Simultaneous management of ipsilateral gonarthritis and extra-articular deformity

Mohamed A.M. Eid

Department of Orthopaedic Surgery, Ain Shams University Hospital, Ain Shams University, Cairo, Egypt

Correspondence to Mohamed A.M. Eid, MD, Department of Orthopedic Surgery, Ain Shams University Hospital, Ain Shams University, 11351 Cairo, Egypt
Tel: +20 106 163 919;
e-mail: moham_eid@yahoo.com

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Background

Total knee arthroplasty (TKA) with extra-articular deformity represents a technical challenge to the reconstructive surgeon. Restoration of proper lower limb alignment is crucial to maximize the functional outcome and long-term implant survival. The current study postulates that simultaneous TKA and deformity correction, whether by intra-articular means or by extra-articular osteotomy, can yield favorable outcomes if the correct surgical strategy is used according to the magnitude and location of the pre-existing extra-articular deformity.

Patients and methods

The study was carried out on 14 consecutive primary total knee replacements in patients with osteoarthritis secondary to extra-articular malunions. The mean preoperative coronal plane deformity was 14.3 ± 5.2° of varus. The mean preoperative mechanical axis deviation was 8.2 ± 2.1 mm medial to the center of the knee and the mean limb-length discrepancy was 1.8 ± 0.7 cm of shortening. The mean time between malunion and TKA was 29 ± 6.1 years. The results were analyzed using the Knee Society clinical and functional scores and the Knee Society radiographic evaluation system.

Results

At a mean follow-up of 30.4 months, the mean preoperative Knee Society knee score of 49.7 points improved to a mean of 90.4 points at the time of the latest follow-up ($P < 0.01$). The mean preoperative functional score of 46.3 points improved to a mean of 86.9 points ($P < 0.01$). At the latest follow-up, all extra-articular osteotomy sites showed union on radiographs and no patients showed evidence of loosening. Postoperative radiographs showed restoration of the mechanical axis and appropriate alignment of the components ($P < 0.001$). The postoperative limb alignment was restored to within 2° of normal in each patient. The only significant difference ($P < 0.05$) between the two techniques was the mean gain in functional scores, being higher for the isolated arthroplasty (42 ± 12) procedures than for the TKA with osteotomies (37 ± 9).

Conclusion

Although isolated TKA with intra-articular deformity compensation and ligamentous balancing may be favored in mild to moderate deformities, there may be faster rehabilitation and functional score gain in the short term after surgery. Yet, simultaneous TKA and extra-articular corrective osteotomy has also yielded favorable outcomes and would still remain the technique of choice in severe deformities (>25°), especially with distant deformities from the knee joint line (diaphyseal, metaphyseodiaphyseal). The closer the deformity to the knee joint line, the more it is amenable to intra-articular correction. Careful preoperative planning is necessary to determine which technique would be better in each particular case.

Keywords:

arthroplasty, deformity, extra-articular, knee replacement, simultaneous correction, total knee arthroplasty

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Introduction

Femoral or tibial deformities that extend beyond the capsuloligamentous envelope of the knee joint have their own impact on the joint's biomechanics and the development of secondary osteoarthritis. Total knee arthroplasty (TKA) with extra-articular deformity represents a technical challenge to the reconstructive surgeon. Restoration of proper lower limb alignment is crucial to maximize the functional outcome and long-term implant survival, and minimize polyethylene wear [1].

Deformity of the femur or the tibia can occur secondary to varied causes such as malunited fractures, previous osteotomies, metabolic bone disease, stress fractures, and excessive femoral bowing [2]. An extra-articular, extraligamentous deformity may not be amenable to routine techniques of intra-articular bone resection and ligamentous balancing. In such situations, the treatment alternatives include adjustment of resurfacing cuts with ligamentous release or advancement, or corrective extra-articular osteotomy in conjunction with, or staged with, TKA [3].

Different strategies were proposed for the management of extra-articular deformities associated with the TKA procedure. The first strategy is to perform an extra-articular corrective osteotomy with TKA in the same surgical setting. The second is a staged procedure wherein the TKA is performed in a second stage after the corrective osteotomy has healed properly. The third strategy is to perform a compensatory intra-articular correction for extra-articular deformities by modifying the bone cuts during the TKA procedure so as to restore the overall limb alignment. However, this asymmetric resection may create residual laxity that has to be compensated for by relevant ligamentous balancing; otherwise, a constrained prosthesis should be used [1].

