Varus Knee Deformity Classification Based on Degree and Extra- or Intra-Articular Location of Coronal Deformity and Osteoarthritis Grade

Vaibhav Bagaria, MBBS, MS, FCPS, DipSICOT

Rajiv V. Kulkarni, MBBS, DOrtho

Omkar S. Sadigale, MBBS, DNB, DOrtho, DipSICOT

Dipit Sahu, MBBS, MSOrtho

Javad Parvizi, MD

Emmanuel Thienpont, MD, MBA, PhD

Investigation performed at Sir H N Reliance Foundation Hospital, Girgaum, Mumbai, Maharashtra, India

Abstract

Background: Medial coronal plane malalignment, also known as varus alignment, is commonly reported in osteoarthritic knees. Although the degree of deformity provides some insight regarding the severity of the disease, it does not always reflect the potential complexity of the surgical treatment.

Methods: This prospective observational study was conducted by analyzing the radiographs of 100 consecutive knees in patients undergoing total knee arthroplasty. For each knee, coronal alignment, expressed as the hip-knee-ankle angle, was measured on a full-leg standing radiograph and classified in 3 stages. The primary location of the varus deformity was identified as intra-articular and/or extra-articular. Additionally, knees were evaluated to assess for 10 radiographic features of varus deformity and then classified in 3 grades of osteoarthritis severity.

Results: The mean (and standard deviation) preoperative varus deformity was 11° ± 6° of varus (hip-knee-ankle, 169°), as measured on standardized full-leg radiographs. Extra-articular varus deformity was observed in 14% of patients. A higher number of radiographic features of varus severity corresponded with higher degrees of deformity. Varus grade correlated strongly with stage of varus deformity. Twenty-three (100%) of 23 stage-III deformities had grade-C features; however, 13 (48%) of 27 stage-I patients also had grade-C disease.

Conclusions: One of every 7 osteoarthritis patients with varus deformity had an extra-articular deformity, and 1 of 2 of these patients had severe intra-articular disease (grade C) despite limited coronal deformity (stage I). These findings reconfirm the need for individual deformity analysis that accounts for the degree, location, and severity of the varus deformity. This insight may help to formulate an algorithmic treatment approach specific to the epiphyseal knee anatomy of the patient and according to the surgical preferences of the surgeon.

Clinical Relevance: Knee surgeons tend to consider knees with higher degrees of coronal deformity as more technically difficult, but the present study shows that knees with less deformity can still present with severe grades of osteoarthritis inside the knee, leading to more challenging joint reconstruction.

Medial coronal plane malalignment, also known as varus alignment, is commonly reported in osteoarthritic knees[1]. Varus deformity is more frequent because, for the general population, native alignment is more often 1° to 2° of varus rather than neutral[2]. Medial load-

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSREV/A769).

bearing and load transmission patterns of the native knee lead to more medial wear[3]. Mechanical changes in the joint, after the loss of anatomical structures such as the medial meniscus or anterior cruciate ligament, can also lead to medial compartment disease[4]. During the development of varus osteoarthritis, aside from obvious joint space narrowing, there might be several other radiographic changes, such as osteophyte formation, metaphyseal beaking (i.e., osseous projection in the medial metaphyseal area), and coronal-plane subluxation[3,5,6]. In some cases, there may even be stress fractures and diaphyseal remodeling of the tibia and fibula, which are the markers of severe disease. These radiographic features are progressive and are the results of both mechanical and biological processes at the molecular and cellular level[7].

It is currently not known how these radiographic features of disease severity correlate with the degree of varus knee deformity. Additional uncertainties include whether more severe radiographic features are always found in more severely varus knees and whether milder radiographic features are always present in knees with lower-staged varus deformity. There are several long-standing questions regarding varus deformity and its treatment, such as why severe varus deformity is sometimes observed in the absence of impressive signs of intra-articular wear, or why advanced medial osteoarthritis sometimes presents with a low degree of varus alignment. In a recent study, Thienpont and Parvizi proposed an improved classification system for varus knee deformity that could help address some of those questions[8]. By utilizing data on the stage, location, and grade of varus deformity, this currently proposed classification system could be utilized to identify clinically relevant signs of disease and aid surgeon decision-making before and during knee arthroplasty. Treating extra-articular varus alignment with use of an intra-articular osteotomy, such as total knee arthroplasty, may prove much more complicated than previously imagined.

The primary aim of the present study was to identify the radiographic features of varus-deformed osteoarthritic knees and correlate these features with the severity of the varus deformity and the degree of coronal deformity, and to determine the location of varus disease.

