# The Insufficient Coverage of Lateral Trochlear Resection is Correlated to the Tibiofemoral Alignment Parameters in Kinematically Aligned TKA: A Retrospective Clinical Study

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**Research article**

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# The insufficient coverage of lateral trochlear resection is correlated to the tibiofemoral alignment parameters in kinematically aligned TKA: A retrospective clinical study


**Abstract**

**Background:** The mismatching of the femoral component and trochlear resection surface is very common in kinematically aligned total knee arthroplasty (KA-TKA) when conventional prostheses are employed. This mismatching is mainly manifested in the insufficient coverage of the bone cut surface of the lateral trochlea. The aim of present study is to explore whether this mismatch is related to the alignment parameters of the tibiofemoral joint.

**Methods:** 45 patients (52 knees) who underwent KA-TKA in our hospital were included. There were 16 patients (16 knees) received surgery using patient specific instrumentations, and conventional instruments with caliper and other special tools were employed in the other 29 patients (36 knees). The widths of exposed resection bone surface at the middle (MIDexposure) and distal (INFexposure) levels on the lateral trochlear were measured as dependent variables, while the hip-knee-ankle (HKA) angle, mechanical lateral distal femoral angle (mLDFA), joint line convergence angle (JLCA), medial proximal tibial angle (MPTA) and transepicondylar axis angle (TEAA) were measured as independent variables. Correlation analysis and subsequent linear regression were conducted among the dependent variables and various alignment parameters of the tibiofemoral joint.

**Results:** The incidence of insufficient coverage of the lateral trochlear cut bone surface was 86.5%, with MIDexposure and INFexposure being 2.3 (0-6mm) and 2.0 (0-5mm), respectively. The widths of two levels of exposed bone resection were significantly correlated to mLDFA and HKA, but were not related to TEAA.

**Conclusions:** the insufficient coverage of trochlear resection surface in KA-TKA is negatively correlated with the degrees of valgus of the distal femoral joint line and the degrees of varus of the knee. The present study suggest that in the development of KA-specific prostheses, attention should be paid to the effects of tibiofemoral alignment parameters on the prosthetic matching of the trochlear resection surface.



**Key Words** Total knee arthroplasty; Osteoarthritis; Kinematic alignment; Trochlea; Anatomy


## Background

Total knee arthroplasty (TKA) can significantly alleviate the pain of patients with end-stage knee osteoarthritis (OA), improve knee joint function and the quality of life. It has achieved tremendous

success in the past few decades. In terms of alignment options, mechanical alignment (MA), as a standard surgical technique, has won the approval of the majority of surgeons and the technical support from almost all knee prosthesis manufacturers. The alignment target of MA is to restore the "neutral" alignment of the lower extremities, but significant variation exists in the alignment of the normal population [1]. Therefore, some studies supposed that the surgical technical requirements of MA are related to the high dissatisfaction rate of patients after TKA [2-4] . Kinematical alignment (KA) is dedicated to restoring the anatomical geometry of the tibiofemoral joint and the laxity of the joint to that which it would have been before the onset of arthritis[5], and abandoning the "neutral" alignment of the MA, it has attracted widespread attention in recent years [6-8].

Patellofemoral complications and anterior knee pain after TKA have been widely concerned. Many factors are related to the disorder of patellofemoral joint, including: patellar resurfacing or not, patellar tracking, the design of the femoral component, malalignment of the components, and alignment options. The technical requirement of mechanically aligned TKA (MA-TKA) is to restore the "neutral" alignment of the lower limbs and the joint line perpendicular to the mechanical axis of the lower extremities, MA-TKA would conflict consequently with the natural joint line inclination. A study showed that MA-TKA can lead to overstuffing of the distal lateral femoral condyle. This is because of the valgus joint line of distal femur in most natural knees. Such overstuffing will increase the tension of the lateral retinaculum during knee flexion, which brings the risk of patellar tracking disorder. In addition, the degree of overstuffing is related to the degree of valgus of the distal femur [9]. Although kinematically aligned TKA (KA-TKA) strives to restore the morphology of the natural tibiofemoral joint, the use of traditional prostheses to perform KA-TKA cannot take the patellofemoral joint into full consideration. Therefore, whether KA-TKA will bring unpredictable patellofemoral disorders has become a research hotspot in recent years.

The published literatures focused on the position of the trochlear groove, the patella-femoral alignment and corresponding biomechanics [10-13]. As far as we know, no study has focused on the mismatching between the femoral component and the trochlear resection surface when KA-TKA is performed using conventional prostheses. In clinical practice, we found that the insufficient coverage of the femoral component on the lateral trochlear resection surface during KA-TKA is very common. We speculated that such scenario was caused by the design of conventional prostheses, which were developed to comply with the requirements of MA. The reference axes of KA-TKA, however, are completely different from that of MA-TKA. Therefore, the alignment parameters of the lower limbs of different individuals, especially the joint line inclination and the rotation alignment parameters of the distal femur, would have an impact on this insufficient coverage. So, this study was conducted with intention to investigate the related alignment parameters that affect the mismatching between the femoral component and the trochlear resection.