In the current study, we hypothesize that simultaneous TKA and deformity correction, whether by intra-articular means or by extra-articular osteotomy, can yield favorable outcomes if the correct surgical strategy is used according to the magnitude and location of pre-existing extra-articular deformity.

Patients and methods

A prospective study including 14 consecutive primary total knee replacements in patients with osteoarthritis secondary to extra-articular malunions was carried out at Ain Shams University Hospital, Egypt, between August 2006 and January 2011. All patients were candidates for total knee replacement surgery, with the main etiology being osteoarthritis secondary to femoral deformities in five cases and tibial deformities in nine, of which combined femoral and tibial deformities coexisted in one patient (Table 1). The mean preoperative coronal plane deformity was 14.3 ± 5.2° of varus. In our series, there were nine men and four women, with a mean age of 57.8 ± 6.4 years. In all patients, the presentation of osteoarthritis was unilateral on the side of the extra-articular deformity. The mean preoperative mechanical axis deviation on scanograms was 8.2 ± 2.1 mm medial to the center of the knee and the mean limb-length discrepancy was 1.8 ± 0.7 cm of shortening. The initial fracture/osteotomy was internally fixed with plate and screws in eight cases and was managed conservatively with casting in six. A previous history of infection was encountered in two cases of the operated group. The mean time between fracture and TKA was 28 ± 6.1 years, which tends to be shorter with injuries in close proximity to the joint. All patients had their knees replaced with a cruciate-substituting fixed-bearing implant design [NexGen system in 10 cases and Legacy Constrained Condylar Knee (LCCK) system in four cases; Zimmer, Warsaw, Indiana, USA].

Table 1 Distribution of malunions and method of correction (14 cases)

Deformity locations	Metaphyseal		Matphyseodiaphyseal		Diaphyseal	
Mode of correction	EA	IA	EA	IA	EA	IA
Femoral deformities	0	1	3	0	0	0
Tibial deformities	2	1	2	0	1	2
Combined deformities	0	1	1	0	0	0

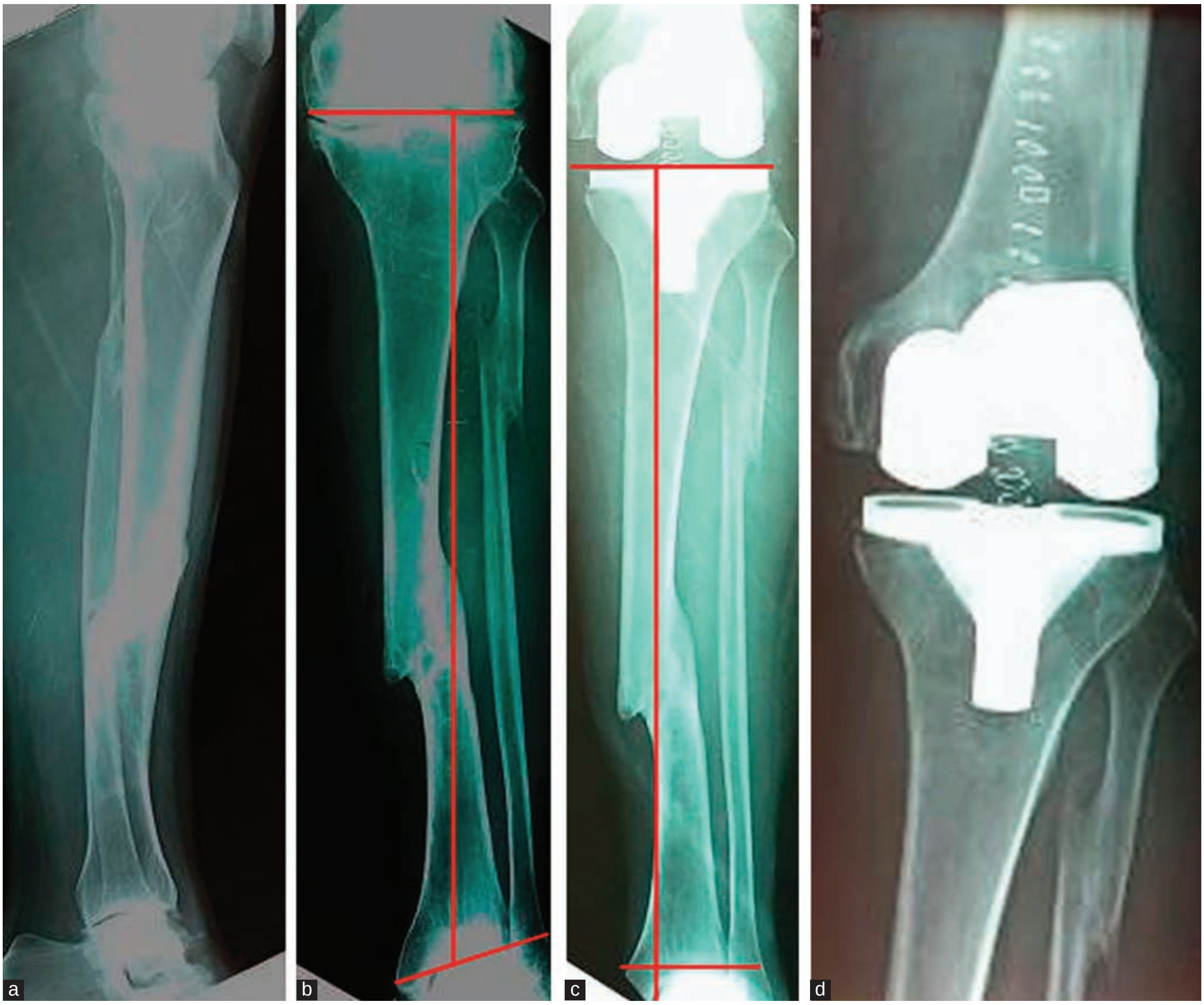
EA, extra-articular osteotomy; IA, intra-articular correction.

