Surgical technique

Total knee arthroplasty for treatment of osteoarthritis associated with extra-articular deformity

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ARTICLE INFO

Article history:

Received 26 September 2016

Accepted 11 January 2017

Available online 22 January 2017

Keywords:

Knee

Total knee arthroplasty

Extra-articular deformities

Arthroplasty planning

Soft-tissues balancing

ABSTRACT

Objective: Our purpose was to review senior author results of TKA in patients with extra-articular angular deformities (correction of mechanical axis was performed without an additional procedure for osteotomy).

Methods: Results of TKA in nine knees with osteoarthritis and associated extra-articular angular deformity of femur were reviewed retrospectively. This group was compared with a control group of 20 patients diagnosed with osteoarthritis that underwent TKA without extra-articular deformity. Angulation of deformity in patients was 19° in coronal plane (range 15°–25°) and 12° in sagittal plane (range 8°–5°). Knee Score (KS) and Functional Score (FS) were measured pre and post-surgery, likewise arc flexion was reported. Results in KS and FS were correlated with extra-articular angulation.

Results: Duration of follow-up averaged 55 months (range, 48–63 months). KS Average and FS increased from 50.5 and 38.4 points, preoperatively, to 96.5 and 84.4 points, respectively, at time of following-up. No statistically significant differences in any postoperative parameters were found between the postoperative group of extra-articular deformities and the control group were found. Positive correlation was obtained between deformity degrees and KS. Arc of motion averaged 86° preoperatively and 118° at time of following-up. No total knee arthroplasty was revised.

Conclusion: In our opinion, best management for extra-articular deformities associated to osteoarthritis is to carry out a knee replacement without corrective osteotomy on condition that planification allow to us avoid ligaments insertions, using an extensive soft-tissue balancing in conjunction with a minimally constrained TKA.

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1. Introduction

Extra-articular deformities of femoral or tibial axis increase stresses through knee and may eventually cause osteoarthritis, this pathology is frequently treated with a total knee replacement.¹ Such deformity may be secondary to metabolic bone disease, Paget disease, a malunited fracture, or a previous osteotomy. Corrective osteotomy and total knee arthroplasty, carried out in one or two stages, as a method to achieve normal alignment of long bones and better ligament balancing when a patient has an arthritic knee with extra-articular deformity.² However, this technique may be associated with substantial complications, including nonunion at osteotomy site, infection and arthrofibrosis. An alternative to

combined osteotomy and total knee arthroplasty (TKA) approach is to perform intra-articular bone resection and soft-tissue balancing, without osteotomy. This procedure may be appropriate when insertion of collateral ligaments of knee are not be jeopardized by intra-articular bone resection. Extensive soft-tissue balancing in conjunction with a minimally constrained total knee prosthesis has been described for management of severe varus and valgus deformity, like described Insall,^{3,4} and only for valgus deformity of knee following high tibial osteotomy, like described Krackow.⁵ Residual misalignment after TKA may result in inferior results cosmetically, functionally, and in long term. For this reason is very important to plan surgery to obtain a successful result (2). We report our experience with use of TKA for treatment of eight patients with osteoarthritis of knee associated to extra-articular deformity, through bone resection intra-articular, without corrective osteotomy.

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2. Methods

2.1. Patients

A total of 3200 patients undergoing TKA from 1990 to 2015 were assessed retrospectively. One surgeon performed every surgery. In this time nine great extra-articular deformities in femur ($>15^\circ$) were operated in one-stage with total knee arthroplasty, that were managed adequately by modified intra-articular bone resection and ligament balancing with no need for an additional osteotomy. All patients were candidates for TKA surgery, with main etiology being osteoarthritis secondary to femoral deformities. Six femur had a uniplanar deformity (four varus and one valgus) and three had a biplanar deformity (three varus+recurvatum and one varus+antecurvatum). Angulation of deformity in eight patients was 19° in coronal plane (range 15° – 25°) and 12° in sagittal plane (range 8° – 5°). There were seven men and two women with an average age of seventy-three old (range 61–85). We compare this cohort with a control group of 20 patients diagnosed with osteoarthritis that underwent TKA without extra-articular deformity (Table 1).