Materials and Methods

From January 2018 until December 2018, the radiographs of 100 consecutive knees undergoing total knee arthroplasty were prospectively assessed for varus deformity as a result of primary osteoarthritis. For each patient, we identified the severity of coronal plane deformity (expressed as the hip-knee-ankle angle [HKA], with an HKA of <178° considered varus disease), the primary location of the apex of deformity (i.e., intra- or extra-articular), and the presence or absence of 10 different radiographic features of osteoarthritis. Knees were then graded (A, B, or C) according to these radiographic features and assessed a stage (I, II, or III) according to the severity of the deformity in the coronal plane (Figs. 1 through 4). Knees were subsequently classified according to their respective grades and

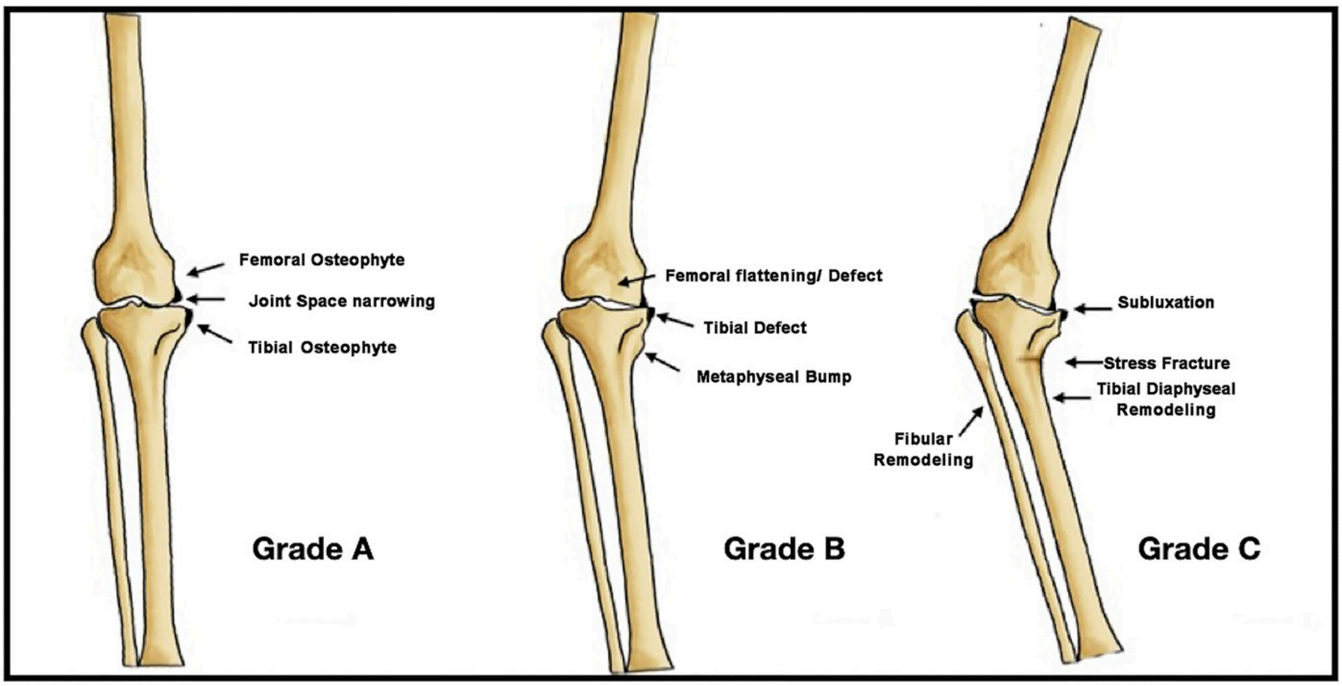

Fig. 1
Illustration showing grade-A, grade-B, and grade-C varus deformity.