## Methods

### Patients

Inclusion criteria for KA-TKA patients: Knee osteoarthritis with Kellgren-Lawrence Grade III

or Grade IV, ≤ 5° of varus of proximal tibia (medial proximal tibial angle, MPTA ≥ 85°), and ≤ 5° of valgus deformity. Exclusion criteria: inflammatory arthritis, previous knee injury or ligament insufficiency, genu recurvatum, and ≥10° of fixed flexion contracture. Given that trochlear dysplasia may have unknown impacts on this study, patients diagnosed with trochlear dysplasia before KA-TKA were excluded from this study. From May 2018 to August 2020, a total of 55 patients underwent KA-TKA in our institution. After excluding 3 patients diagnosed with trochlear dysplasia and 7 patients with missing intraoperative measurement data of bone cut exposure, 45 patients (52 knees) were finally included in this study. Eleven patients were men and 34 patients were women. The mean age was 69.5±6.7 years (56-85 years), and the mean body mass index was 28.6±4.2kg/m$^2$ (26-34 kg/m$^2$). The preoperative radiographic changes of 1 knee were in accordance with Kellgren-Lawrence Grade III, and the other 51 knees were in compliance with grade IV. 50 patients had varus knees and 2 patients had valgus knees. Among them, 16 patients (16 knees) were performed KA-TKA with the assistance of patient-specific instrumentation (PSI-KA) , and 29 patients (36 knees) were performed KA-TKA using conventional instruments with measurement tools (Calipered kinematically aligned instrumentation, Calipered-KA). All bilateral KA-TKAs (7 patients) were performed using Calipered-KA technique.

**Surgical plans**

The design of PSI was based on full-length computed tomography (CT) of lower extremities, while the surgical technique of Calipered-KA followed the technique recommended by Howell et al[14]. No matter which assistant alignment instrument was used, articular surface-based bone cut approach is adopted [7]. A Vernier caliper was used to measure the thickness of the resected bone pieces of the distal femoral condyles, posterior condyles, and tibial plateau. The general principle is that the sum of the thickness of the resected bone piece, the compensation thickness of the worn cartilage, and the width of saw kerf is equal to the thickness of the component.

For the manufacturing of PSI, CT data (Slice thickness, 0.625mm) was collected and imported into Mimics (version 17，Materialise NV, Belgium) for 3D reconstruction, then the solid models was imported into NX 9.0 (Siemens PLM Software, TX, US) for the design of PSI (Figure 1a,b) . Rapid prototyping technology (Formiga P 110, EOS, Krailling, Germany) was used for 3D printing of the PSI. The printing material is medical nylon (PA2200 Polymer powder, EOS, Krailling, Germany), which can be sterilized using autoclaving.

For the intraoperative application of PSI, all the residual articular cartilage should be removed using a curette before the PSI was secured to its unique position. Different from the management of articular cartilage in PSI-KA, Calipered-KA only removed the residual cartilage on the severely worn side. If the contralateral articular cartilage is intact, then keep it in place. Stacked neodymium magnets (1mm of thickness each) were used to compensate the cartilage thickness on the severely worn side (Figure 2a, b).

The distal femoral resection was parallel to the joint line of the distal femur, the posterior condyle resection was parallel to the posterior condyle axis (PCA), and the posterior condyle resection was performed using posterior referencing technique. The tibial plateau resection was based on the

original inclination of proximal tibial joint line, and the tibial rotation alignment was consistent with the anteroposterior axis of the lateral plateau. The posterior tilt of resection was consistent with the posterior slope of the natural tibial plateau. A single posterior cruciate retained (CR) designed prostheses (Gemini MK Ⅱ, Link, Hamburger, Germany) were used in current study.

**Parameters measurement**

Before KA-TKA, the full-length weight bearing radiographs of lower limbs were obtained from all patients. hip-knee-ankle angle (HKA) was measured from the full-length radiograph. HKA was defined as the angle between the mechanical axes of the femur and the tibia, the value of varus HKA was defined as a positive, and the value of valgus HKA was defined as a negative. Other alignment parameters' measurements followed the methods described by Paley [15]. Measured and recorded the mechanical lateral distal femoral angle (mLDFA), the medial proximal tibial angle (MPTA), and the joint line convergence angle (JLCA). Retrieved the full-length CT data of all PSI-KA patients, determined the angle between the surgical transepicondylar axis (TEA) and the posterior condylar axis (PCA) using the in-house Maximum intensity projection (MIP) technology (SOMATOM Sensation, Siemens, Germany) and defined this angle as transepicondylar axis angle (TEAA). (Figure 3a). In addition, TEAA was also measured and recorded using a protractor in all patients included in this study during operation (Figure 3b). The above parameters were used as independent variables in this study.

Measured the distances from the lateral edge of the trochlear resection surface to the femoral component trial at two levels: the corner of the anterior condyle resection and the anterior chamfer resection (inferior exposure, INFexposure) and the middle level between this corner and the apex of the anterior flange of the femoral trial (middle exposure, MIDexposure) (Figure 4). The widths of the exposed trochlear resection at these two levels were used as the dependent variable for subsequent analysis.

**Statistical analysis**

All measurement parameters are subjected to Shapiro-Wilk test. Parameters that conformed to the normal distribution were presented as mean±standard deviation, and those that did not conform to the normal distribution were presented as Median (Interquartile range). In patients receiving PSI-KA, the reliability test of the two sets of TEAA data from CT measurement and intraoperative measurement was conducted. Reliability was determined by calculating the intraclass correlation coefficient (ICC) with 95% confidence interval (CI). An ICC value of >0.8 indicates very good, 0.6–0.8 good, 0.4–0.6 moderate, and <0.40 poor[16]。Correlation test was performed between the dependent variables and all independent variables, and linear regression analyses were conducted between variables with significant correlations. All analyses were performed using SPSS (v. 22.0, IBM, Armonk, NY), and $P$ <0.05 was considered as statistically significant.

**Results**

The data of mLDFA, MPTA and TEAA conformed to the normal distribution, while other parameters did not conform to the normal distribution. The exposed width of the distal and middle

level of lateral trochlear bone cut surface were 2.0(2.4)mm (0-5mm) and 3.0(2.9)mm (0-6mm), respectively. The other measurement results of the respective variables are shown in Table 1. Only 7 knees out of 52 knees had no obvious bone resection exposure of the lateral trochlear, and other knees had various extent of bone cut surface exposure (incidence rate 86.5%).

