Varus Morphology And Its Surgical Implication In Osteoarthritic Knee And Total Knee Arthroplasty

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Abstract

Background

Knee varus alignment represents a notorious cause of knee osteoarthritis. It can be caused by tibial deformity, combined tibial-femoral deformity and/or ligament imbalance. Understanding malalignment is crucial in total knee arthroplasty (TKA) to restore frontal plane neutral mechanical axis. The aim of this study was to determine which factor contributes the most to varus osteoarthritic knee and its related surgical implications in performing a TKA.

Methods

We retrospectively evaluated 140 patients operated for TKA due to a varus knee. Full-leg hip to ankle preoperative X-rays were taken. Radiological parameters recorded were: mechanical axis deviation (MAD), hip-knee-ankle (HKA), anatomical-mechanical Angle (AMA), medial neck-shaft angle (MNSA), mechanical lateral distal femoral angle (mLDFA), medial proximal tibial angle (MPTA), joint line convergence angle (JLCA), lateral proximal femoral angle (LPFA), lateral distal tibial angle (LDTA), femoral bowing and length of tibia and femur. We also determined ideals tibial and femoral cuts in mm according to mechanical alignment technique. A R2 was calculated based on the linear regression between the predicted values and the observed data.

Results

The greatest contributor to arthritic varus (R=0,444) was MPTA. Minor contributors were mLDFA (R= 0.076), JLCA (R = 0,1554), LDTA (R = 0.065), Femoral Bowing (R= 0,049). We recorded an average of 7,6 mm in lateral tibial cut thickness to restore neutral alignment.

Conclusions

The radiological major contributor to osteoarthritic varus knee alignment is related to proximal tibia deformity. As a surgical consequence, during performing TKA, the majority of the correction should therefore be made on tibial cut.

1. Introduction

Varus malalignment represents a notorious cause of knee osteoarthritis in adults. The pathogenesis is correlated to an increased loading of the medial tibiofemoral compartment that can lead to faster degeneration of the cartilage of medial compartment. Varus malalignment of the knee may be caused by tibial deformity, combined tibial and femoral deformity and may also present ligament imbalance [1–3]. This malalignment can occur constitutionally, that refers to a knee with a HKA (Hip-Knee-Ankle angle) <

3°, or secondary to injuries, tumors and other pathologies[1,2,4,5]. It’s already well known in literature that Medial Proximal Tibial Angle (MPTA) contributes the most to a varus knee in case of varus constitutional conformation[6,7]. Conversely, regarding varus knee deformity for all causes but constitutional varus, literature offers great variability of observations [7,8,9,19,20,21]. Indeed, some authors pointed the mechanical-Lateral Distal Femoral Angle (mLDFA) and the Medial Neck Shaft Angle (MNSA) as important contributors to varus [7,8]. Others also observed that the lateral femoral bowing could be related to progression of varus osteoarthritic knee[9].

In Total Knee Arthroplasty (TKA) pre-operative planning is mandatory to establish the limb alignment (varus or valgus) and to determine the eventual correctability of knee deformities [10]. Indeed, pre-operative planning allows to estimate soft-tissue status and ligament balance.

The aim of this study was to determine which factor contributes the most to varus osteoarthritic knee and which are the clinical implications in performing a TKA in a varus knee [6,7]. The hypothesis was that varus osteoarthritic knee is related to many lower limb parameters some of that related to the constitutional varus and other to the osteoarthritis disease progression itself.

2. Materials And Methods

We retrospectively evaluated 140 patients operated for TKA due to a varus knee between 2016 and 2018 at our Institution. There were 106 female and 34 male patients. Inclusion criteria to the study group consisted of all patients of any age or gender with a weight-bearing full-leg pre-operative X-rays on a bipodal stance showing varus mechanical axis alignment.