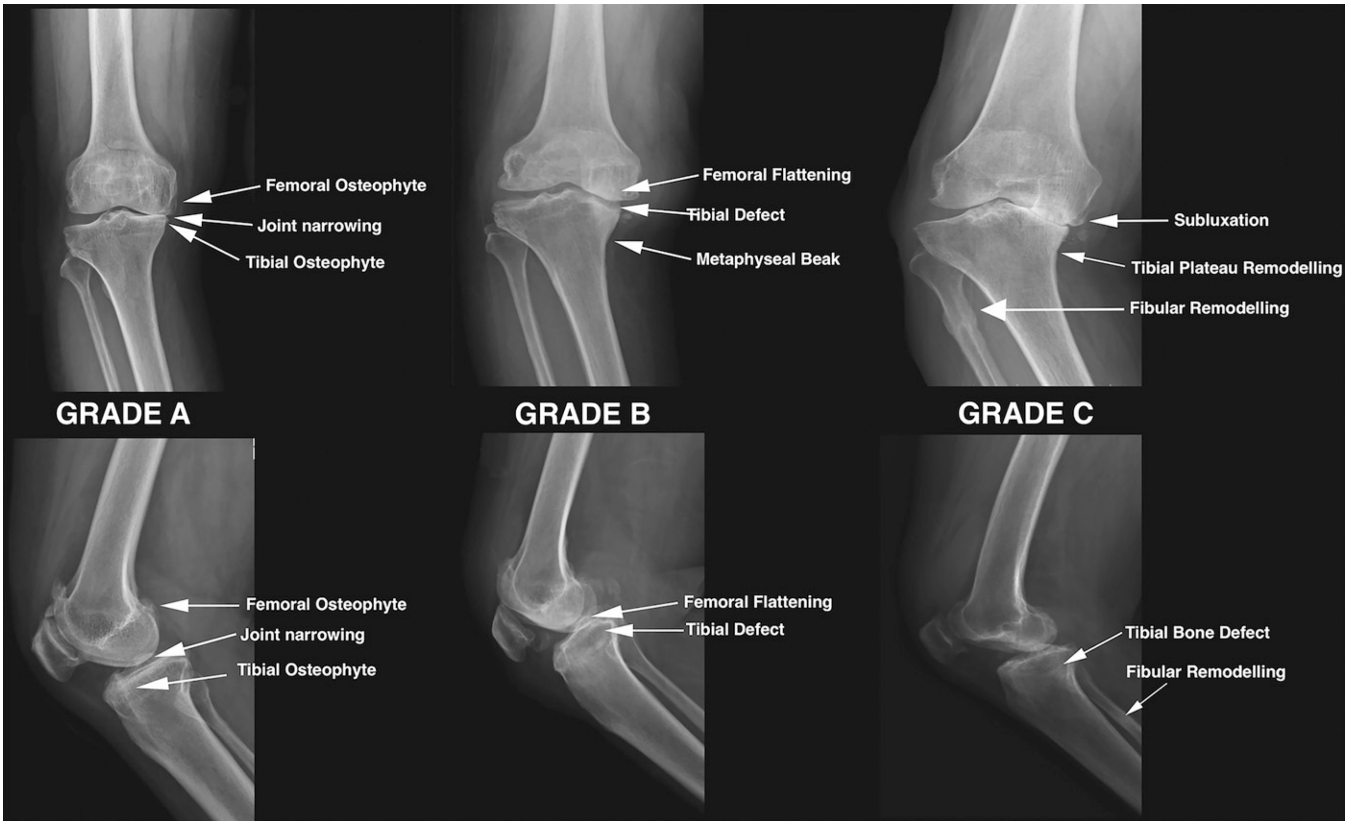

Fig. 2
Radiographs showing grade-A, grade-B, and grade-C deformity.

stages, as well as the location of the deformity, as described by Thienpont and Parvizi (Fig. 1).

Stages of Varus Deformity

The severity of the varus deformity, reported as the HKA, was measured on full-length scanogram films by drawing lines from the center of the femoral head to the center of the knee above the tibial spine and then to the center of the talus bone in the ankle. The angle subtended between the 2 lines on the medial side of the knee was recorded and subtracted from 180°. The resulting angle was recorded, with HKAs of <178° considered varus.

Knees were then classified into 1 of 3 stages of varus deformity: stage I, 0° to 10° of varus (HKA, 180° through 170°); stage II, 11° to 20° of varus (HKA, 169°

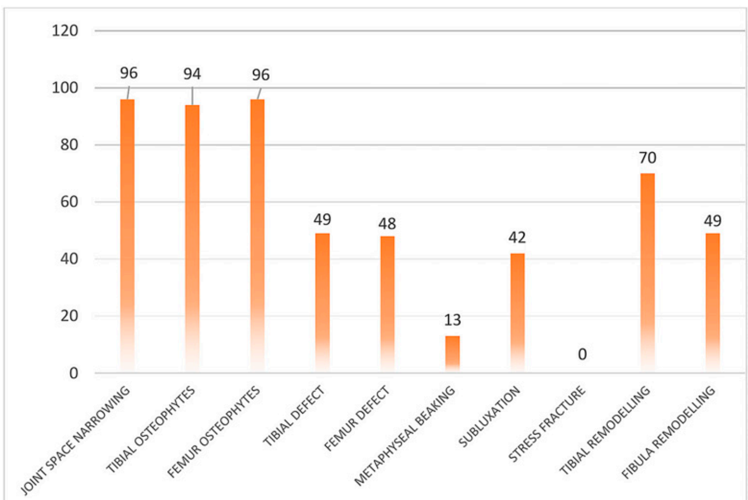

Fig. 3
Bar graph showing the distribution of radiographic features of varus deformity in the study population.