Surgical technique

Overall, an isolated TKA procedure with intra-articular realignment was performed in five cases (four tibial and one femoral). In this group, restoration of the normal mechanical axis of the lower limb was achieved by altering the standard cut performed for the proximal tibia or the distal femur so as to neutralize the effect of a pre-existing extra-articular deformity on the overall mechanical axis. The altered resection plane would create laxity in the over-resected compartment of the knee, and if not compensated for by proper ligamentous balancing of the under-resected side, a constrained prosthesis should be used. In this group, the LCCK system was used in two cases in which intramedullary stem extensions were used. This group included either moderate metaphyseal deformities (two tibial and one femoral) or mild diaphyseal deformities (two tibial) (Fig. 1). Postoperatively, the standard protocol was followed with quadriceps exercise, straight leg raising, range of motion exercise, and full weight-bearing on a walker was started from the second postoperative day.

TKA procedure-associated extra-articular corrective osteotomy was performed in nine cases (five tibial, four femoral). In this group, restoration of the mechanical axis of the lower limb was achieved mainly by extra-articular closing-wedge corrective osteotomy at the apex of the deformity. The osteotomy was initially stabilized so as to ensure proper rotation at the osteotomy site and provide relative stability during the TKA procedure. Short plate and screws were used for femoral osteotomies (Fig. 2) and staples for metaphyseal tibial osteotomies. Implants were applied eccentrically so as to provide room for intramedullary instrumentation during the TKA procedure. Only one diaphyseal tibial malunion in this group was fixed definitely by plate and screws and in this case an extramedullary cutting jig was used for the tibia during the TKA procedure. In this group, long press-fit intramedullary stem extensions were used to bypass and fix the osteotomy, and unload the uniting metaphysis. Locking screw holes were developed for the long stem extensions to confer more stability to the osteotomy site, especially with metaphyseodiaphyseal

Figure 1



(a, b) Osteoarthritis knee with a mild diaphyseal tibial deformity (note the valgus inclination of the ankle joint line relative to the knee). (c, d) Isolated total knee arthroplasty with intra-articular deformity correction (note the parallism between the tibial tray and the ankle plafond ascribed to the preintended compensatory varus positioning of the tibial tray relative to the proximal tibia).