Table 1 Descriptive statistics of various measurement parameters

| | Shapiro-Wilk(Sig.) | mean±SD | Median(Interquartile range) |
|---|---|---|---|
| HKA(°) | 0.001 | NA | 6.0（3.0） |
| mLDFA(°) | 0.658 | 88.2±2.0 | NA |
| JLCA(°) | 0.000 | NA | 4.9（1.8） |
| MPTA(°) | 0.466 | 87.2±1.3 | NA |
| TEAA(°) | 0.093 | 3.4±1.2 | NA |
| INFcover(mm) | 0.035 | NA | 2.0（2.4） |
| MIDcover(mm) | 0.023 | NA | 3.0（2.9） |

The reliability test (ICC, Two-way mixed effects, random, fixed effects) of the two sets of TEAA measurements was performed in 16 patients who received PSI-KA, ICC is 0.792 (0.501-0.922), indicating the two measurement approaches had good consistency. For the data collection of TEAA, MIP approach of CT has better accuracy than intraoperative measurement[17], so the TEAA data of PSI-KA patients are all derived from CT measurements.

The results of Spearman correlation analysis showed that the two levels of bone cut exposure were significantly correlated to mLDFA and HKA, but not correlated to other independent variables (Table 2). Further linear regression analyses showed that INFexposure and MIDexposure are more sensitive to the values of mLDFA, with regression coefficients of -0.480 (R2=0.496) and -0.724 (R2=0.702), respectively; while HKA has a slight influence on the exposure of the trochlear bone cut surface. The regression coefficients were -0.310 (R2=0.357) and -0.384 (R2=0.340), respectively (Figure 5a, b).

Table 2 Nonparametric Spearman's correlation results among measurement parameters

| | | HKA | mLDFA | JLCA | MPTA |
|---|---|---|---|---|---|
| MIDcover | Correlation Coefficient | -0.636 | -0.834 | 0.049 | 0.129 |
| | P （2-tailed） | <0.01 | <0.01 | 0.732 | 0.363 |
| INFcover | Correlation Coefficient | -0.646 | -0.689 | -0.064 | 0.242 |
| | P （2-tailed） | <0.01 | <0.01 | 0.652 | 0.084 |

## Discussion

Current study confirmed that the extent of the exposed bone cut surface of the lateral trochlear during KA-TKA is indeed negatively correlated with mLDFA: the more valgus the joint line of the distal femur, the larger the exposed bone cut surface on the lateral trochlea. In addition, the extent of exposed bone cut surface is also weakly correlated with the alignment of the lower extremities: the more severe the varus knee, the smaller the exposed bone cut surface of the trochlea. The results of this study suggested that the design of a new prosthesis that meets the technical requirements of

KA might require lateralization of the front flange of the femoral component to a certain extent. During the design of the front flange of the femoral component for KA-TKA, because of significant variation in mLDFA among individuals, such lateralization adjustment should be meticulous, otherwise, in some patients, it would result in overhang of the femoral component, irritation of the lateral retinaculum and patellar maltracking. The results of this study implied that personalized custom prostheses may be more promising for the restoration of patellofemoral anatomy in KA-TKA.

Before this study, we speculated that the femoral rotation alignment changes of KA-TKA relative to MA-TKA would affect the exposure of the trochlear resection. In terms of femoral component rotation alignment, the reference axes in KA-TKA and MA-TKA are primary femoral axis and TEA, respectively. The primary femoral axis is the connecting line between the centers of best-fit sphears of medial and lateral condyles[18], while TEA is the most reliable reference axis in the measured resection technique of MA-KTA. The primary femoral axis had been proved relatively internally rotated compared with TEA[19]. The rotational alignment of the femoral component significantly affect the patellofemoral kinematics: an average 5°of rotation of the femoral component result in a 4° of tilt of the patella[20]. However, the results of this study were beyond the preoperative speculation: the extent of exposed trochlear resection is not significantly related to TEAA. This indicates that the rotational alignment of the femoral component does not significantly affect the matching between the component and trochlear resection surface. This result may be explained by that the relative internal rotation of the femoral component will only lead to a relative decrease in the amount of the lateral trochlear resection rather than a significant medialization of the anterior flange.

To our knowledge, there is no study on the matching of the femoral component to the trochlear resection surface in KA-TKA. KA-TKA related researches on the patellofemoral joint are mostly aimed at the trochlear position[21], trochlear orientation[12], patellar tracking[13], or kinematics of the patellofemoral joint[10, 11]. All of the above studies did not take the matching of the femoral component and the trochlear resection surface as consideration.

From the patellofemoral reconstruction perspective, the results of this study confirmed that the insufficient coverage of lateral trochlear resection surface is very common in KA-TKA when conventional prosthesis is used. Although lateralization of the femoral component could alleviate the insufficient coverage of the exposed resection, the adjustment extent of such lateralization is very limited, because of the matching of tibiofemoral joints must be taken into account simultaneously. Concerned about the irritation of the lateral retinaculum, oscillating saw was used to trim the remaining ridges in some patients. The results of this study suggested that when developing a prosthesis that meets the requirements of KA-TKA, the design of the femoral front flange should not only be based on the anatomical parameters of the natural trochlea, but also take the inclination of the femoral joint line and lower limb alignment parameters into consideration.