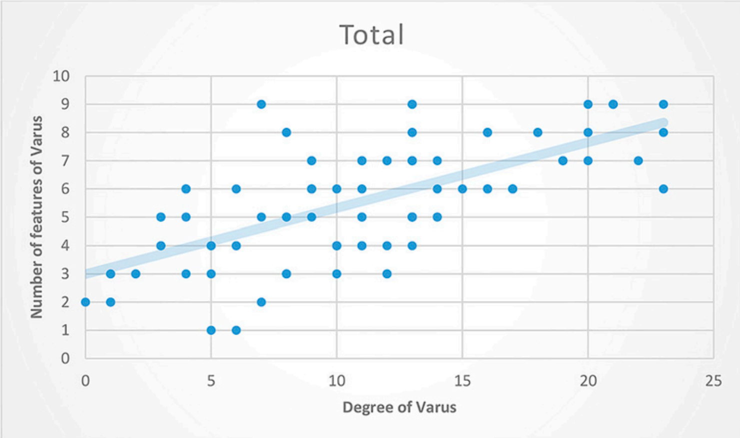

Fig. 4
Scatterplot showing the degree of varus and the number of radiographic features of varus osteoarthritis for individual knees.

through 160°); and stage III, >20° of varus (HKA, <160°).

Location of Varus Deformity

The location of the varus deformity was also evaluated. Deformities assessed as extra-articular were those that had an apex ≥7 cm beyond the tibial joint line and ≥3 cm beyond the femoral joint line. These anatomical reference points were chosen because the medial collateral ligament reportedly inserts distally at 6.2 cm ± 5.5 mm from the tibial joint line[9] and proximally at the medial epicondyle, which is 3 cm from the femoral joint line (Fig. 5).

The extra-articular apex location was determined by identifying the center of rotation of angulation. To do so, the epiphyseal axis and diaphyseal axis of the tibia were drawn, with the epiphyseal axis perpendicular in its middle to the tangent of the tibial plateau. The diaphyseal axis corresponds with the anatomical axis of the patient, which was drawn from the mid-diaphyseal points of the tibia at 2 different locations. The center of rotation of angulation is the point at which the proximal and distal anatomical segments intersect, and defines the location of the deformity[10] (Fig. 5). If the apex of the deformity was extra-articular, the knee was considered to have constitutional varus because all cases involved primary knee osteoarthritis.

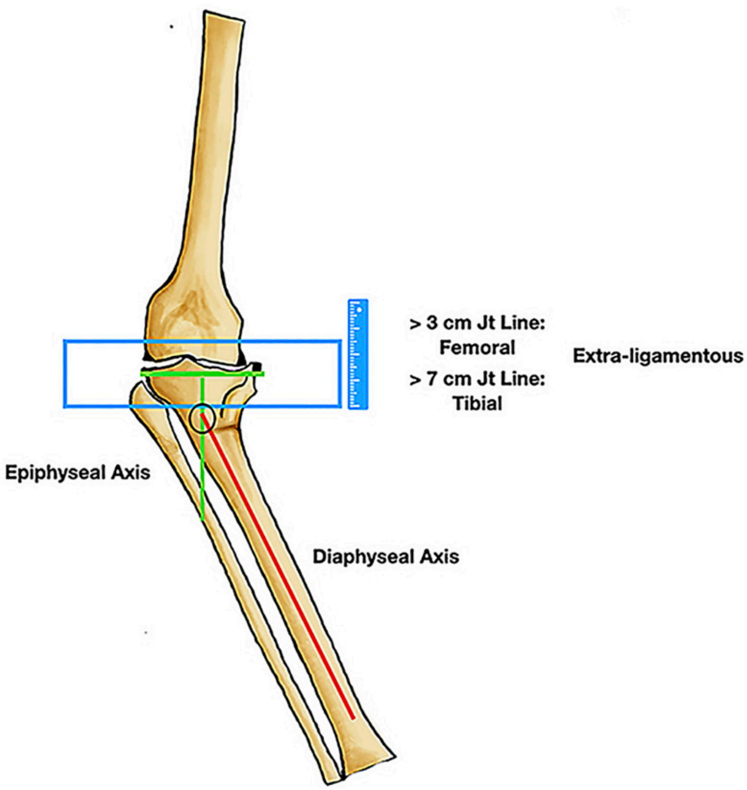

Fig. 5
Illustration demonstrating the calculation of extra-articular varus in the lower limb. Jt = joint.

TABLE I Distribution of Stages and Grades of Varus Deformity*

Stage	Grade A (16)	Grade B (10)	Grade C (74)
Stage I	10	4	13
Stage II	6	6	38
Stage III	0	0	23

*Stage I, 0° to 10° of varus; stage II, 11° to 20° of varus; stage III, >20° of varus.