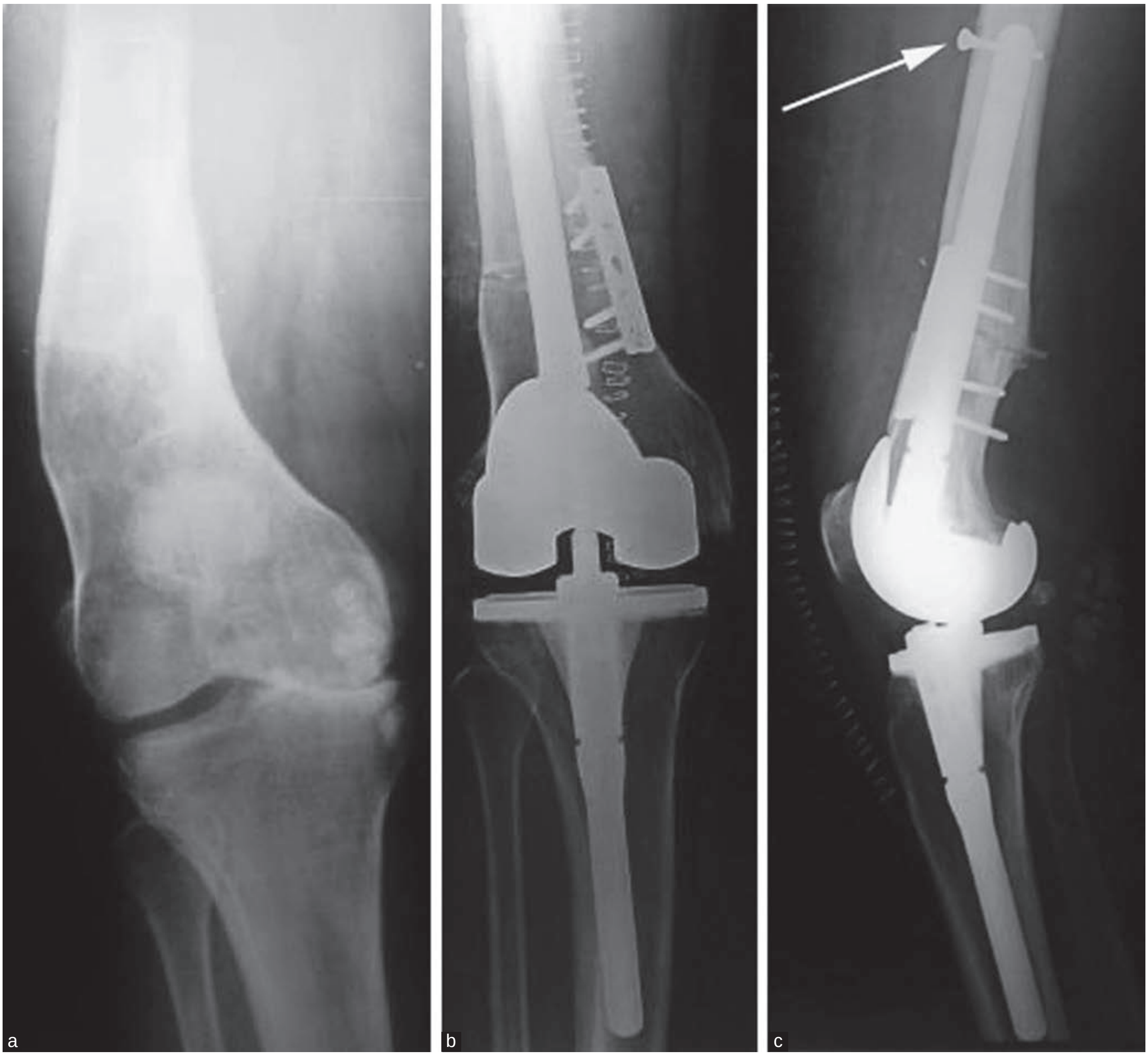
osteotomies (Fig. 2). Morsellized bone graft from the cuts and the wedge osteotomy were impacted at the osteotomy site by the end of the procedure after thorough lavage of the operative field. This group included mostly moderate metaphyseodiaphyseal deformities (two tibial and four femoral), severe metaphyseal deformities (two tibial), and a moderate diaphyseal deformity (one tibial). Postoperatively, a graduated hinged knee brace was applied with progressive range of motion exercises. Non weight-bearing ambulation on crutches was allowed with the brace on for 6 weeks, and then shifted to progressive partial weight-bearing on a walker until radiographic evidence of bone healing at the osteotomy site.