There were several limitations in this study: First, only one type of prostheses were employed in this study, it does not mean that other commercial prostheses have the same extent of trochlear

resection exposure. Further clinical studies involved multiple prostheses or computer simulation studies are necessary to confirm current result. Second, not all patients had CT data in this study. The majoraty of TEAA data were acquired from intraoperative measurement, which might impact the accuracy of TEAA. However, The preoperative CT data were retrospectively collected from 16 patients who received PSI-TKA , and the reliability test result of the two sets of TEAAs is "good". Despite the above-mentioned limitations, the results of this study are sufficient to prove that the insufficient coverage of trochlear resection surface in KA-TKA is not only related to the design philosophy of the conventional prostheses, but also correlated with the degrees of valgus of the distal femur and the degrees of varus of the knee.

## Conclusions

The insufficient coverage of trochlear resection surface in KA-TKA is negatively correlated with the degrees of valgus of the distal femoral joint line and the degrees of varus of the knee. The present study suggest that attention should be paid to the effects of tibiofemoral alignment parameters on the matching between implants and femoral trochlea in the development of KA-specific prostheses.

## Abbreviations

KA-TKA: Kinematically aligned total knee arthroplasty; MIDexposure: The exposed resection surface at the middle level on the lateral trochlea; INFexposure: The exposed resection surface at the distal level on the lateral trochlea; HKA: hip-knee-ankle; mLDFA: Mechanical lateral distal femoral angle; JLCA: Joint line convergence angle; MPTA: medial proximal tibial angle; TEAA: Transepicondylar axis angle; TKA: Total knee arthroplasty; OA: Osteoarthritis; MA: Mechanical alignment; KA: Kinematical alignment; MA-TKA: Mechanically aligned total knee arthroplasty; PSI: Patient-specific instrumentation; Calipered-KA: KA-TKA using conventional instruments and caliper; CT: Computed tomography; PCA: Posterior condyle axis; CR: Cruciate retained; TEA: Transepicondylar axis; MIP: Maximum intensity projection; ICC: Intraclass correlation coefficient; CI: 95% confidence interval

## Declarations

### Ethics approval and consent to participate

The study has been approved by the Institutional Review Board of Beijing Chaoyang Hospital affiliated to Capital Medical University, Beijing. Written informed consents for receiving KA-TKA were obtained from all patients. This written informed consent includes surgical benefits, possible risks, and data related to KA-TKA may be used for any related retrospective clinical studies.

### Consent for publication

Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient.

## Availability of data and materials

The organized dataset used and/or analyzed in the current study has been uploaded as a supplement to the manuscript, and the raw data is available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.


## Funding

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## Authors' contributions

ZW and LW participated in the design of the study, ZW, LW, DM and TQ performed the surgery and took the measurements, LZ and XD participated in the design of PSI and CT measurement, ZW and LW conducted the statistical analyses, ZW and TQ drafted the manuscript. All authors read and approved the final manuscript.


## Acknowledgements

Not applicable


## References


1. Bellemans J, Colyn W, Vandenneucker H, Victor J: **The Chitranjan Ranawat award: is neutral mechanical alignment normal for all patients? The concept of constitutional varus**. *Clinical orthopaedics and related research* 2012, **470**(1):45-53.
2. Maderbacher G, Keshmiri A, Krieg B, Greimel F, Grifka J, Baier C: **Kinematic component alignment in total knee arthroplasty leads to better restoration of natural tibiofemoral kinematics compared to mechanic alignment**. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2019, **27**(5):1427-1433.
3. Vendittoli PA, Blakeney W: **Redefining knee replacement**. *Orthopaedics & traumatology, surgery & research : OTSR* 2017, **103**(7):977-979.
4. Theodore W, Twiggs J, Kolos E, Roe J, Fritsch B, Dickison D, Liu D, Salmon L, Miles B, Howell S: **Variability in static alignment and kinematics for kinematically aligned TKA**. *The Knee* 2017, **24**(4):733-744.
5. Konan S, Howell S, Oussedik S: **Alignment Targets in Total Knee Arthroplasty**. In: *Total Knee Arthroplasty.* edn.: Springer; 2015: 145-159.
6. Shelton TJ, Gill M, Athwal G, Howell SM, Hull ML: **Outcomes in Patients with a Calipered Kinematically Aligned TKA That Already Had a Contralateral Mechanically Aligned TKA**. *The journal of knee surgery* 2019.
7. Kim KK, Howell SM, Won YY: **Kinematically Aligned Total Knee Arthroplasty with Patient-Specific**