Deformities assessed as intra-articular were those arising from the epiphyseal anatomy and with an origin in 1 of 3 angles. (1) The mechanical lateral distal femoral angle (LDFA), which is formed between the mechanical axis of the femur and the distal aspect of the femur in the frontal plane. If this angle was >90°, the femur was considered a source of the varus deformity. (2) The medial proximal tibial angle (MPTA), which is subtended between the medial slope of the tibial joint line and a line perpendicular to the mechanical axis of the tibia. When this angle was <87°, the proximal aspect of the tibia was considered a source of the varus deformity. (3) The joint line convergence angle, which was the angle made by a drawing a line between the femoral condyles and a line along the tibial plateau. A convergence angle of >2° signified medial cartilage loss with tightening of the medial structures and/or opening of the lateral side as a contributor to the varus deformity.

Radiographic Features of Varus Knee Deformity (Figs. 1 and 2)

The presence or absence of 10 radiographic features of varus knee deformity was noted on each radiograph[11-13]. These were:

1. Medial joint space narrowing (up to complete loss of the medial joint space).
2. Osteophytes at the epimetaphyseal aspect of the tibia.
3. Osteophytes at the epimetaphyseal aspect of the femur.
4. Tibial bone defect or alteration in the shape of the proximal aspect of the tibia.
5. Femoral bone defect or alteration in the shape of the distal aspect of the femur.
6. Metaphyseal beaking.
7. Subluxation of >3 mm at the midpoint of the tibiofemoral knee joint orientation line.
8. Stress fracture in the subchondral-metaphyseal region, which was identified on the basis of a bone densification.
9. Tibial plateau remodeling, which was identified by a differential increase in cortical density in the

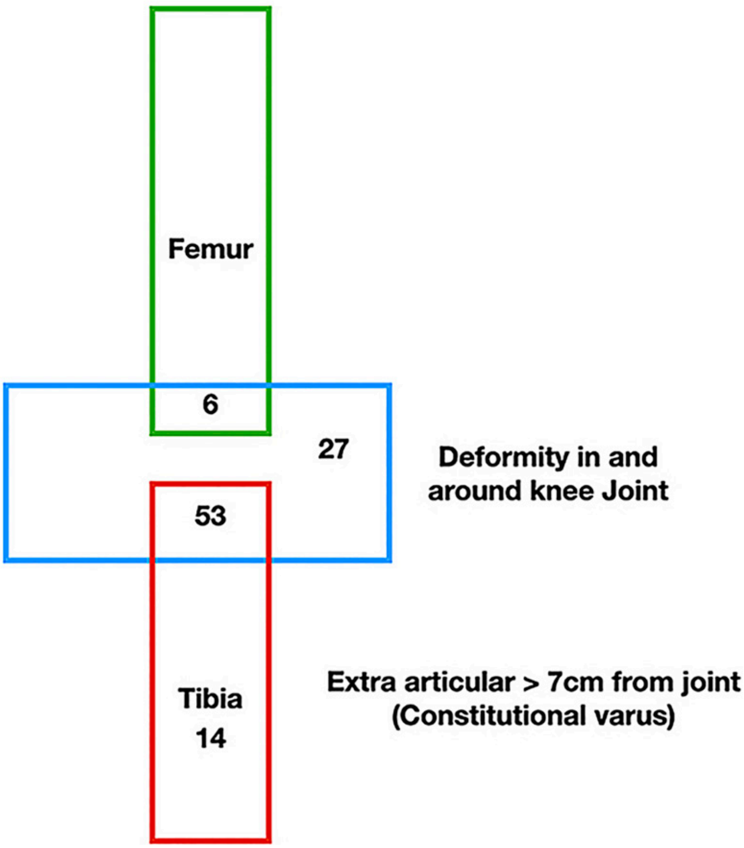

Fig. 6
Venn diagram showing the location of deformity for the 100 knees included in the study. Fourteen knees had an extra-articular deformity, or constitutional varus.

concave and convex sides of the tibial plateau or evidence of a healed insufficiency fracture.

10. Fibular remodeling, which was identified by a differential increase in cortical density in the concave and convex sides of the proximal aspect of the fibula or evidence of a healed insufficiency fracture.

The angular measurements were made by 2 different orthopaedic surgeons, including 1 consultant and 1 final-year trainee, and repeated after an interval of 1 week. The interobserver reliability was calculated with use of the kappa statistic. These measurements were performed manually on the scanograms by 2 independent observers. The imaging system (PACSystem; Agfa Healthcare, Belgium) had a measurement accuracy of 0.5°. Intraobserver accuracy was tested by repeating the same angle measurement 10 times, and was 1° for the described measurements.

Grades of Varus Deformity

According to which of the 10 radiographic features were identified, knees were then classified as 1 of 3 grades, grade A (mild deformity), grade B (moderate deformity), and grade C (severe deformity), with each subsequent grade denoting a temporal progression of severity. These grades were assessed by the first author (V.B.). Grade-A knees were those that had ≥1 of the following: medial joint space narrowing, tibial osteophytes, or femoral osteophytes. Grade-B knees were those that had a tibial bone defect, femoral bone defect, and/or metaphyseal beaking. Grade-C knees were those that had subluxation of >3 mm, stress fracture, tibial plateau remodeling, and/or fibular remodeling (Table I).