The results were analyzed using the Knee Society clinical and functional scores, and the Knee Society radiographic evaluation system. The characteristics of the series were described as means and SDs for the continuous variables. The clinical assessment described by the knee and function scores was analyzed using the Student's *t*-test. The proportions of metaphyseal and diaphyseal deformities in the two techniques were compared using the χ^2-test. The significance threshold was set at P value less than 0.05.

Results

The overall mean coronal extra-articular deformity was 14.3 ± 5.2°. The mean femoral extra-articular deformity in the coronal plane was 16.4° varus (range, 32° varus to 5° varus). The mean tibial extra-articular deformity in the coronal plane was 12.3° varus (range, 24° varus

Figure 2



(a) Osteoarthritis knee with a femoral extra-articular deformity (old malunited corrective osteotomy for tibia valga). (b, c) Corrective femoral osteotomy with a long-stemmed femoral component and short plate fixation to control rotation (note the proximal locking screw, white arrow). The residual tibia valga was compensated intra-articularly from the tibial cut (combined deformity).

to 8.5° valgus). The mean extra-articular deformity in the sagittal plane was 5° flexion (range, 11° flexion to 6° extension). At a mean follow-up of 30.4 months (range, 24–37 months), the mean preoperative Knee Society knee score of 49.7 points (range, 32–65 points) improved to a mean of 90.4 points (range, 84–93 points) at the time of the latest follow-up ($P < 0.01$). The mean preoperative functional score of 46.3 points (range, 35–50 points) improved to a mean of 86.9 points (range, 72–100 points) ($P < 0.01$). The flexion arc increased from a mean of 85° to a postoperative mean of 110° (range, 95–115°) at the time of the latest follow-up. The radiographic parameters in all cases ($n = 14$) are summarized in Table 2. All extra-articular osteotomy sites showed union on radiographs at the last follow-up. There were no postoperative infections, and no complications related to wound necrosis, joint instability, or patellar problems were encountered until the latest follow-up. No patients showed evidence of loosening on radiographs at the latest follow-up. Only two knees showed nonprogressive radiolucent lines less than 2 mm in width in tibial zones 1 and 4.

Postoperative radiographs showed restoration of the mechanical axis and appropriate alignment of the components ($P < 0.001$). The postoperative limb alignment, on the basis of measurement of the mechanical axis in the coronal plane on a full-length

Table 2 Radiographic parameters in all cases (*n* = 14)

Parameters	Mean (deg.)	SD (deg.)	95% confidence interval (deg.)
Preoperative HKA angle	166.7	9.3	163.7–170.6
Postoperative HKA angle	179.3	1.4	178.7–179.6
Coronal alignment of the femoral component	90.3	1.0	90.1–90.6
Coronal alignment of the tibial component	90	0.6	89.8–90.1
Sagittal alignment of the femoral component	92.7	4.9	92.1–93.2
Tibial component slope	86.8	1.9	86.4–87.7

HKA, >180° implies valgus and <180° implies varus alignment. Neutral coronal alignment with respect to the mechanical axis is recorded as 90°, >90° implies valgus, and <90° implies varus alignment. Neutral sagittal component alignment with respect to the distal femoral medullary axis or the mechanical axis of tibia is recorded as 90°, >90° implies extension or anterior sloping, and <90° implies flexion alignment or posterior sloping.

anteroposterior radiograph of the lower extremity, was restored to within 2°of normal in each patient. The extra-articular osteotomy site healed by an average of 12 weeks. The only significant difference ($P < 0.05$) between the two techniques was the mean gain in functional scores, being higher for the isolated arthroplasty (42 ± 12) procedures than for the TKA with osteotomies (37 ± 9).