**Instrument**. *Yonsei medical journal* 2020, **61**(3):201-209.

8. Niki Y, Nagura T, Kobayashi S, Udagawa K, Harato K: **Who Will Benefit From Kinematically Aligned Total Knee Arthroplasty? Perspectives on Patient-Reported Outcome Measures**. *The Journal of arthroplasty* 2019.
9. Rivière C, Iranpour F, Auvinet E, Aframian A, Asare K, Harris S, Cobb J, Parratte S: **Mechanical alignment technique for TKA: Are there intrinsic technical limitations?** *Orthopaedics & Traumatology: Surgery & Research* 2017, **103**(7):1057-1067.
10. Koh IJ, Park IJ, Lin CC, Patel NA, Chalmers CE, Maniglio M, McGarry MH, Lee TQ: **Kinematically aligned total knee arthroplasty reproduces native patellofemoral biomechanics during deep knee flexion**. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2019, **27**(5):1520-1528.
11. Keshmiri A, Maderbacher G, Baier C, Benditz A, Grifka J, Greimel F: **Kinematic alignment in total knee arthroplasty leads to a better restoration of patellar kinematics compared to mechanic alignment**. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2019, **27**(5):1529-1534.
12. Riviere C, Dhaif F, Shah H, Ali A, Auvinet E, Aframian A, Cobb J, Howell S, Harris S: **Kinematic alignment of current TKA implants does not restore the native trochlear anatomy**. *Orthopaedics & traumatology, surgery & research : OTSR* 2018, **104**(7):983-995.
13. Ishikawa M, Kuriyama S, Ito H, Furu M, Nakamura S, Matsuda S: **Kinematic alignment produces near-normal knee motion but increases contact stress after total knee arthroplasty: A case study on a single implant design**. *The Knee* 2015, **22**(3):206-212.
14. Howell SM, Papadopoulos S, Kuznik KT, Hull ML: **Accurate alignment and high function after kinematically aligned TKA performed with generic instruments**. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2013, **21**(10):2271-2280.
15. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A: **Deformity planning for frontal and sagittal plane corrective osteotomies**. *The Orthopedic clinics of North America* 1994, **25**(3):425-465.
16. Walter SD, Eliasziw M, Donner A: **Sample size and optimal designs for reliability studies**. *Statistics in medicine* 1998, **17**(1):101-110.
17. Yoshino K, Hagiwara S, Nakamura J, Tsukeoka T, Tsuneizumi Y, Ohtori S: **Intra- and interobserver reliability and agreement in three-dimensional computed tomography measurements of component positions after total knee arthroplasty**. *The Knee* 2019, **26**(5):1102-1110.
18. Howell SM, Howell SJ, Hull ML: **Assessment of the radii of the medial and lateral femoral condyles in varus and valgus knees with osteoarthritis**. *The Journal of bone and joint surgery American volume* 2010, **92**(1):98-104.
19. Eckhoff D, Hogan C, DiMatteo L, Robinson M, Bach J: **Difference between the epicondylar and cylindrical axis of the knee**. *Clinical orthopaedics and related research* 2007, **461**:238-244.
20. Merican AM, Ghosh KM, Iranpour F, Deehan DJ, Amis AA: **The effect of femoral component rotation on the kinematics of the tibiofemoral and patellofemoral joints after total knee arthroplasty**. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2011, **19**(9):1479-1487.
21. Lozano R, Campanelli V, Howell S, Hull M: **Kinematic alignment more closely restores the groove location and the sulcus angle of the native trochlea than mechanical alignment: implications for prosthetic design**. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 2019, **27**(5):1504-1513.

## Figures and Legends

Figure 1 Computer aided design (a) and intraoperative application (b) of PSI.

Figure 2 Stacked neodymium magnets (white arrows) are used to compensate the thickness of worn articular cartilage (2mm) in Calipered-KA

Figure 3 Transepicondylar axis angles (TEAA) were measured by preoperative superimposed CT(a) and protractor in the operating room(b). (a) Determined the recess of the medial epicondyle, the prominence of the lateral epicondyle, and the highest point of the medial and lateral posterior condyles by MIP approach of CT, the TEAA value was automatically obtained by the in-house program; (b) Intraoperative measurement required electrocautery to mark the position of the medial and lateral epicondyles on the distal femoral resection surface. The arms of the protractor were parallel to the posterior pedals of instruments and the electrocautery marks, respectively.

Figure 4 Intraoperative caliper measurement of the exposed bone resection of the lateral trochlea. The white and blue arrows represent the width of the exposed bone cut surface at the distal (INFexposure) and middle (MIDexposure) level of the trochlea, respectively.

Figure 5 The influence of distal femoral joint line (mLDFA) and the alignment of lower extremities (HKA) on the insufficient coverage of the lateral trochlear resection, where INFexposure and MIDexposure represent the width of the exposed bone resection at the distal and middle level of the trochlea, respectively.