Correlation Statistics

Correlation between the stage and grade of the varus deformity was assessed with use of a scatterplot (Fig. 4).

Radiographic Protocol

Full-length scanograms of the lower limbs were assessed with use of InstaRad version 1.9 (Meddiff). These standing full-leg digital anteroposterior radiographs were made with both patellae facing forward and with the knees in full extension in order to eliminate errors caused by rotational malalignment. Both patellae were facing the x-ray beam, which was positioned at a 10° caudal tilt parallel to the joint line, as described by Dixon et al. and Paley and Tetsworth[14,15]. In addition to these radiographs, single-leg weightbearing radiographs were made in patients who had ligament laxity or cartilage loss in 1 of the compartments, as the effects of weightbearing are important to document in such cases. These radiographs were made by asking the patient to put maximum weight on the operative leg and not more than 10 to 15 kg on the contralateral leg. These radiographs were then repeated, switching the weightbearing of the injured and contralateral legs.

Source of Funding

There was no external funding for this study.

Results

The mean age (and standard deviation) of the patients was 67 ± 8.5 years. Sixty-two knees were in female patients and 38 were in male patients. The mean varus deformity was 11° ± 6° (corresponding to an HKA of 169°).

Stages and Locations of Varus Deformity

Of the 100 knees, 27 had stage-I varus, 50 had stage-II varus, and 23 had stage-III varus. There were 86 cases of intra-articular deformity and 14 cases of extra-articular deformity (Fig. 6).

Radiographic Features and Grades of Varus Deformity

The most common radiographic findings were medial joint space narrowing (96%), femoral osteophytes (96%), and tibial osteophytes (94%). Other findings included tibial remodeling (70%), subluxation (42%), and metaphyseal beaking (13%). There were no cases of stress fracture (Fig. 3).

A total of 16 knees had grade-A deformity, including 10 with stage-I varus and 6 with stage-II varus. A total of 10 knees had grade-B deformity, including 4 with stage-I varus and 6 with stage-II varus. Finally, a total of 74 patients had grade-C deformity, including 13 with stage-I varus, 38 with stage-II varus, and 23 with stage-III varus.

Correlation Between Stages and Grades of Varus Deformity

With a correlation coefficient of 0.668, there was a strong relationship between the stage and grade of varus deformity ($p < 0.001$) (Table I; Fig. 4).

All patients in this cohort were independently classified by 2 different observers. The Pearson correlation coefficient was calculated for the results produced by both observers. There was a strong positive correlation, with an R value of 0.887, and the p value calculated from the Pearson coefficient was 0.00001.

Discussion

The present study had 3 important findings. First, for most knees, higher degrees of varus (i.e., stage III) had worse radiographic features of deformity (i.e., grade C). Second, some knees with lesser degrees of varus also had worse radiographic features of deformity, with 13 stage-I knees and 38 stage-II knees having grade-C deformity. Third, a small subset of patients with stage-III varus had milder radiographic features of deformity (grade A or B) as a result of the deformity being extra-articular.

Despite differing from the conventional techniques for estimating coronal deformities and varus disease, the present grading system might be more representative of the underlying pathology. Osteoarthritis grades should reflect the net effect on the native epiphyseal anatomy of osseous disease and soft-tissue changes, such as ligamentous alterations secondary to the mechanical and biological effect of disease progression. Increased mechanical stress leads to the local release of transforming growth factor beta, as well as other growth factors such as vascular endothelial growth factor and fibroblast growth factor, which are responsible for osteophyte formation[16]. Usually, knees with a higher stage of deformity will also have a higher grade of osteoarthritis. This correlation was shown in the present study, with grade-C deformity observed more frequently among knees with varus of >20° (i.e., stage III). Otsuki et al.[5] demonstrated that the increased mechanical load resulting from varus deformity led to the proliferation of mesenchymal progenitor cells and their aggregation as clusters. Other studies have also described this effect at different stages of disease progression[3,17,18]. Joint space reduction, subchondral sclerosis, and osteophyte formation are succeeded by subluxation and the progressive development of tibial and femoral defects[19]. The most severe cases of varus disease will show features of metaphyseal and diaphyseal remodeling of the bone further away from the joint line[20].