2.1 Radiological assessment

One hundred and fifty TKAs were preoperatively classified as varus aligned in our database by the measurement of HKA, according to what has been postulated by Paley [2] and recently revised by Bahadir et al [11]. In the neutrally aligned limb, the HKA angle approaches 180° (Varus deviations are negative HKA angle and valgus deviations are positive HKA angle). The weight-bearing full-leg radiographs were obtained as described by Paley [12] with the subjects standing barefoot and the feet together at attention position while the patellae were oriented forward. This standard position ensured that the tibias were vertical and facing forward with minimal rotation. Two observers performed all the x-ray measurements independently from each other to power up the accuracy of the investigation. We used CarestreamHelth (Rochester, NY) for all analyses. The center of the femoral head was determined using a digital template with concentric circles. The center of the knee was determined as the intersection of the midline between the tibial spines and the midline between the femoral condyles and tip of the tibiae. The center of the ankle was determined as the middle of the talus. The mechanical femoral axis was defined as the line from the center of the femoral head to the center of the knee. The mechanical tibial axis was defined as the line from the center of the knee to the center of the ankle. The anatomical femoral axis was defined as the line from the center of the knee to the bisector of the medullary canal of the femur. For length measurements, the distance from the center of the femoral head to the center of the knee was defined as the femoral length. We evaluated radiologic parameters as described first by Paley [2] and then revised by Bahadir et al[11] including the mechanical axis deviation (MAD), hip-knee-ankle (HKA), anatomical-mechanical Angle (AMA), medial neck-shaft angle (MNSA), mechanical lateral distal femoral angle (mLDFA), medial proximal tibial angle (MPTA), joint line convergence angle (JLCA), lateral proximal femoral angle (LPFA), lateral distal tibial angle (LDTA), femoral bowing and length of tibia and femur (Figure 1. A-E). MAD is the distance between the mechanical axis line and the center of the knee. Medial MAD was referred to as varus alignment while lateral MAD was referred to as valgus alignment. HKA was defined as the angle formed by the mechanical femoral axis and the mechanical tibial axis. The HKA value included between 178°-182° was defined as normal alignment, as varus with a negative value and as valgus with positive value. AMA was defined as the angle between the anatomical and mechanical femoral axes. MNSA was defined as the angle between the longitudinal axis of the neck and the longitudinal axis of the femoral shaft. mLDFA was defined as the lateral angle formed between the mechanical femoral axis and the knee joint line of the distal femur. The MPTA was defined as the medial angle formed between the mechanical tibial axis and the knee joint line of the proximal tibia. The JLCA was defined as between the tangent through the two most convex distal points of the femoral condyles and a line along the flat portion of the subchondral bone of the tibial plateau. The LPFA was defined as the angle between the line connecting the tip of the greater trochanter with the center of the femoral head and the mechanical femoral axis. The LDTA was defined as the angle between the mechanical tibial axis and a line through the tip of the medial and lateral talus shoulder. Lateral femoral bowing was defined as an acute angle formed between the line drawn at the center of the femur below the level of the lesser trochanter to pass the center of the femur at a point 5 cm distal to the starting point and the line extending from the center of the femoral distal condyle through the center of the femur at a 5 cm proximal portion and a 5 cm further proximal point (Figure 1. A-E). In the presence of a JLCA>2°, associated with a clinical positive varus stress at 0° and/or 30° of flexion, a stress radiograph was made to evaluate the varus stress JLCA. This angle was only checked pre-operatively to determine the joint line congruency under stress and so to evaluate the lateral soft tissues straining. All other measures were performed pre- and post-operatively at six weeks after surgery. On pre-operative calibrated digital radiographs, we planned the thickness of tibial and femoral cuts in millimeters following the principles of mechanical alignment, making resections at 90° to the femoral and tibial mechanical axes. Intraoperatively, with the use of a caliber, we measured and recorded the real thickness of the resected medial-lateral tibial plates bone cuts and medial-lateral distal femoral condyles bone cuts. The two measurements, the ones based on pre-operative planning and the ones measured during surgery, were then compared.

2.2 Statistical analysis

We used the software StatPlus:mac for Macintosh to elaborate statistical data. We analysed the correlation between HKA median value and all other recorded median parameters. Every observation was made by the regression linear model using the Ordinary Least Squares. An R2 was calculated based on the linear regression between the predicted values and the observed data. An R proximal to 1 was considered a good predictor of the dependent variable, while a R proximal to 0 represents absence of correlation and -1 represents a negative correlation. We put all data on the x-y graphics for each parameter to calculate the straight-line equation between all HKA values and all other parameters. This line estimates the nature of data correlation between HKA and all other parameters (directly vs inversely proportional). The “intraclass correlation coefficient” (ICC) was used to measure the variability in between the digitally planned cuts’ thickness and the effective cuts performed intraoperatively. An ICC between 0.75 and 1.00 was considered as excellent (almost no variability in between the two measurements).