# Figures

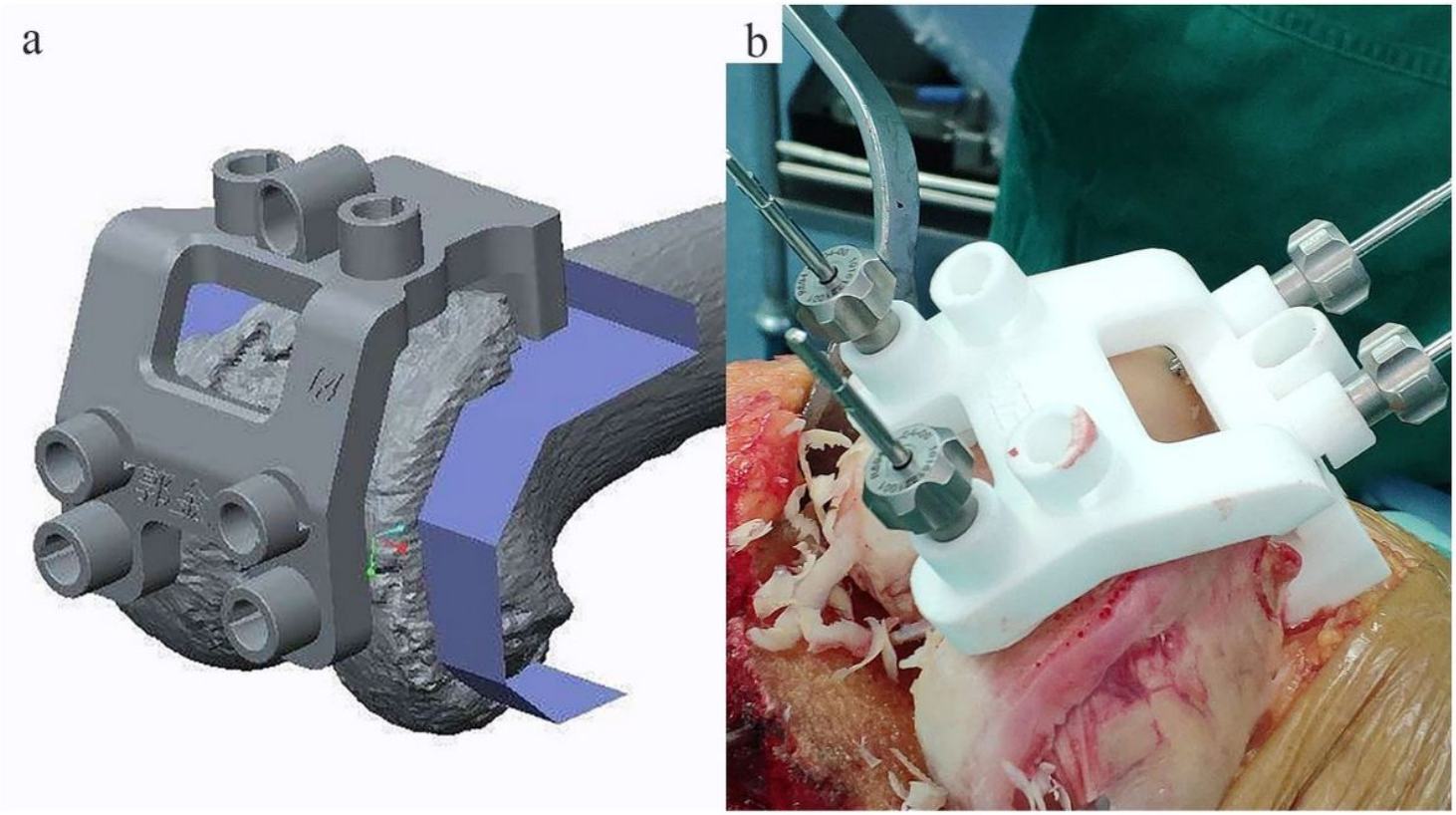


**Figure 1**

Computer aided design (a) and intraoperative application (b) of PSI.

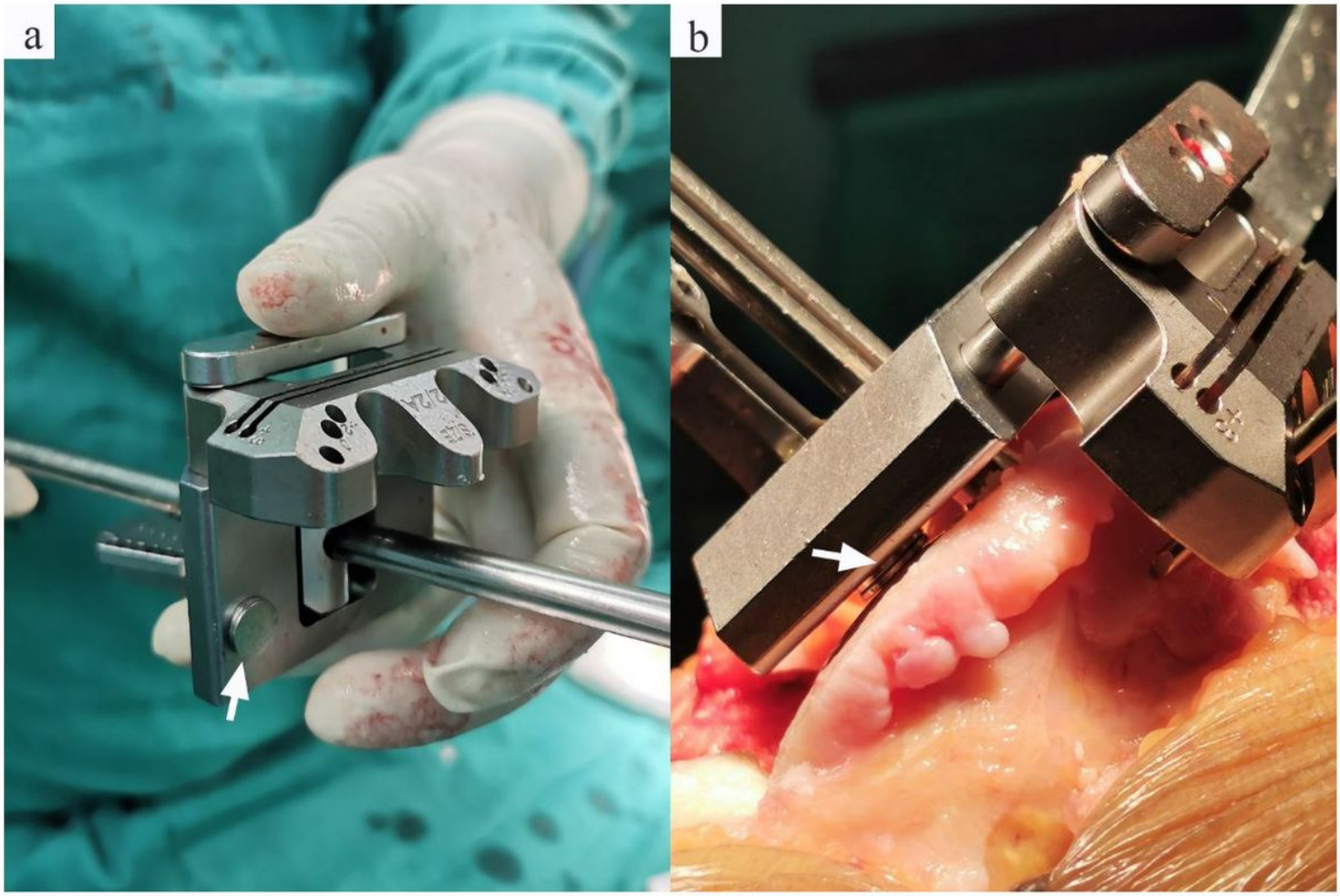


**Figure 2**

Stacked neodymium magnets (white arrows) are used to compensate the thickness of worn articular cartilage (2mm) in Calipered-KA