Discussion

The long-term success of TKA is dependent, in part, on proper restoration of the mechanical axis and soft-tissue balancing. However, in the presence of an extra-articular deformity, complex imbalance of the collateral ligaments may result when the deformity is treated solely by modified intra-articular bone resection and soft-tissue releases. Such deformities may be found after fracture malunion or periarticular osteotomy or they may be associated with metabolic diseases such as osteomalacia, rickets, and Paget's disease. To limit such ligament imbalance and to reduce the need for constrained implants, these patients can be treated with simultaneous or staged osteotomy and resurfacing knee arthroplasty [4].

The literature on TKA associated with extra-articular deformity is scarce. Most authors report small series, whose main limitation is the absence of precise localization of the deformity in relation to the knee joint line. In the series reported by Lonner *et al.* [5] on 31 knees, corrective osteotomy was associated with TKA in only four cases, suggesting considerable extra-articular deformity, with no further details on the rest of the population studied. In another publication, the same authors seemed to prefer associated prosthesis and osteotomy to correct femoral varus deformities [4]. Papadoupoulos *et al.* [6] performed six osteotomies in association with TKA for the treatment of 21 cases of post-traumatic osteoarthrosis secondary to distal femoral fractures. Wu *et al.* [7] presented a general discussion on the problem of post-traumatic osteoarthritis of the knee without specifying a corrective technique of choice for extra-articular deformities. Wang and Wang [8] described precisely their technique for recovering an extra-articular varus deformity in the bone cuts with specific ligament balancing. However, the relevant indications and limitations of the technique were not clearly demarcated [8].

Furthermore, some authors found the simultaneous osteotomy and TKA procedure to be technically demanding and associated with inferior results when compared with those of primary arthroplasty performed without a concomitant corrective osteotomy [9,10]. In addition, authors from the Hospital for Special Surgery have determined that one-stage TKR with intra-articular correction of the extra-articular deformity is the treatment of choice. They reported that with proper planning, appropriate bone cuts to restore alignment, and the necessary soft tissue releases to balance the knee in flexion and extension, a satisfactory TKR can be achieved. Their technique had been performed successfully in 15 previous cases, and more recently, they presented the outcome in two patients with arthritis and a severe extra-articular deformity (varus/valgus deformity >20°, recurvatum, and malunion of a tibial or femoral fracture). The procedure was clinically successful in both patients without complications. At the 2-year follow-up, Knee Society scores improved from 40 to 95, with no evidence of loosening in either case [1].

In the present study, a statistically significant improvement in knee scores, functional scores ($P < 0.01$), and limb alignment (mechanical axis restoration, $P < 0.001$) could be achieved using either technique. The cornerstone behind successful surgery was the correct choice of the relevant surgical technique for each particular case in terms of 'magnitude and location' of the extra-articular deformity. The greater the magnitude and the more distant the deformity from the knee joint line, the more the temptation to use an extra-articlar corrective osteotomy in association with TKA for restoration of the lower limb mechanical axis. In contrast, with milder deformity and with closer proximity to the knee joint line, the more likely it is that isolated

TKA with intra-articular deformity compensation and relevant ligamentous balancing can successfully restore neutral alignment.

Mann *et al.* [3] previously reported the results of the preferred technique of Insall after it had been used to treat a series of deformities that were associated with arthrosis of the knee. In their study, coronal plane deformities averaged 14° (range, 5–22°) and sagittal plane deformities averaged 12° (range, 0–38°). The authors reported that such deformities may be addressed adequately by modified intra-articular bone resection and ligament balancing, obviating the need for additional osteotomy. The authors reported a marked improvement in scores after a minimum of 2 years of follow-up [3].

Wang and Wang [8], in their results of conventional TKA performed for 15 extra-articular deformities, concluded that TKA performed with intra-articular bone resection and soft-tissue release is effective when there is 20° deformity or lower of the femur and 30° deformity or lower of the tibia in the coronal plane [8]. In addition, Wang *et al.* [2] reported that TKR with intra-articular bone resection effectively corrected the extra-articular deformity of the femur in the presence of antecurvatum of up to 16° and recurvatum of up to 15°.

However, dealing with large deformities solely by intra-articular bone resection and extensive soft-tissue release may cause imbalance of the collateral ligaments that necessitate the use of constrained implants [11]. Lonner *et al.* [4] commented that this technique may be reasonable if the function and balance of the collateral ligaments are not compromised. The theoretical concerns in such cases are that structural support may be insufficient and oblique shear forces may make the bone–cement interfaces vulnerable to early demarcation and perhaps lead to long-term failure [4].

