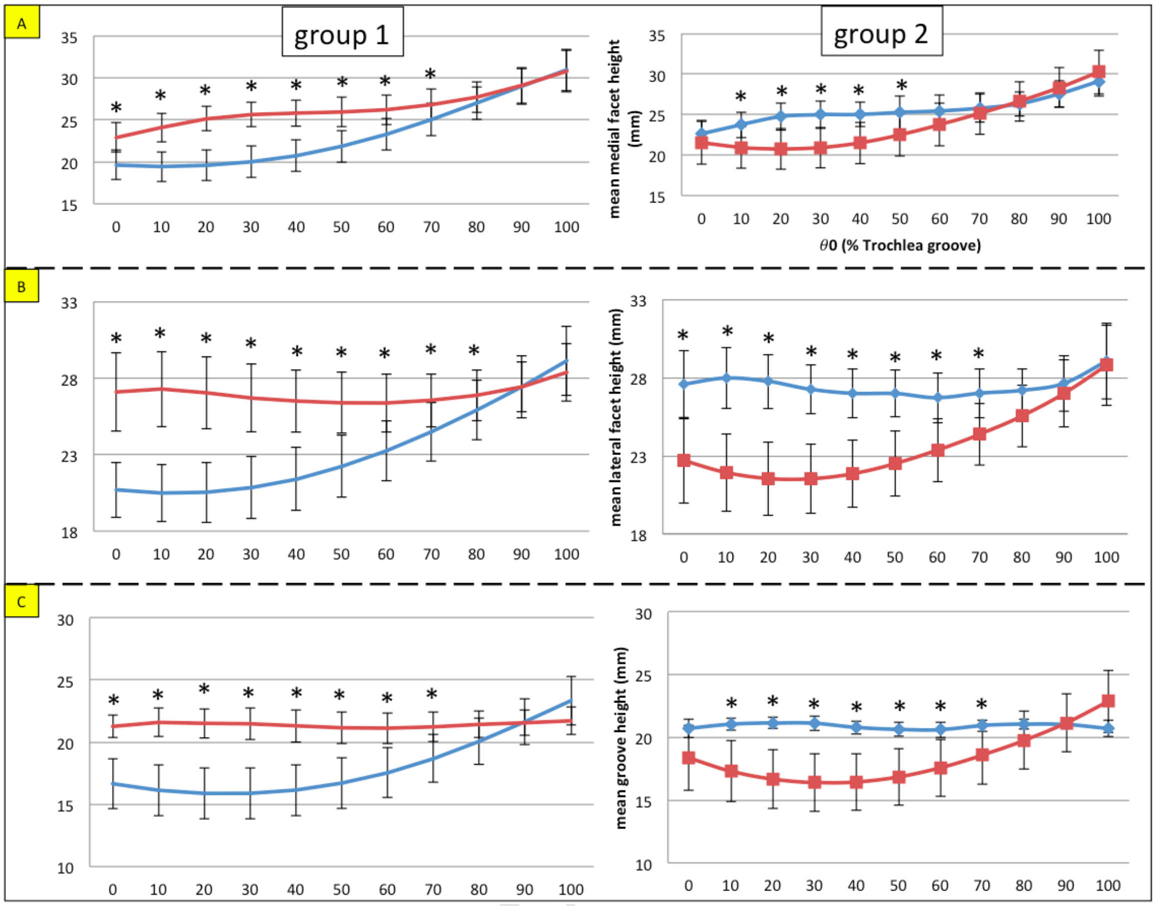

group 1
- 34 bone-cartilage 3D models from healthy knee MRI
- Laser scanned Persona Femoral component
simulation KA TKA
comparison native and planned prosthetic KA trochleae
increase of implant size for 10 KATKAs in order to match the lateral facet height (= simulation ATKA TKA)
comparison of native and planned ATKA trochleae, and assessment of mediolateral component overhang
group 2
- 13 bone-cartilage 3D models from preop osteoarthtritic knee MRI
- 13 Bone-KA implant 3D models, from postoperative CT, with overlaid laser-scanned femoral component improving the shape accuracy of the implanted femoral component
co-registration of pre and postoperative models
comparison native and performed prosthetic KA trochleae