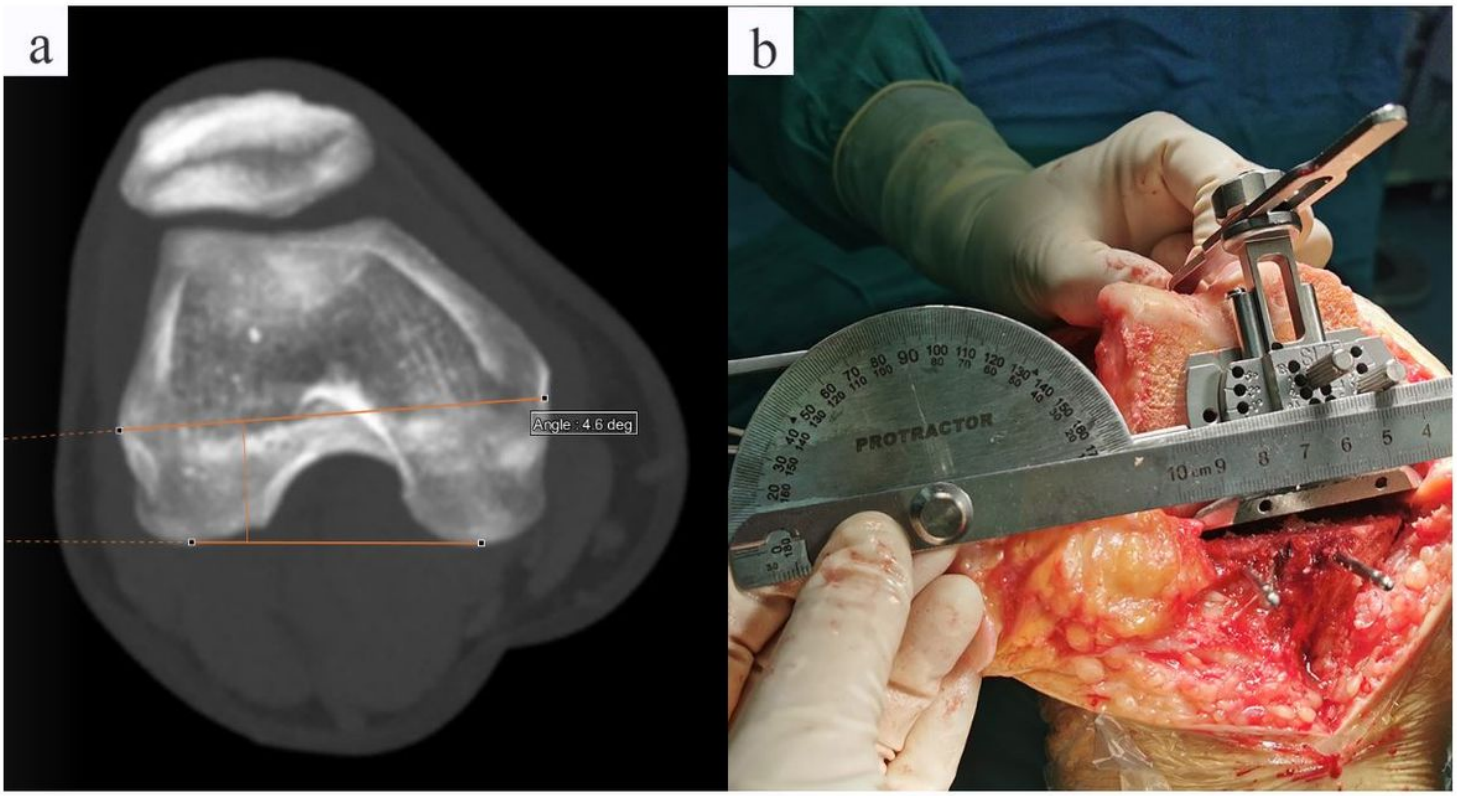


**Figure 3**

Transepicondylar axis angles (TEAA) were measured by preoperative superimposed CT(a) and protractor in the operating room(b). (a) Determined the recess of the medial epicondyle, the prominence of the lateral epicondyle, and the highest point of the medial and lateral posterior condyles by MIP approach of CT, the TEAA value was automatically obtained by the in-house program;(b)Intraoperative measurement required electrocautery to mark the position of the medial and lateral epicondyles on the distal femoral resection surface. The arms of the protractor were parallel to the posterior pedals of instruments and the electrocautery marks, respectively.