With asymmetric resection that is oblique to the epicondylar axis in extension, and a consequence of ligamentous imbalance in extension, the posterior aspects of the femoral condyles, however, maintain their appropriate relationships with the tibia in flexion. This resultant scenario is difficult to manage. Ligament advancement, to address an asymmetrical soft-tissue envelope, has yielded mixed and unpredictable results, in part because patients do not have a comparable imbalance in both extension and flexion [12].

Another concern, pointed out by Wolff *et al.* [13], is that, in the presence of notable femoral deformity, restoration of the normal mechanical axis with intra-articular resection may only normalize the orientation of the knee, but hip adduction or abduction is still necessary to keep the knee and ankle parallel to the ground in the stance phase of gait. This may result in localized areas of stress concentration in the hip and may ultimately contribute to accelerated coxarthrosis [13].

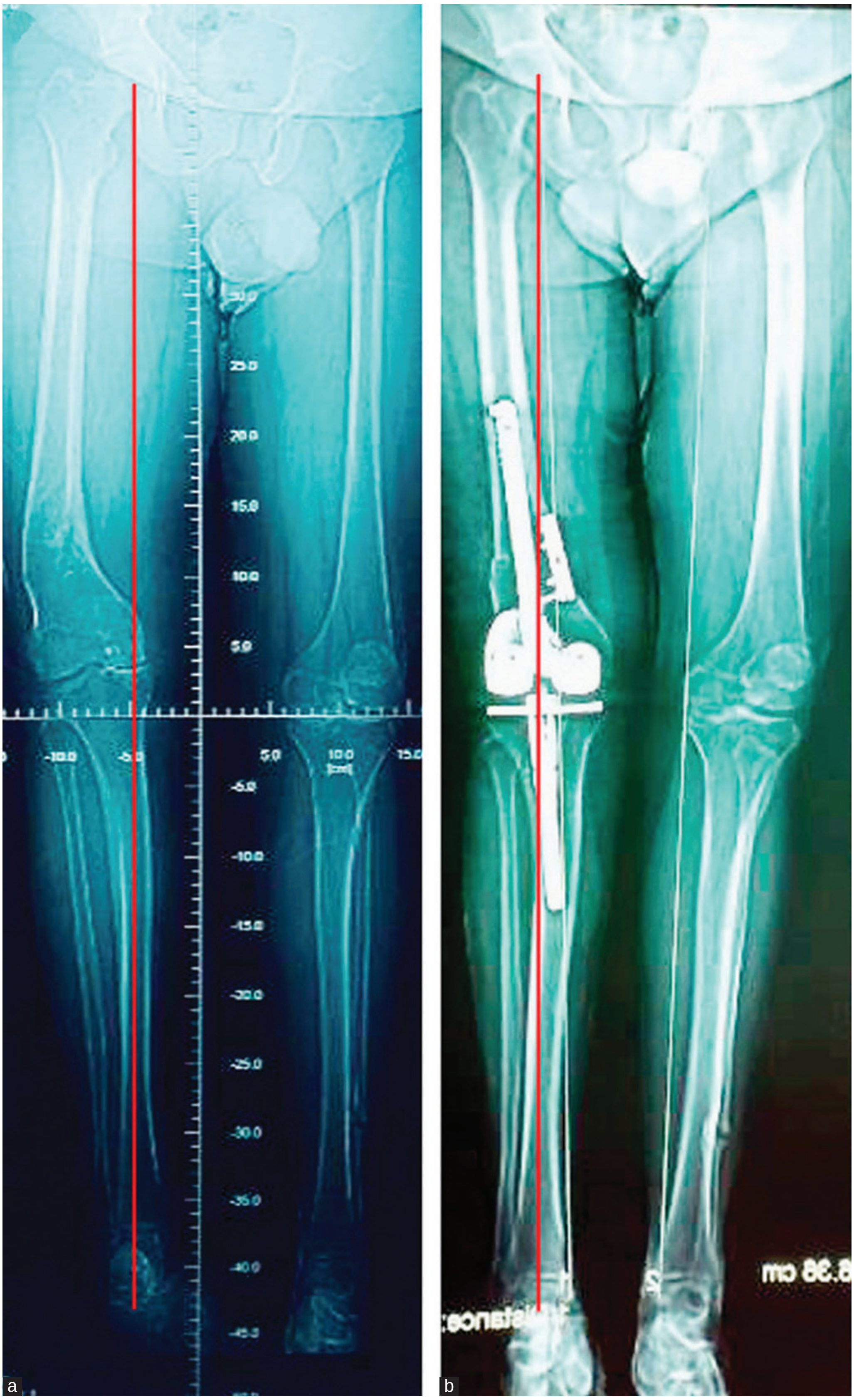
Therefore, on the basis of our experience from the current series, we strongly agree with Lonner and colleagues that, if the planned level of bone resection for the intra-articular technique on preoperative long films would compromise a major surface area of collateral ligament attachment or if the planned resection would create large asymmetrical gaps that make soft-tissue balancing difficult, a corrective extra-articular osteotomy should be used to normalize long-bone anatomy simultaneously with TKA.