In the present study, some knees with low degrees of varus (i.e., stage I) showed advanced radiographic features of deformity (i.e., grade C). These cases often involved knees in which the overall morphotype (i.e., varus or valgus) had been modified by an iatrogenic intervention or trauma. Patients with a native valgus alignment (i.e., a valgus morphotype, with a valgus hip, a valgus femur and tibia, and a planovalgus foot) may develop medial bone-on-bone osteoarthritis following a complete tear of the anterior cruciate ligament and medial meniscectomy; this is because the overall valgus alignment reduces the intra-articular varus component as a result of changes to the epiphyseal anatomy. The results of the present study show that a cursory review of full-leg standing radiographs may not reveal the full severity of varus deformity in the knee. With use of the grading and staging system outlined in the present study, surgeons can be forewarned about the need for a more customized surgical approach. Despite signs of medial bone-on-bone disease, a patient may have a valgus-type femur with dysplasia of the trochlea and the lateral posterior condyle. By considering both grading and staging, the surgeon might be alerted earlier to a condition that requires an alternative surgical approach, such as an extra-articular deformity or an epiphyseal anatomy that necessitates a more specific reconstruction technique. Patients might also have more soft-tissue laxity as a result of a compensatory unloading mechanism or more external rotation, leading to an underestimation of the varus measurement.

A small subset of knees in the present study had milder radiographic features of deformity (i.e., grade A or B) despite having a higher degree of varus (i.e., stage II or III). Subgroup analysis revealed that knees with stage-II or III varus grade-A deformity typically had an extra-articular deformity location. In primary knee osteoarthritis, an extra-articular deformity can be considered a sign of constitutional varus. Correction of only the intra-articular deformity will retain the constitutional varus for this patient group. Although the philosophy of this concept continues to be debated, the results of the present study provide data for surgeons to make informed decisions regarding the treatment of extra-articular defects, deviating from the long-standing belief that the surgical treatment of knee osteoarthritis should result in a neutral mechanical alignment[20]. For such cases, the use of 3-dimensional imaging will be useful to find the origin of the deformity and to allow the surgeon to decide which component positioning and what type of intra-articular correction should be utilized for the individual patient. Such preoperative planning will make clearer whether the correction can be performed within the soft-tissue envelope of the various collateral ligament structures.

The present study is the first, to our knowledge, to demonstrate that the degree of varus (i.e., stage) is correlated with the severity of radiographic deformity (i.e., grade) in knees with varus osteoarthritis. Further, the interaction between varus stage and osteoarthritis grade seemed to differ between knees with intra- versus extra-articular deformities, leading to a magnification of the stage (varus morphotype) or a reduction of the stage (valgus morphotype).

The present study had several limitations. First, a relatively small number of knees were analyzed, and only radiographic assessments were performed. Furthermore, coronal deformity is often the result of dynamic interplay between the soft tissues and the osseous anatomy[21], a factor that is often missed on static radiographic studies. Computed tomography was not performed to differentiate the individual rotational alignments of the femur and tibia. Furthermore, the utility and potential positive impact of the proposed classification system have not been tested. However, this study did demonstrate the importance of assessing the morphotype, epiphyseal anatomy, and disease staging and grading of each patient, along with radiographic or, if available, 3-dimensional imaging. Simulations performed with use of these preoperative findings will help the surgeon to make better-informed decisions regarding the surgical procedure. For example, notable angular deformity in the absence of grade-C radiographic features should alert the surgeon to a potential extra-articular deformity or constitutional varus; as a result, the surgeon is able to adjust the surgical plan preoperatively rather than during the procedure.

Conclusions

Coronal deformity, often reported as the HKA, has always been considered as an expression of disease severity. Osteoarthritis can be staged, but as shown in the present study, angular deformity should be considered alongside the location, intra- or extra-articular, of the deformity. Grading the osteoarthritis can help the surgeon to better understand the extent of intra-articular disease and the potential complexity of the epiphyseal reconstruction during knee arthroplasty.

Constitutional varus and stage-grade disparity may be considered signs of morphological outliers. Advanced preoperative planning and a patient-specific preoperative approach and implant selection may make a difference in patients with varus deformity of the knee.

Vaibhav Bagaria, MBBS, MS, FCPS, DipSICOT[1],
Rajiv V. Kulkarni, MBBS, DOrtho[1],
Omkar S. Sadigale, MBBS, DNB, DOrtho, DipSICOT[1],
Dipit Sahu, MBBS, MSOrtho[1],
Javad Parvizi, MD[2],
Emmanuel Thienpont, MD, MBA, PhD[3]

[1]Department of Orthopaedics, Sir H N Reliance Foundation Hospital, Girgaum, Mumbai, Maharashtra, India

[2]Department of Orthopaedic Surgery, Rothman Institute, Philadelphia, Pennsylvania

[3]Department of Orthopaedic Surgery, University Hospital Saint Luc-UCL, Brussels, Belgium

Email for corresponding author: emmanuel.thienpont@uclouvain.be

References

1. Ahlbäck S. Osteoarthrosis of the knee. A radiographic investigation. Acta Radiol Diagn (Stockh). 1968;227:277: 7-72.

2. Hunter DJ, Sharma L, Skaife T. Alignment and osteoarthritis of the knee. J Bone Joint Surg Am. 2009 Feb;91(Suppl 1):85-9.