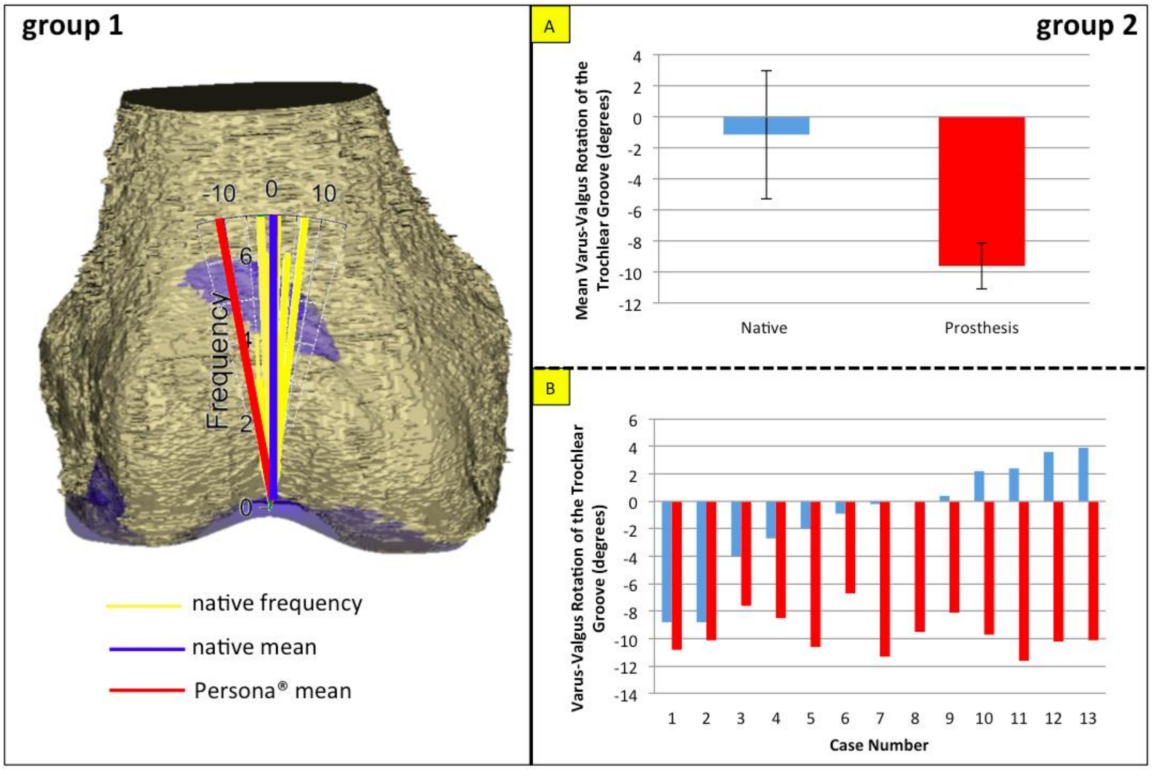

alternative technique
flush technique

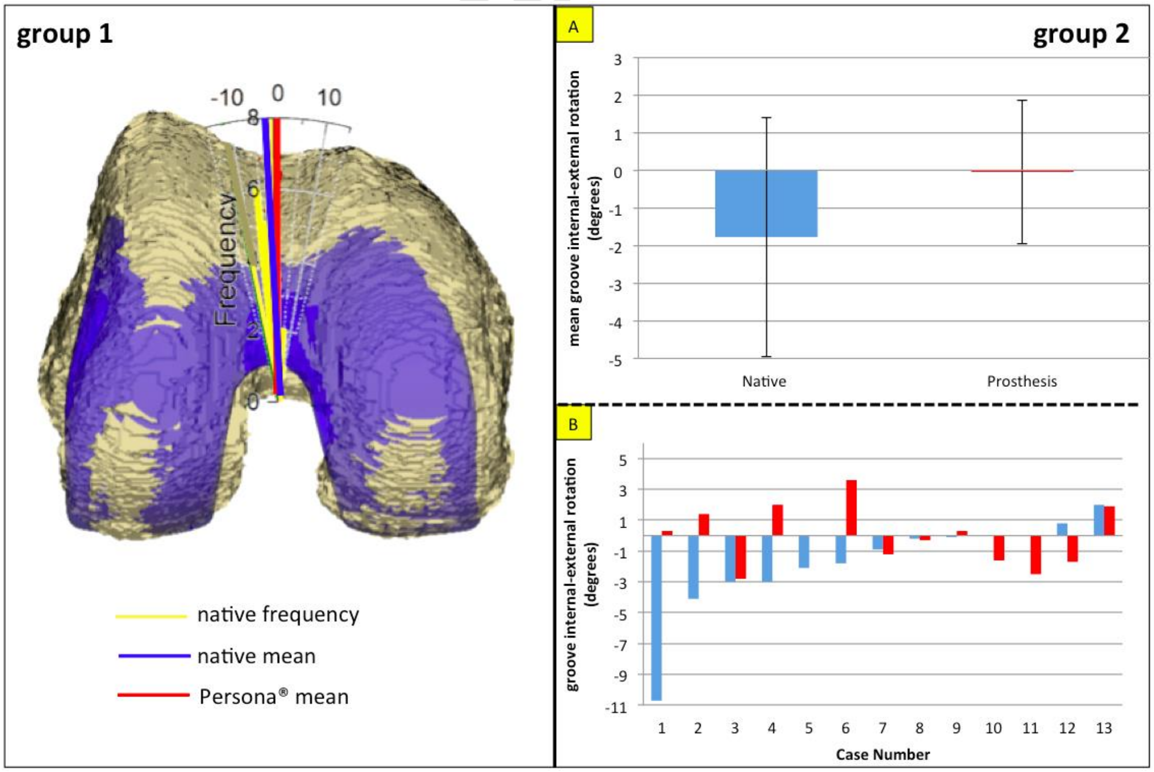

patella axis