Femoral deformity resulted from fracture malunion in six patients and secondary to femoral osteotomy in three cases. Preoperative radiographs were used for planning bone resection, designing on paper cuts. Distal femoral resection was made perpendicular to mechanical axis of femur. Theoretical intra-articular resection of femoral bone was determined on same radiographs, with a plan for a 90° osteotomy was considered necessary if, on full-length weight-bearing radiograph, it appeared that distal femoral bone resection at a right angle to mechanical axis could compromise integrity of insertion of either medial or lateral collateral ligament. A CT scan was made for each case in patella's cuts, in this way femoral rotation could be calculated in relation with transepicondylar line and used to carry out anterior and posterior resections.

2.2. Surgical technique

Standard medial parapatellar approach was released in all cases. Intramedullary guide was used to cut femoral condyles, associated to extramedullary checking. Point of drilling was placed on lateral femoral condyle for varus deformities and on medial femoral condyle for valgus deformity. In order to achieve a normal mechanical axis in limb with a varus deformity, more lateral condyle than medial condyle have to be removed from distal part of femur or proximal part of tibia. Soft-tissue balancing after bone resection was an important part of this procedure in all cases. This resulted in relative lengthening of lateral soft-tissue structures. Extramedullary guide was used for tibial cut, with posterior slope of 7° . Bone resected from lateral or medial aspect of tibia was limited to 10 mm. Therefore, extensive release of medial soft-tissue

complex was required, and technique described by Insall.³ This procedure includes meticulous subperiosteal release of medial collateral ligament and anserinus tendons from their tibial insertions. With valgus deformities, more medial condyle than lateral condyle would have to be removed from distal part of femur or proximal part of tibia, after multiple horizontal stab incisions were made through ilio-tibial band (ITB) and lateral capsule until medial-lateral soft tissue balance was achieved, using “pie crusty” technique.⁶ In all cases, patellar replacement was released after of bone milled.

Type of prosthesis selected for extra-articular deformities cases were generally posterior stabilized (PS), seven cases received Nex-Gen 2 (Zimmer) and one case received Insall Burstein II (Zimmer), while for control group every cases were performed with PS Nex-Gen 2 (Zimmer). Tourniquet was used in all interventions, and was released after suture.

Clinical and functional evaluations were carried out comparing preoperative and postoperative objective scores according to system of Knee Society.⁷ This scale includes a 100-points Knee Score (KS) for evaluation of such categories as pain, range of motion, and stability, with deductions for flexion contracture, extension lag, instability, and malalignment. It also assigns a maximum of 100 points for functional capacity, Functional Score (FS), which includes such parameters as ability to walk on level ground and on stairs as well as necessity for assistive devices. Alignment shaft was checked with alignment rod. Angular deformity of mechanical axis of femur was determined preoperatively on weight-bearing full-length radiographs that incorporated ipsilateral hip and ankle (Figs. 1–8). Alignments of femoral and tibial components were measured on initial postoperative anteroposterior and lateral radiographs, in addition radiographs were made to determine presence of interface radiolucencies and to document any progression.

2.3. Statistical analysis

Data was analysed with Statistical Package for Social Science software (SPSS 22.0). To test whether administered surgery had an effect over treated disease, we conducted an Analysis of Covariance for repeated measures (AnovaRM), with Time (Pre, Post1, Post2, and Post3) as within-subject factor. We performed two separate AnovaRM for Knee Score and Function Score, respectively. Furthermore, to control for a potential effect of level of knee deformity previous surgery over treatment effect, we performed two separate Analysis of Covariance for Repeated Measures (AncovaRM) for Knee Score, and Function Score, respectively, with Time as within-subject factor (Pre, Post1, Post2, and Post3), and degree of extra-articular deformities covariate. Greenhouse-Geisser corrections were used when data violated assumption of sphericity. We conducted post-hoc comparisons with Bonferroni

Table 1
Patients data.