3. Results

There were 106 females (75%) and 34 males (24%). Everyone had varus alignment with a HKA between 159° and 174° (average of 171°). According to Bahadir et al.[11], 92 knees (65%) had an osseous malalignment that is the presence of a tibial varus deformity (MPTA<85° (median 85,7°)), or Femoral varus deformity (LDFA>90° (median 90°)) or combined femoral and tibial varus deformity (LDFA>90° and MPTA <85°). 44 (31%) of these had a tibia vara deformity, 30 (21%) a femoral varus deformity and 12 (8,5%) a combined femoral and tibial varus deformity. In 48 knees (34%) we identified an intra-articular malalignment, that is the presence of normal femur and tibia osseous alignment with an altered knee joint congruity: JCLA> 2° (median 5°). Six of them had an associated clinical positive varus stress, therefore we performed stress radiographs that showed a mean varus stress JLCA of 5.1 ± 1.1. 10 knees (7%) had a combination of osseous malalignment and JLCA >2° (Table 1). The greatest contributor to arthritic varus (R=0,444) was MPTA. Other contributor was mLDFA (R= 0.076), JLCA (R = 0,1554), LDTA (R = 0.065), Femoral Bowing (R= 0.049), and MNSA (R = 0.003) (Figure 2. A-F). Based on the straight-line equation, MPTA, mLDFA, JLCA and femoral bowing showed a directly proportional correlation with HKA values variations. We found an average of 7,6 mm of thickness of the lateral tibial cut (range 2,2 - 20,5 mm). An ICC of 0.92 was found in between the pre-operative planned cuts’ thickness and the intraoperative cuts’ thickness. Lateral tibial cut showed direct correlation with increase in cuts’ thickness and reduction of both MPTA and HKA values (R = 0.471 and R = 0.543 respectively) (Table 1). Indeed, in most of the cases, the thickness of the lateral tibial cut was inversely related both to the degree of MPTA and HKA (Figure 3. A, B). The mean HKA was corrected from a preoperative of 170° (SD ± 4) to postoperative 180° (SD ± 2).

Table 1
Radiographic assessments and intra-operative findings

Parameter	Range values	Median
HKA angle (°)	159-180	171,3
mLDFA (°)	83-98	90
MPTA (°)	79-93	85,7
JLCA (°)	0-15	5
MNSA (°)	113-145	128,7
LPFA (°)	70-103	88,8
LDTA (°)	69-99	87
Femoral bowing angle (°)	4,6-7,8	6,7
MAD (mm)	3-76	32,5
Distal Medial Femoral cut (mm)	3,1-14,7	7,2
Distal Lateral Femoral cut (mm)	1,8-12,5	6,8
Medial Tibial plateau cut (mm)	1,7-13,2	6,5
Lateral Tibial plateau cut (mm)	2,2-20,5	7,6
AMA (°)	4-8	6,2
Femoral length (mm)	393-791	466,5
Tibial length (mm)	282-417	354,4

Discussion

Meniscal damage, meniscal extrusion, varus–valgus malalignment, and medial–lateral laxity are local factors that may be present in primary knee osteoarthritis [13]. Varus malalignment increases loading of the medial tibiofemoral compartment during gait by increasing the external adduction moments (force toward the sagittal plane) acting on the knee during the late-stance phase of the gait cycle [14,15]. In TKA, gold standard is restoration of neutral mechanical axis, considered critical for long-term success. A tibial cut made at 90° compared to the tibial mechanical axis allows long survival of the tibial component in terms of aseptic loosening [16–18].

In this study, we aimed to discriminate factors that contribute to arthritic varus and to the global limb malalignment. We observed several of our patients with varus angulation of their tibia, contributing to the global limb malalignment. In literature different observations are reported about morphology to varus arthritic knee. Bellemans et al. previously demonstrate that the strongest parameter that influences HKA in healthy knees with constitutional varus is MPTA [7]. Similarly, in our study, the deformity of the proximal tibia was the most important factor related to the varus osteoarthritic knee (Figure 2A). Varus malalignment determines a medial overload that results in a tibial cartilage wearing with secondary subchondral bone collapse. Correcting intra-operatory by cutting the most lateral tibial plateau with the guide aligned 90° from mechanical axis of the tibia, we observed a restoration of neutral limb alignment. Moreover, tibial cuts measured pre-operatively were predictable of what have been measured during surgery.

Weiping et al.[19] observed that femorotibial geometric alignment referred to increased mLDFA and decreased MPTA was one of the two potential components giving the major contribution to varus deformity of the lower extremity in knee osteoarthritis. In our population, the conformation of the distal femur had a minor impact in the contribution of varus knee than the geometry of the proximal tibia. At the same time, observing the correlation diagram between mLDFAs and HKAs, millimetric augment of varus grade on the distal femur corresponds linearly to HKA varus grade augmentation (Figure 2B). Bellemans [7] observed a good correlation of these two parameters also in constitutional knees.