0%
100%

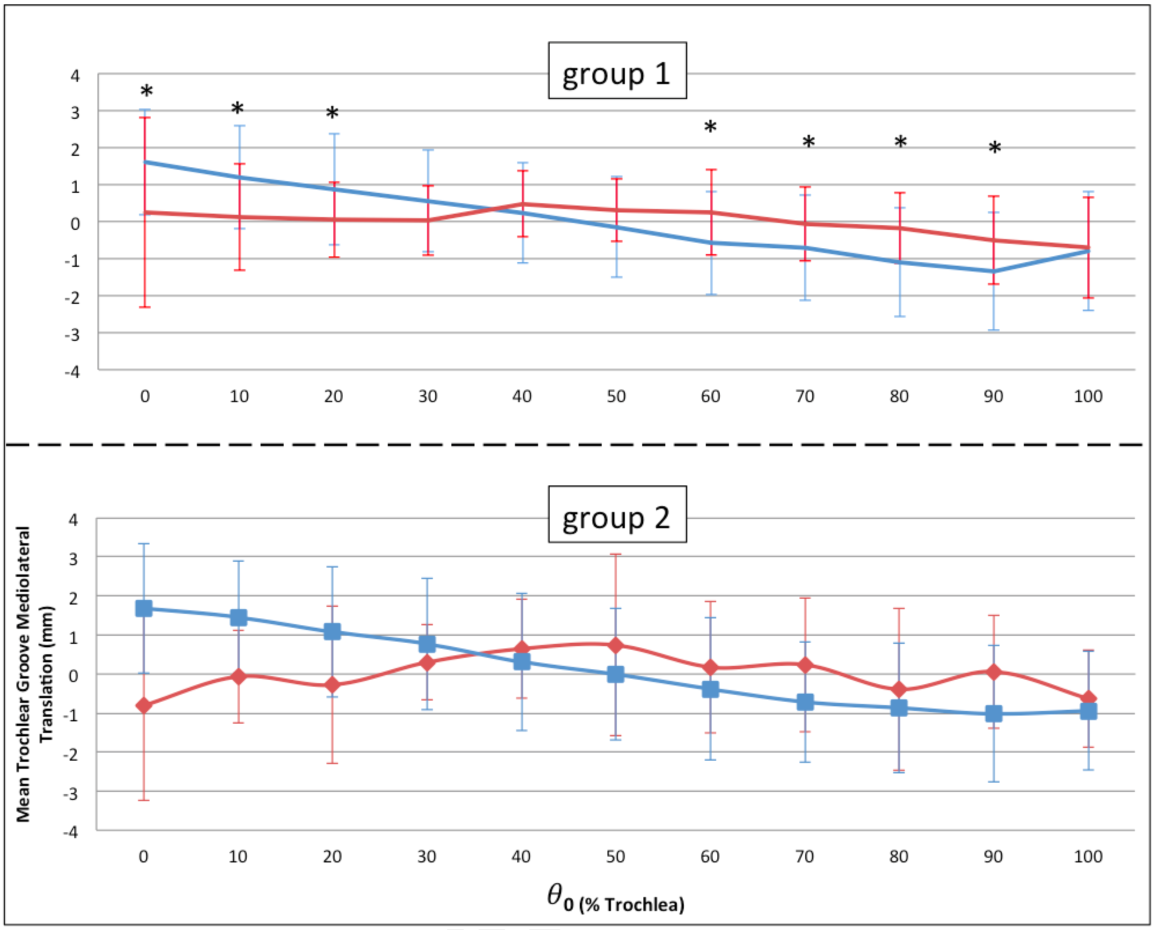

A
b
a
c
patella axis
d
B
ER
IR
d
cylindrical axis
C
varus
valgus
cylindrical axis