3. Thienpont E, Schwab PE, Cornu O, Bellemans J, Victor J. Bone morphotypes of the varus and valgus knee. Arch Orthop Trauma Surg. 2017 Mar;137(3):393-400. Epub 2017 Jan 21.

4. Brouwer GM, van Tol AW, Bergink AP, Belo JN, Bernsen RM, Reijman M, Pols HA, Bierma-Zeinstra SM. Association between valgus and varus alignment and the development and progression of radiographic osteoarthritis of the knee. Arthritis Rheum. 2007 Apr;56(4): 1204-11.

5. Otsuki S, Nakajima M, Okamoto Y, Oda S, Hoshiyama Y, Iida G, Neo M. Correlation between varus knee malalignment and patellofemoral osteoarthritis. Knee Surg Sports Traumatol Arthrosc. 2016 Jan;24(1):176-81. Epub 2014 Oct 2.

6. Ozdemir F, Tukenmez O, Kokino S, Turan FN. How do marginal osteophytes, joint space narrowing and range of motion affect each other in patients with knee osteoarthritis. Rheumatol Int. 2006 Apr;26(6):516-22. Epub 2005 Jul 16.

7. Sharma L, Song J, Dunlop D, Felson D, Lewis CE, Segal N, Torner J, Cooke TD, Hietpas J, Lynch J, Nevitt M. Varus and valgus alignment and incident and progressive knee osteoarthritis. Ann Rheum Dis. 2010 Nov;69(11):1940-5. Epub 2010 May 28.

8. Thienpont E, Parvizi J. A new classification for the varus knee. J Arthroplasty. 2016 Oct;31(10): 2156-60. Epub 2016 Mar 24.

9. Liu F, Yue B, Gadikota HR, Kozanek M, Liu W, Gill TJ, Rubash HE, Li G. Morphology of the medial collateral ligament of the knee. J Orthop Surg Res. 2010 Sep 16;5(1):69.

10. De Muylder J, Victor J, Cornu O, Kaminski L, Thienpont E. Total knee arthroplasty in patients with substantial deformities using primary knee components. Knee Surg Sports Traumatol Arthrosc. 2015 Dec;23(12):3653-9. Epub 2014 Sep 24.

11. Chang CB, Koh IJ, Seo ES, Kang YG, Seong SC, Kim TK. The radiographic predictors of symptom severity in advanced knee osteoarthritis with varus deformity. Knee. 2011 Dec;18(6):456-60. Epub 2010 Sep 17.

12. Lespasio MJ, Piuzzi NS, Husni ME, Muschler GF, Guarino A, Mont MA. Knee osteoarthritis: a primer. Perm J. 2017;21:16-183.

13. Pinsornsak P, Naratrikun K, Kanitnate S, Sangkomkamhang T. The one-leg standing radiograph: An improved technique to evaluate the severity of knee osteoarthritis. Bone Joint Res. 2016 Sep;5(9):436-41.

14. Dixon MC, Parsch D, Brown RR, Scott RD. The correction of severe varus deformity in total knee arthroplasty by tibial component downsizing and resection of uncapped proximal medial bone. J Arthroplasty. 2004 Jan; 19(1):19-22.

15. Paley D, Tetsworth K. Mechanical axis deviation of the lower limbs. Preoperative planning of uniapical angular deformities of the tibia or femur. Clin Orthop Relat Res. 1992 Jul;(280):48-64.

16. Lingaraj K, Poh CK, Wang W. Vascular endothelial growth factor (VEGF) is expressed during articular cartilage growth and re-expressed in osteoarthritis. Ann Acad Med Singap. 2010 May;39(5): 399-403.

17. Thippanna RK, Kumar MN. Lateralization of femoral entry point to improve the coronal alignment during total knee arthroplasty in patients with bowed femur. J Arthroplasty. 2016 Sep;31(9):1943-8. Epub 2016 Mar 4.

18. Calliess T, Bauer K, Stukenborg-Colsman C, Windhagen H, Budde S, Ettinger M. PSI kinematic versus non-PSI mechanical alignment in total knee arthroplasty: a prospective, randomized study. Knee Surg Sports Traumatol Arthrosc. 2017 Jun;25(6):1743-8. Epub 2016 Apr 27.

19. Boegård T, Jonsson K. Radiography in osteoarthritis of the knee. Skeletal Radiol. 1999 Nov;28(11):605-15.

20. Burr DB, Gallant MA. Bone remodelling in osteoarthritis. Nat Rev Rheumatol. 2012 Nov; 8(11):665-73. Epub 2012 Aug 7.

21. Fang DM, Ritter MA, Davis KE. Coronal alignment in total knee arthroplasty: just how important is it? J Arthroplasty. 2009 Sep; 24(6)(Suppl):39-43. Epub 2009 Jun 24.