N° Patient	Age	Sex	Diag. preop.	Deformity preop (degrees)	Type of TKA
1	64	Man	Distal femoral osteotomy	20 varus, 12 recurvatum	Nex-Gen
2 (Figs. 3 and 4)	61	Woman	Distal femoral fracture	24 varus, 10 antecurvatum	Nex-Gen
3	63	Man	Distal femoral osteotomy	17 valgus	Nex-Gen
4 (Figs. 5 and 6)	83	Man	Distal femoral osteotomy	16 varus	Nex-Gen
5	73	Man	Distal femoral fracture	15 varus	Nex-Gen
6 (Figs. 7 and 8)	79	Woman	Distal femoral fracture	15 varus	Nex-Gen
7	78	Man	Distal femoral fracture	21 varus	Nex-Gen
8 (Figs. 1 and 2)	73	Man	Proximal femoral fracture	25 varus, 15 recurvatum	Insall
9	64	Man	Distal femoral fracture	25 varus, 12 recurvatum	Nex-Gen

Fig. 1. A, B and C: Case 8 is a patient with a proximal femoral fracture when he was 20 years old (in the Spanish Civil War). This are the preoperative images which show an extraarticular femoral deformity of 25° of the varus, and 15° of recurvatum.

Fig. 2. A, B and C: Images of the case 8 postoperative, after to be implante an Insall arthroplasty which returned the axis to 6° of valgus.

corrections when factor Time was significant. Level of significance was set at $p = 0.05$.

3. Results

Extra-articular deformities group obtained an average degree of femoral deformity preoperative of 19° (range 15°–25°) in coronal plane and 12° in sagittal plane (range 8°–15°) (Table 2). Duration of follow-up averaged 55 months (range 48–63), while control group obtained 6° (range 4°–9°) in coronal plane and 2° (range 0°–3°) in sagittal plane. Average postoperative Knee Score was 96.5 points

(range 84 to 100 points), representing a mean improvement of 46 points ($p < 0.001$) in extra-articular deformities group, while in control group was 97 points (range 88–100), for a mean improvement of 38 points ($p < 0.001$). Mean postoperative Function Score was 84.4 points (range 75–100 points), representing a mean improvement of 36 points ($p < 0.001$) in extra-articular deformities group, likewise mean postoperative Function Score was 88 points (range 80–100 points) in control group, representing a mean improvement of 40 points ($p < 0.001$). Flexion arc increased 32°, from a mean of 86° to a postoperative mean of 118° (range 108°–129°) at time of latest follow-up ($p < 0.001$) in

Fig. 3. A, B and C: These images belong to the patient 2, which had a distal femoral fracture in the childhood, and it show a extraarticular deformity with 24° of varus and 10° of antecurvatum. On the images preoperative was made the planning of surgery.

Fig. 4. A and B: These are the postoperative images (patient 2) with a Nex-Gen arthroplasty that got a physiological alignment.

extra-articular deformities group, while flexion arc increased 28° in control group, from a mean of 95° to a postoperative mean of 123° (range 115°–135°). Mechanical alignment in coronal plane was restored to 6.3° of valgus in extra-articular deformities group and in control group was restored to 6.1° of valgus. No statistically significant differences in any postoperative parameters were found between the postoperative group of extra-articular deformities and the control group were found (Table 3).

There is a positive correlation between deformity degrees and Knee Score in every group. A linear regression showed that amount

of improvement achieved by treatment was higher for those patients who showed highest deformity degrees ($p < 0.001$).

One knee of extra-articular deformities had nonprogressive radiolucent lines of less than two millimeters in medial edge of tibiae. Two knees of control group had nonprogressive radiolucent lines of less than two millimeters in medial edge of tibiae. One patient died 19 years after to surgery, as a result of a cardiopathy in extra-articular deformities group. Three patients died in control group, two as a result of a cardiopathy and one as a result of a cancer of colon. No more complications were reported in both groups.

Fig. 5. Aand B: These images are the preoperative Rx of number 4 case, which received a distal osteotomy in his childhood. The extraarticular deformity is of 16° of varus.

Fig. 6. Aand B: These images are postoperatives (case 4), and it shows the correct alignment with 6° of valgus in its axis.

4. Discussion

A successful outcome of TKA requires restoration of mechanical axis, balancing of periarticular soft tissue, and accurate orientation

of individual prosthetic components.^{2,8} However, in presence of an extra-articular deformity is necessary to consider some several questions: magnitude of deformity and its deformity plane, relationship of knee deformity, side of deformity (varus or valgus),

Fig. 7. A and B: These images corresponding to the patient number 6, with a distal femoral fracture that finished in an extra-articular deformity of 21° of varus.