Thienpont et al.[20] suggest that the mean varus alignment of the lower limb (178° HKA°) is rather a result of lateral soft tissue laxity with joint line opening (JLCA of 3°) on the lateral side in varus knees. Despite in our population we found a median JLCA of 5°, it wasn’t significantly related to the amount of varus osteoarthritic deformity as it was for the MPTA. Moreover, the amount of JLCA didn’t change the definitive tibial plateau cuts’ thickness. Tibial cuts had major thickness on the lateral side than in the medial side. That was directly related to the grade of varus deformity and so on the grade of MPTA (Figure 3A, B). Secondary to these observations, the majority of correction during TKA should be obtained on the lateral tibial plateau, in order to correct tibial deformity. A JLCA >2° could be more related to the amount of medial soft tissue release needed to balance the knee in extension once the mechanical alignment of the tibia has already been restored through the tibial cut. This is definitively important in order to get a neutral, well balanced, HKA. Indeed, not so much intra-articular deformity correction can be obtained on the femoral side compared to the tibial side associated with soft tissue release in extension on the concave side (medial collateral ligament in extension).

Cho et al. [9] in a selected Asiatic population, found that lateral femoral bowing shows a tendency to increase his value directly proportional to the grade of varus knee deformity. In our European population, we also found an increase of femoral bowing according to the degree of varus knee deformity (Figure 2E), but not statistically significant and with mean values at the edge of normal parameters (4,6-7,8°). Therefore, diaphyseal femoral deformity had not such a strong impact both on HKA and on osteoarthitis progression in knee varus deformity, compared to what was found in Asiatic population (Table 1).

Finally, Issin et al.[8] shows that abnormal forces applied to ankle may cause collapse in distal lateral tibial metaphysis and decrease LDTA in varus knees and that medial neck shaft angle may decrease due to possible abnormal loading angles to the femoral neck in some individuals with varus gonarthrosis. In our series different grades of HKA were associated with variable LDTA values showing a completely dissociated correlation between those parameters (Figure 2D). The same was observed for MNSA (Figure 2F).

The limitations to this study include the nature of retrospective analysis. We used standard full leg standing radiographs, which are the standard for alignment assessment, but may not be as accurate and reproducible as 3D computer tomography or biplanar radiographs. Furthermore, the use of bipodal weight-bearing view without the augment of the unipodal view cannot be helpful to evaluate the presence of ligament imbalance. The rotational position of the lower extremities might influence the outcome of the measurements. We performed varus-valgus stress radiograph only in case of clinical varus positive stress at 0° and/or 30°. We did not compare the grade of medial compartment release to JLCA values. Another limitation is the lack of explanation for the patho-etiology and the natural course of tibia vara. Furthermore, we don't have consecutive images to document the natural progression of this condition overtime.

According to our findings the major contributor to osteoarthritic varus knee malalingment on radiological evaluation is related to proximal tibia deformity. As a clinical consequence, performing TKA requests consciousness of lower limb alignment. Pre-operative planning could be mandatory to investigate the exact position of deformity. During performing TKA, the majority of the correction should therefore be made on tibial cut.

Abbreviations

TKA
total knee arthroplasty
MAD
mechanical axis deviation
HKA
hip-knee-ankle
AMA
anatomical-mechanical Angle
MNSA
medial neck-shaft angle
mLDFA
mechanical lateral distal femoral angle
MPTA
medial proximal tibial angle
JLCA
joint line convergence angle
LPFA
lateral proximal femoral angle
LDTA

lateral distal tibial angle

ICC

intraclass correlation coefficient

Declarations

Ethics approval and consent to participate

All partecipants agreed to be included in the study. Our etichal board commetee approved the study

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

M.I. proposed the study, made the design, made satystical analisys and reviewed the article.

C.S. collected data, found patients to participate the study

D.S., L.Z., C.C., R.C., F.M. participated in bibliographic collection, data check and measurements, reviewed the article.

All authors read and approved the final manuscript.

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Figures

Figure 1

Radiographic assessment of pre-operative measurements. A. HKA: Hip-Knee-Ankle Angle; AMA: anatomical-mechanical Angle; MNSA: medial neck-shaft angle. B. deformity analysis angles. LPFA: lateral proximal femoral angle; mLDFA: mechanical lateral distal femoral angle; MPTA: medial proximal tibial angle; LDTA: lateral distal tibial angle. C. LFBA: lateral femoral bowing angle. D. JLCA: joint line converge angle. E. MAD: mechanical axis deviation distance.

Figure 2

Linear regression between all pre-operative angle assessments and HKA angle. All values are expressed in degrees. A. Linear regression between MPTA and HKA. B. Linear regression between LDFA and HKA. C. Linear regression between JLCA and HKA. D. Linear regression between LDTA and HKA. E. Linear regression between Femoral bowing and HKA. F. Linear regression between MNSA and HKA.

Figure 3

Linear regression between Lateral tibial cut thickness and both MPTA (A) and HKA (B).