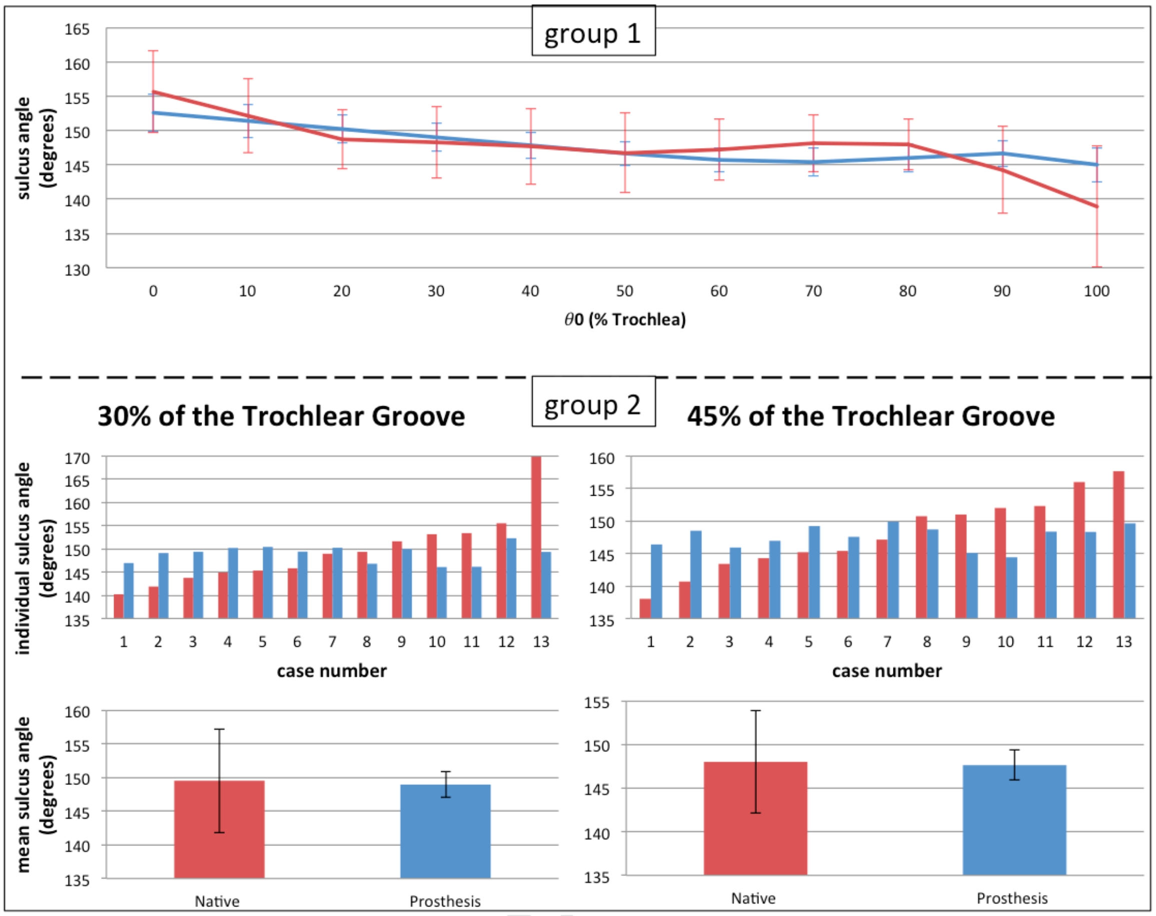

A
C
B

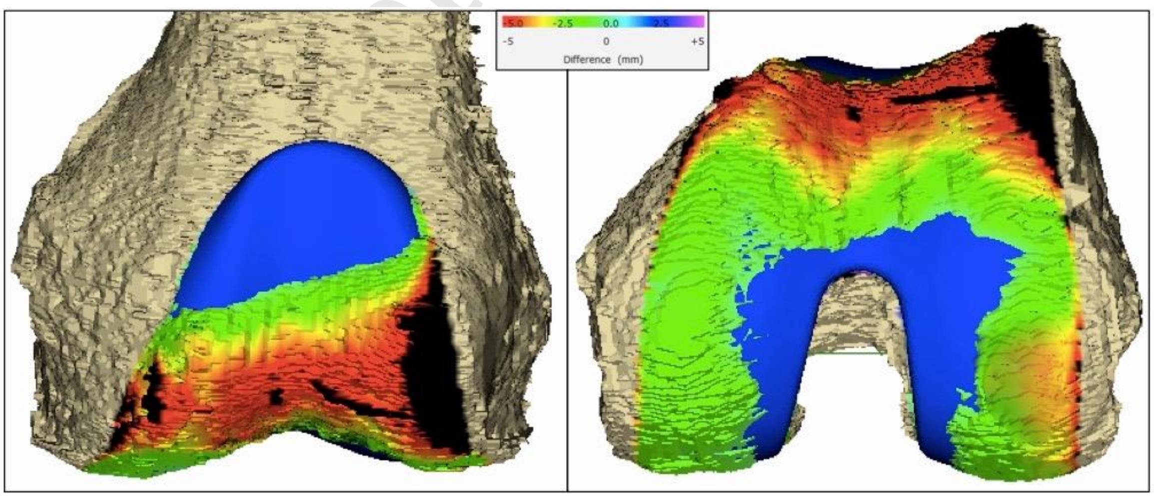

A
B
C
group 1
group 2
mean medial facet height (mm)
mean lateral facet height (mm)
mean groove height (mm)
θ0 (% Trochlea groove)