Fig. 8. A and B: Postoperative images of patient number 6 with a correctly alignment.

whether femur or tibia is affected by deformity, carried out corrective osteotomy or not and, timing of surgery in affirmative case.

A larger deformity is more important, but just as important is its relationship to knee. Angular deformities closer to knee and >20° in coronal plane are more challenging but still possible without to associate osteotomy to arthroplasty. However, this point has been thoroughly discussed without agreement, in this way Ritter noted that maximum angulation may be 15° and Wang,⁹ Lonner² and Rajgopal¹⁰ consider 10° top maximum, and Koenig¹¹ indicated that deformities >20° could be management without osteotomy.

Determination depends on whether planned bone cuts compromise insertion of either collateral ligament with 20 mm trapezoidal wedge resection.¹¹ If deformity is so large that line compromises ligaments, an extra-articular correctional osteotomy may be indicated.^{12,9} Large deformities distant to knee have little impact on knee.¹³ Varus deformities require lateral intra-articular over resection, which produces lateral instability. Valgus deformities require medial over resection, which produces medial instability. Lateral instability is stabilized by dynamic lateral stabilizers (popliteus, lateral head of gastrocnemius, biceps femoris, and iliotibial tract) and is better tolerated than medial instability. Best way to determine consequence of misalignment in question is to template knee by drawing mechanical axis from femoral head or ankle to knee center, and then resection level that will be required.¹⁴

Wolff et al.¹³ noted that if a corrective osteotomy is performed in a knee joint (intra-articular) presence of an extra-articular femoral varus deformity would necessitate removal of more of lateral condyle than medial condyle when cutting distal femur during TKA. In such situations, asymmetrical distal femoral resection results in relative lengthening of soft tissue structures on side that has been preferentially resected as knee comes to extension. Wolff said that an extra-articular deformity can only be corrected at site of deformity before or at time of TKA, however, it is important to note that correcting an extra-articular deformity intra-articular with a 1-stage TKR is difficult and does not apply to all cases of arthritis with an extra-articular deformity.

For this reason, and based on Insall theory,^{3,4} we have carried out management of extra-articular femoral deformities without osteotomy, and our results have been worthy mentioning. We have corrected several deformities on femoral deformities (more challenging, theoretically), until 25° (mean of 19°), with encouraging results in Knee Score (KS) and Functional Score (FS), obtaining an improvement of 46 and 36 points, respectively. No complications have had in our series. These results did not differ from those obtained by the control group, without extra-articular deformities, which strengthens our hypothesis that a large extra-

Table 2

Patients preoperative and postoperative data (arc flexion, Knee Score and Functional Score Society test).

N° Patient	Arc Flex. Preop. (degrees)	KS Preop. (points)	FS Preop. (points)	Follow-up (months)	Arc Flex. Postop. (degrees)	KS Postop. (points)	FS Postop. (points)
1	15–70	42	50	63	0–120	99	100
2 (Figs. 3 and 4)	25–65	23	60	60	5–108	84	80
3	20–75	41	50	56	0–129	98	80
4 (Figs. 5 and 6)	15–70	53	35	62	0–125	99	80
5	10–65	62	70	48	0–120	97	90
6 (Figs. 7 and 8)	15–75	91	45	52	5–125	99	70
7	25–60	65	25	51	5–115	100	80
8 (Figs. 1 and 2)	25–65	55	12	48	0–110	96	90
9	20–70	45	40	24	0–120	98	90

Table 3

Comparative between Deformities Group and Control Group.

	Deformities Group	Control Group	p value
Age	73	74.6	$p > 0.3$
Coronal Deformity (degrees)	19	7.8	$p < 0.05^*$
Improvement Knee Score (points)	46	38	$p > 0.2$
Improvement Function Score (points)	36	40	$p > 0.3$
Improvement Arc Flexion (degrees)	32	28	$p > 0.3$

* Statistically significant.

articular femoral deformity can be corrected with a primary TKA without osteotomies.