In the unfortunate situation of combined femoral and tibial deformities, as encountered in one case in this series, we strongly discourage the performance of simultaneous extra-articular osteotomies at both levels in association with the TKA procedure. In doing so, the magnitude of surgical trauma may lead to potential complications such as nonunion, arthrofibrosis, infection, and pulmonary embolism [11]. In the combined deformity case presented in this series (Fig. 3), the major deformity on the femoral side was addressed by extra-articular corrective osteotomy and the minor deformity on the tibial side was addressed by intra-articular correction simultaneously with the TKA procedure.

Other authors believed that computer-assisted surgery for significant extra-articular deformity may be superior to conventional techniques because the mechanical axis is established irrespective of the local bone morphology or deformity [10,14]. In the series of Chou *et al.* [10], computer-navigated TKA using intra-articular bone resection and measured soft-tissue release have yielded excellent alignment and clinical results in 22 femoral and 18 tibia deformities. The authors suggested that a navigation system without intramedullary reaming is a potent strategy in the TKA surgery for the knee with malunion of the distal femur, presumably with the advantages of avoiding excess bone cut, less blood loss, and decreased risk of fat embolism. With all femoral deformities in their series, it was possible to restore alignment and soft-tissue balance without corrective osteotomy [10].

However, from our point of view, careful preoperative planning is still required in these cases because the computer cannot determine which cases would require an extra-articular correction. Computer navigation allows for precise, measured intra-articular bone resection and soft-tissue release. The computer only takes into consideration the hip, knee, and ankle centers and ignores deformity of the shafts of the femur and tibia.

Figure 3



(a) Scanogram showing osteoarthritis right knee with combined extra-articular deformity on the femoral (old malunited corrective osteotomy) and tibial (tibia valga) sides. Note the mechanical axis deviation (dashed line) and shortening. (b) Extra-articular correction was performed on the femoral side (fixed with diaphyseal an engaging long stem with locking screw and short plate for additional rotational stability of the osteotomy). Intra-articular correction was performed on the tibial side (the varus tibial cut partially compensates the tibia valga so as to ensure a neutral mechanical axis with the horizontal ankle joint line disregarding the mild residual anatomic tibial deformity). The overall mechanical axis was restored to neutral alignment and limb length was equalized.

In cases of significant anatomical deformity, it is critical that the mechanical axis be properly measured and restored. Although computer-assisted navigation can help to establish this, it is not a substitute for proper surgical technique, judgment, or experience. There are clear situations in which traditional approaches may work better and others in which a computer-aided approach is favored.

In conclusion, performing TKA in patients with extra-articular deformity is a technically challenging procedure, although isolated TKA with intra-articular deformity compensation and ligamentous balancing may be favored for mild to moderate deformities in view of the more rapid rehabilitation and functional score gain in the short term after surgery. Yet, simultaneous TKA and extra-articular corrective osteotomy has also yielded favorable outcomes and would still remain the technique of choice in severe deformities (>25°), especially with distant deformities from the knee joint line (diaphyseal, metaphyseodiaphyseal). The closer the deformity to the knee joint line, the more it is amenable to intra-articular correction. Careful preoperative planning is necessary to determine which technique would be better in each particular case.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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