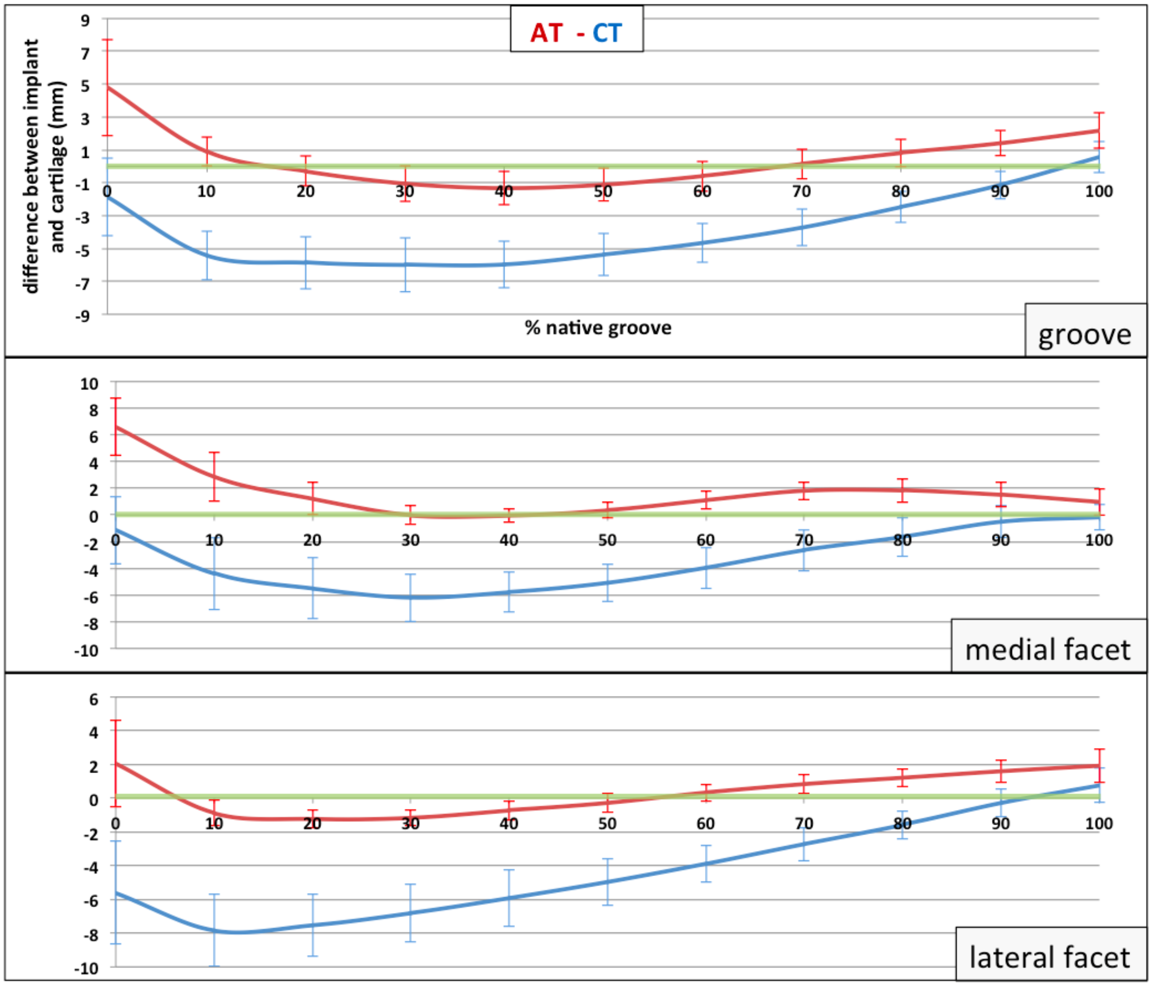

group 1
-10
0
10
Frequency
native frequency
native mean
Persona® mean
A
group 2
Mean Varus-Valgus Rotation of the Trochlear Groove (degrees)
Native
Prosthesis
B
Varus-Valgus Rotation of the Trochlear Groove (degrees)
Case Number