In addition, we calculated relation between degree of deformity and improvement on KS, our result was a positive correlation, so that amount of improvement achieved by treatment was higher for those patients who showed highest deformity degrees. This success is according to Mann et al.¹² that reported their results in a series of 11 patients with deformities in femur associated with arthrosis of knee. Average deformity of femur was 14° in coronal plane and 12° in sagittal plane, they obtained 93 and 83 points in KS and FS. According to authors such a deformity could be managed adequately by modified intra-articular bone resection and ligament balancing with no need for an additional osteotomy. Koenig et al.¹¹ believed this could be compensated with soft tissue balancing and a stabilized prosthesis. Likewise, they noted that angulation is not decisive for choosing management, in condition that ligament insertions are respected. They carried out 2 deformities with a 33° varus of tibia and another with a 32° valgus of femur, with an improvement of KS of 55 points (pretest 40 and posttest 95 points). Bone cuts determination not compromised insertion of either collateral ligament with 20 mm trapezoidal wedge resection, so it was possible to corrective deformities without osteotomies.

RiBTer and Faris¹ believed that with proper attention to ligamentous instability any deformity could be intra-articularly corrected and found that outcomes following extra-articular osteotomy (staged or simultaneous) were worse in relation to alignment with a poor range of motion. They carried out a very important case series of 38 extra-articular deformities most of them without osteotomy, just using Insall principles for intra-articular correction. But this series hasn't been published. Likewise, Wang et al.⁹ also reported no complications in their series of 13 cases where TKA was made in conjunction with intra-articular bone resection. In their series, TKA with intra-articular bone resection associated to soft tissue balancing, achieved satisfactory outcomes in patients with arthritis of knee and an extra-articular varus deformity of <20° in femur and ≤30° in coronal plane of tibia, they reported an improvement on KS and FS of 22 and 28, respectively. Recently, Del Sel et al.¹⁵ published an important series

of 22 extra-articular deformities, with a mean deformity of 13°, which were treated by means of bone resections, without osteotomies. These authors noted improvements on KS and FS, of average postoperative of 86 and 85, in addition they noted two complications. Zhang et al.¹⁶ reported a series of nine patients with mean deformities of 13.3° in coronal plane and 11° in sagittal plane. Their improvements were 54° in range flexion, from 46° to 100°, and 71 points in KS, without complications.

Other opinion reported Lonner et al.² reported results of simultaneous femoral osteotomy and TKA for 11 severe extra-articular deformities, in 1-staged, nine of them with >20° coronal deformity associated to several sagittal deformity, however, they noted an increase in KS and FS of 10 and 22 points, respectively, and a flexion arc that was from 56° to 89°, and improvements smaller than our results. This procedure was successful in improving function, reducing pain and maintaining stability. Likewise, Rajgopal¹⁰ suggested that intra-articular resection of bone, soft tissue balancing and primary TKA in 1-stage showed good results in patients with arthritis of knee with extra-articular deformity of less than 18° in coronal plane and 15° in sagittal plane in femur and up to 24° in coronal plane in tibia, their results were comparable to our results. It increased KS and FS in 48 and 49 points, respectively, likewise, an improvement of flexion from 54° to 114°.

Papadopoulos et al.¹⁷ reviewed Mayo Clinic data and noted 22 extra-articular post-traumatic deformities that needed TKA, six of them were operated using osteotomy corrective, rest received soft tissue balancing, however, they found six complications in this patients, two of them had to be operated newly, so that in their opinion osteotomies were a good option like first stage. Along same lines, Eid¹⁸ noted that deformities until 25° in coronal plane of femur could be manage without osteotomy, and reported his results in 14 patients, but in his series deformity mean was 8° in coronal plane. Nine cases were treated combining TKA and corrective osteotomies, without complications, but follow-up was only 33 months. Yagi¹⁹ noted, also, good results in 2-stage surgery, in only one patient with 20° varus deformity, however, their points in KS and FS preoperative (6 and 10, respectively) were extremely small, and this didn't permit to assess their results correctly.

To conclude we may say that more studies are needed to know best management of extra-articular deformities associated to TKA. There are not studies of level 1 or 2 to value this treatment. Literature shows us only expert's opinions, where they could establish some several principles. Planning prior surgery is most important, because we know limits of ligamentous to carry out bone cuts correctly, and to make corrective osteotomy if it was necessary. Timing of surgery isn't critical, but it seems advisable to carry out in one stage to avoid surgery problems. It is also important to keep in mind magnitude of deformity and its deformity plane, relationship of deformity to knee, side of deformity (varus or valgus) and whether femur or tibia is affected by deformity.