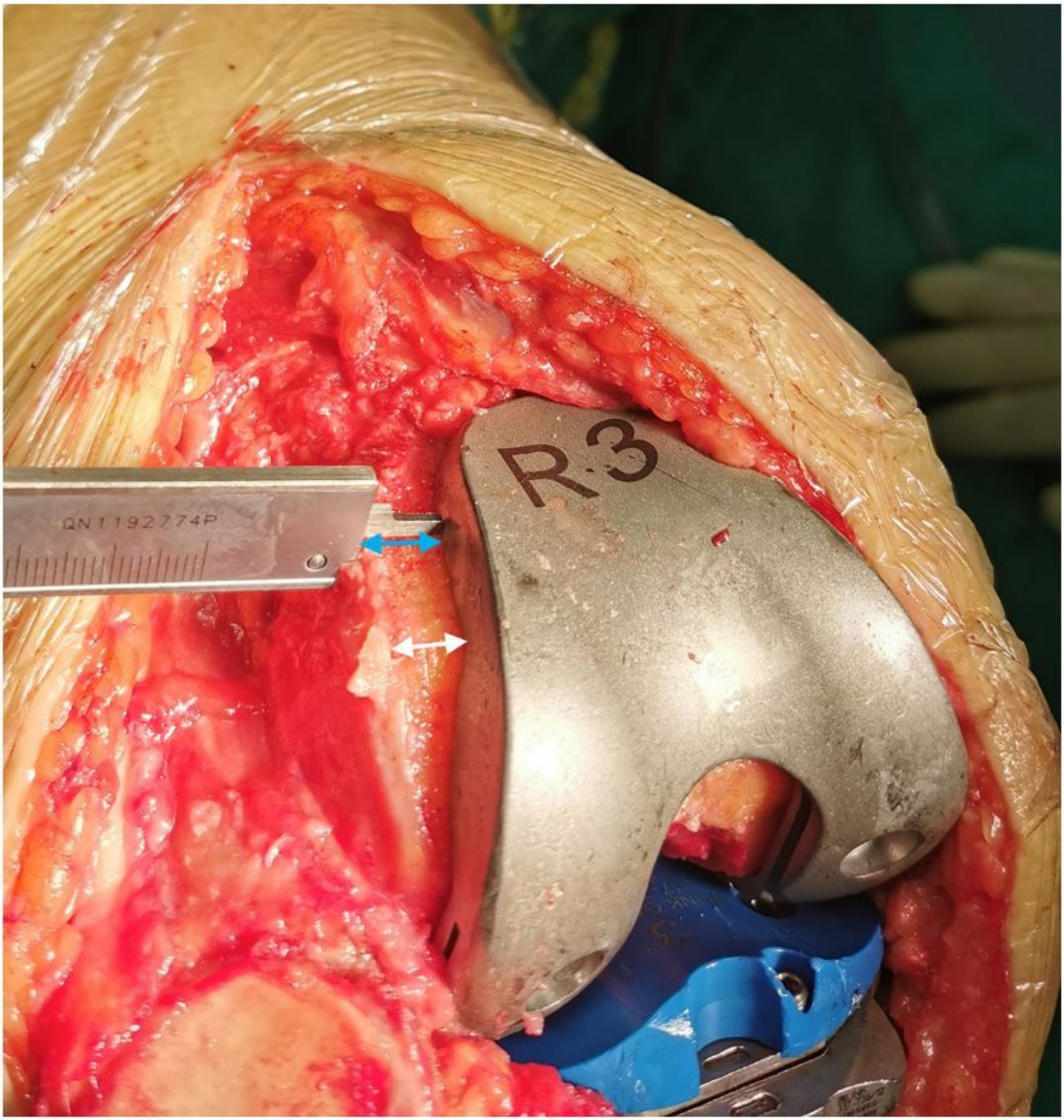


**Figure 4**

Intraoperative caliper measurement of the exposed bone resection of the lateral trochlea. The white and blue arrows represent the width of the exposed bone cut surface at the distal (INFexposure)and middle(MIDexposure)level of the trochlea, respectively.

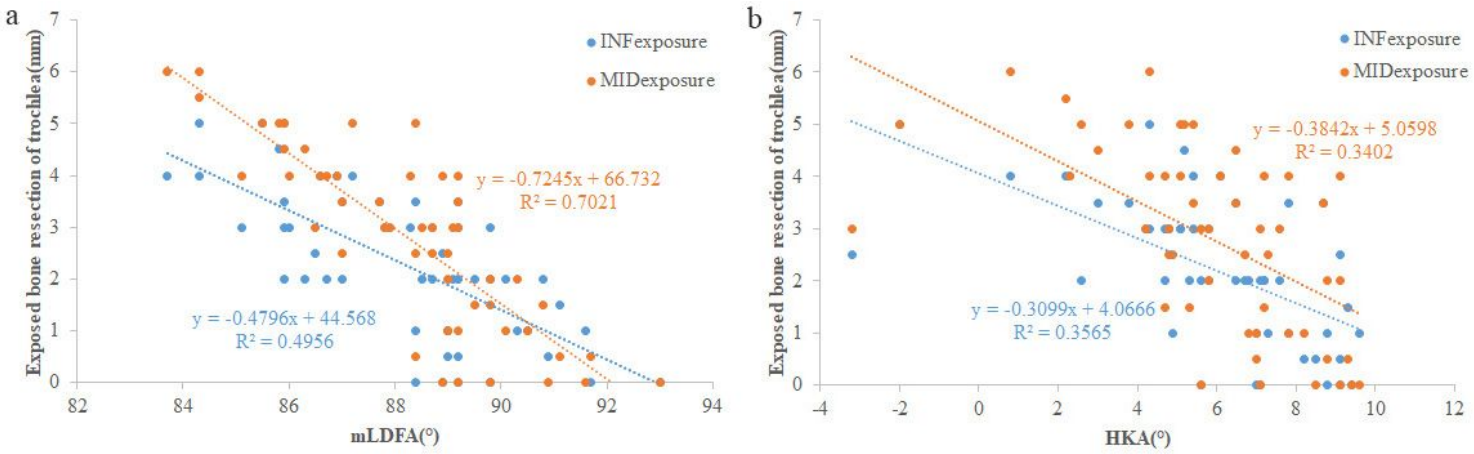


**Figure 5**

The influence of distal femoral joint line (mLDFA) and the alignment of lower extremities (HKA) on the insufficient coverage of the lateral trochlear resection, where INFexposure and MIDexposure represent the width of the exposed bone resection at the distal and middle level of the trochlea, respectively.

# Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- dataupdate.xlsx