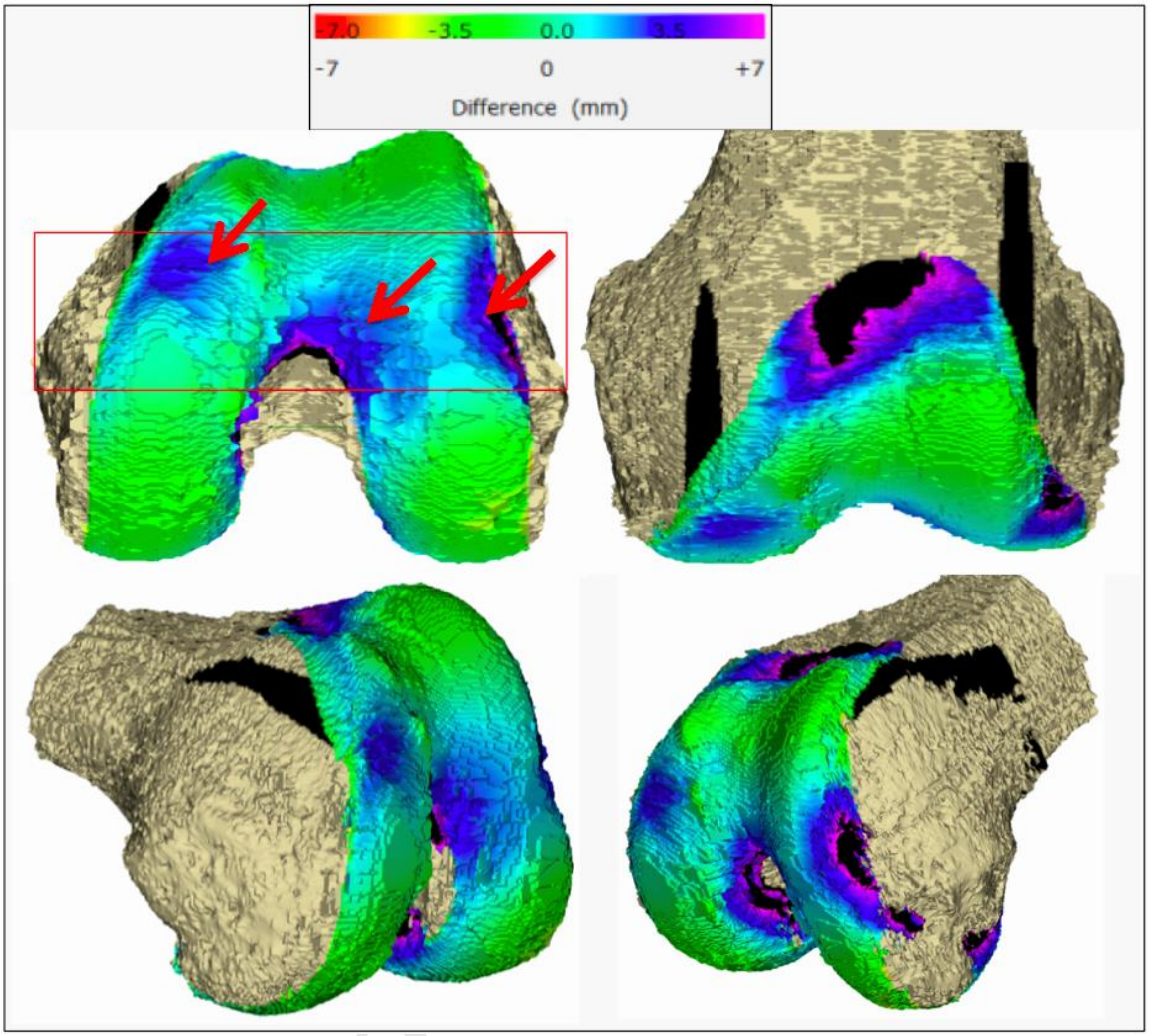

group 1
-10
0
10
Frequency
native frequency
native mean
Persona® mean
A
group 2
mean groove internal-external rotation (degrees)
Native
Prosthesis
B
groove internal-external rotation (degrees)
Case Number