Advantages of single stage procedure include an avoidance of any additional incision for a corrective osteotomy, and also rules out complications associated with osteotomies such as nonunion or delayed union, failure of internal fixation, infection at osteotomy site, and any wound break down at osteotomy site. For all these reasons, best management for extra-articular deformities associated to osteoarthritis is carried out knee replacement without corrective osteotomy on condition that planning permit us to avoid ligaments insertions, using an extensive soft-tissue balancing in conjunction with a minimally constrained total knee prosthesis.

"All patients gave the informed consent prior being included into the study with one exception, because the patient (number 8) was died and his family authorized us to publish his information The informed consent was waived by the Local Research Ethics Committee.

All procedures were in accordance with the 1964 Helsinki declaration and its later amendments".

The study was approved by the local Research Ethics Committee.

**We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.*

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there

are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

References

1. Ritter MA, Faris GW. Total knee replacement following extra-articular deformities. *Orthopedics*. 2003;26(9):969–970.
2. Lonner JH, Siliski JM, Lotke PA. Simultaneous femoral osteotomy and total knee arthroplasty for treatment of osteoarthritis associated with severe extra-articular deformity. *J Bone Jt Surg*. 2000;82(A):342–348.
3. Insall JN. *Surgery of the Knee*. New York: Churchill Livingstone; 1984:8.
4. Insall JN, Ranawat CS, Scott WN, et al. Total condylar knee replacement: preliminary report. *Clin Orthop Relat Res*. 1976;120:149–154.
5. Krackow KA, Holtgrewe JL. Experience with a new technique for managing severely overcorrected valgus high tibial osteotomy at total knee arthroplasty. *Clin Orthop*. 1990;258:213–224.
6. Clarke HD, Fuchs R, Scuderi GR, et al. Clinical results in valgus total knee arthroplasty with the pie crust technique of lateral tissue releases. *J Arthroplasty*. 2005;20(8):1010–1014.
7. Insall JN, Dorr LD, Scott RD, et al. Rationale of the knee society clinical rating system. *Clin Orthop Relat Res*. 1989;248:13–14.
8. Lotke PA, Ecker ML. Influence of positioning of prosthesis in total knee replacement. *J Bone Jt Surg A*. 1977;59:77–79.
9. Wang JW, Wang CJ. Total knee arthroplasty for arthritis of the knee with extra-articular deformity. *J Bone Jt Surg Am*. 2002;84(10):1769–1774.
10. Rajgopal A, Vasdev A, Dahiya V, et al. Total knee arthroplasty in extraarticular deformities: a series of 36 knees. *Indian J Orthop*. 2013;47(1):35–39.
11. Koenig JH, Maheshwari AV, Ranawat AS, et al. Extra-articular deformity is always correctable intra-articularly: in the affirmative. *Orthopedics*. 2009;32(9).
12. Mann III JW, Insall JN, Scuderi GR. Total knee arthroplasty in patients with associated extra-articular angular deformity. *Orthop Trans*. 1997;21:59.
13. Wolff AM, Hungerford DS, Pepe CL. The effect of extra-articular varus and valgus deformity on total knee arthroplasty. *Clin Orthop*. 1991;271:35–51.
14. Hungerford DS. Extra-articular deformity is always correctable intra-articularly: to the contrary. *Orthopedics*. 2009;32(9).
15. Del Sel H, Vedoya SP, Garabano G, et al. Reemplazo total de rodilla en gonartrosis asociada a deformidad extraarticular. *Rev Asoc Argent Ortop Traumatol*. 2012;77(3):178–184 [Spanish].
16. Zhang XG, Khurram S, Cao L. One-stage total knee arthroplasty for patients with osteoarthritis of the knee and extra-articular deformity. *Int Orthop*. 2012;36:2457–2463.
17. Papadopoulos EC, Parvizi J, Lai CH, et al. Total knee arthroplasty following prior distal femoral fracture. *The Knee*. 2002;9:267–274.
18. Eid MA. Simultaneous management of ipsilateral gonarthrosis and extra-articular deformity. *Egypt Orthop J*. 2013;48:269–276.
19. Yagi K, Matsui Y, Nakano S, et al. Treatment of knee osteoarthritis associated with extraarticular varus deformity of the femur: staged total knee arthroplasty following corrective osteotomy. *J Orthop Sci*. 2006;11:386–389.