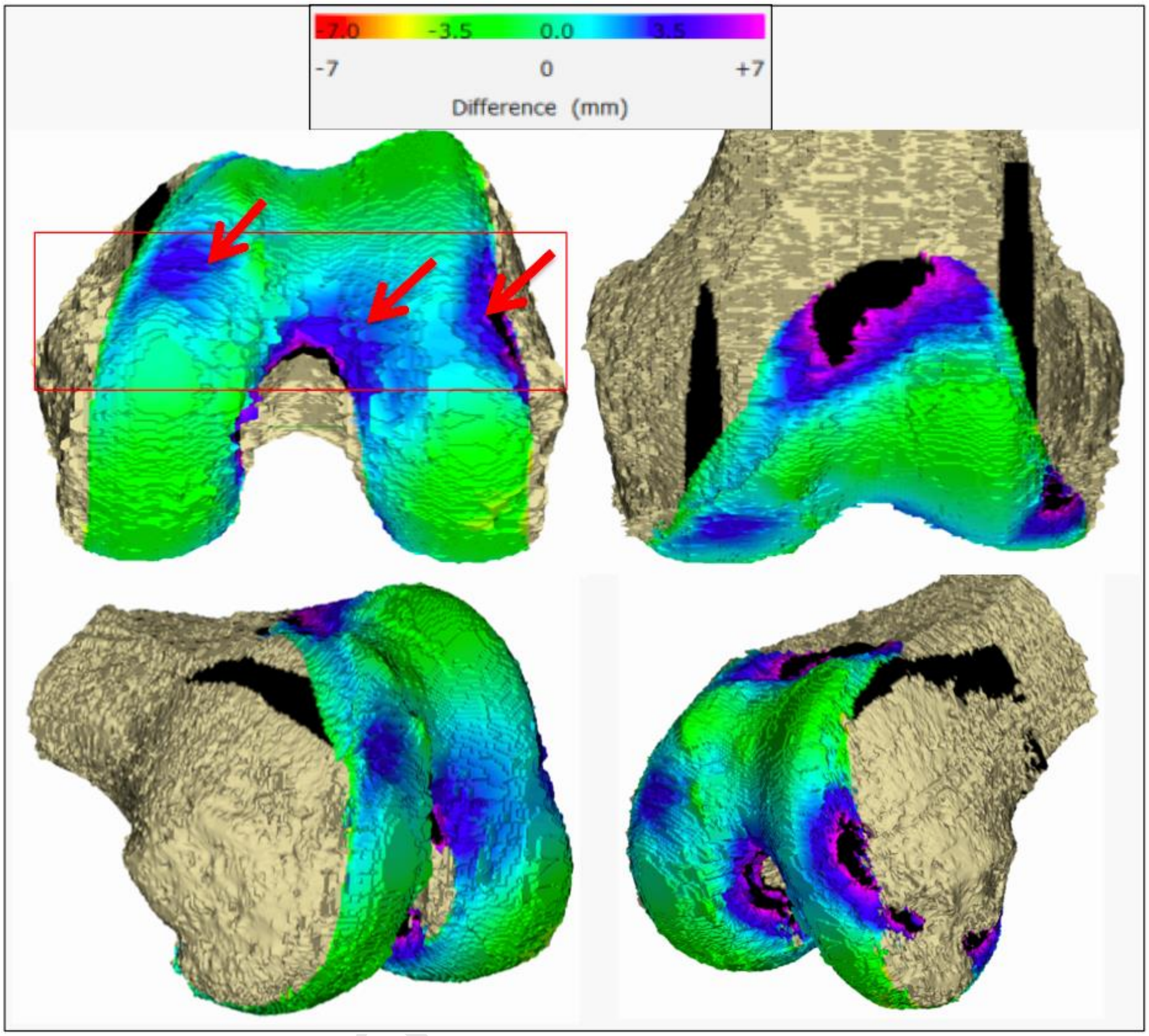

group 1
4
3
2
1
0
-1
-2
-3
-4
*
0
10
20
30
40
50
60
70
80
90
100
group 2
Mean Trochlear Groove Mediolateral Translation (mm)
θ_0 (% Trochlea)

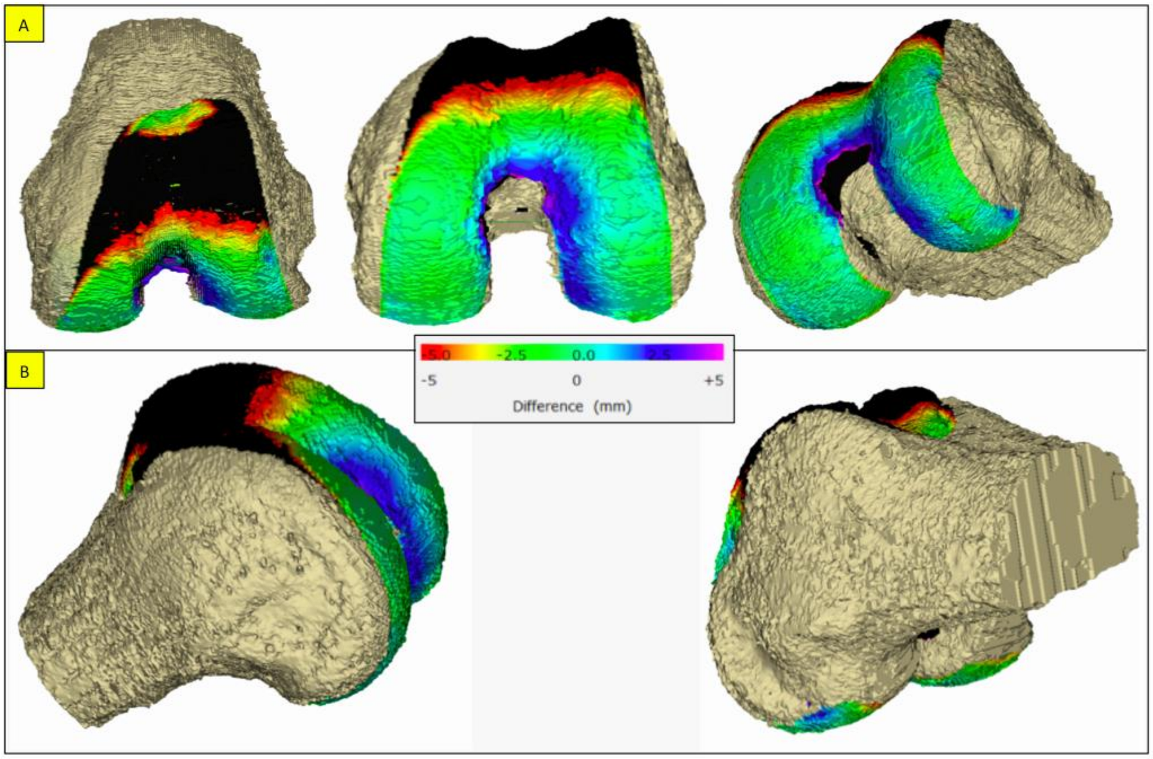

group 1
sulcus angle (degrees)
θ0 (% Trochlea)
group 2
30% of the Trochlear Groove
45% of the Trochlear Groove
individual sulcus angle (degrees)
case number
mean sulcus angle (degrees)
Native
Prosthesis

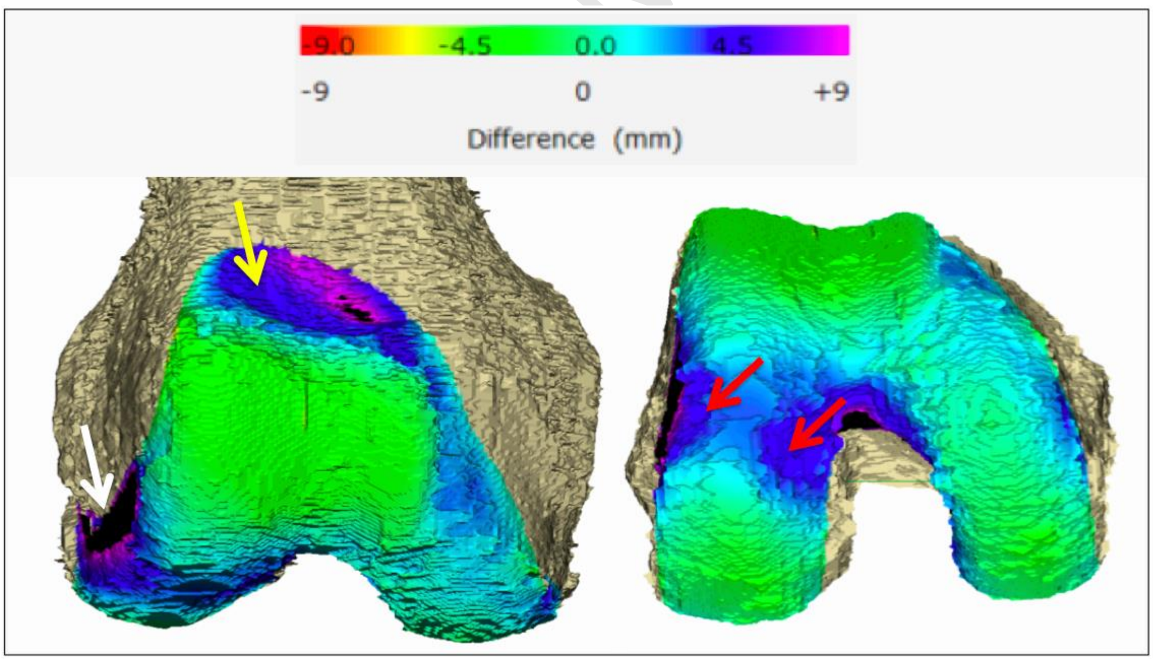

-5.0 -2.5 0.0 2.5
-5 0 +5
Difference (mm)


AT - CT
difference between implant and cartilage (mm)
% native groove
groove
medial facet
lateral facet


-7.0
-3.5
0.0
3.5
-7
0
+7
Difference (mm)


-7.0 -3.5 0.0 3.5
-7 0 +7
Difference (mm)


A
B
-5.0
-2.5
0.0
2.5
-5
0
+5
Difference (mm)


-9.0
-4.5
0.0
4.5
-9
0
+9
Difference (mm)