

Knee Arthroplasty without Metal Augmentations in Patients with Major Tibial Defects: A Retrospective Study

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What's Known

- Total knee arthroplasty in severe osteoarthritis may be associated with a major bony defect in the tibia making the surgery very difficult. Its management with the resultant instability needs major bone grafting with metal augments and stem extensions.
- The metal extensions are expensive and often unavailable in our region.

What's New

- There is no report on reconstructing major defects of the tibial plateau in knee arthroplasty without metal augments or metal stems.
- Well-balanced knee arthroplasty without the use of any metal wedge or stem extension, with about 10 years follow-up obtained excellent survival in 98% of knees, with very good outcome scores.

Abstract

Background: Knee arthroplasty procedures improve pain, function, stability, and appearance of the limb. Total knee arthroplasty (TKA) in severe, long-standing osteoarthritis (OA) with large medial tibial defects could be a challenge. This paper looks at TKA outcomes when large tibial defects are managed without metal wedges or stems.

Methods: TKA cases done for OA with tibial defects of 15-25 mm, without any metal wedge or stem from 2004 to 2017 by a single surgeon in Shiraz, Iran, were clinically and radiographically evaluated. The preoperative questionnaires of SF36, WOMAC, KSS, and radiographs were compared with the follow-up assessments of the same parameters. Data were analyzed by R programming language using student *t* test, ANOVA, and Kruskal-Wallis. $P < 0.05$ was considered significant.

Results: 91 knees in 72 patients at 65.99 ± 8.66 years of age and 8.28 ± 2.58 years follow-up were studied. The tibial defects were managed with extra tibial cuts and adjustment of tibial component position in all, and the addition of structural autograft in 14 knees. 89 (98%) knees survived with a knee society score (KSS) of 79.4 ± 17.6 and were significantly functioning well ($P < 0.001$). Two knees required revision surgery. Significant improvement in outcome measurements was seen in all cases ($P < 0.001$). No radiographic loosening, alignment change, or clinical instability was detected. The tibial plateau reconstruction without bone grafting and the ones that had autologous bone grafting had similar functional results and radiographic outcomes.

Conclusion: TKA with tibial defects of 15-25 mm treated with a semi-constrained posterior-cruciate ligament (PCL) sacrificing condylar prosthesis without any metal wedges or stem extensions with or without additional autogenous bone graft obtained very good functional and radiographic outcome and 97% survival in 6-17 years follow-up.

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Keywords • Arthroplasty, replacement, knee • Osteoarthritis, knee • Transplantation, autologous • Outcome assessment, health care

Introduction

Total knee arthroplasty (TKA) is a rewarding reconstruction in severe knee osteoarthritis. A 10-year survival rate of above

95% is expected in well-performed TKA with proper alignment and adequate soft tissue balancing.¹⁻³ A good performance and survival in knee arthroplasty are to be expected with a well-balanced ligamentous tension and stability when lower limb alignment is restored through positioning the components on the patients' own supporting bone, usually with a semi-constrained condylar design. Large, progressive bony defects and angular deformities in long-standing osteoarthritis of the knee would produce major challenges in reconstruction. They are commonly associated with major depression and defects in the medial compartment and sometimes corner fractures of the tibial plateau posteromedially.⁴ When there is significant bone loss, a good metaphyseal bone support may be hard to obtain.⁵ Secondary medial collateral ligament (MCL) insufficiency along with large defects in the medial plateau may hinder a successful primary knee arthroplasty. The use of structural autografts or allografts for uncontained tibial defects is feasible, but the major issues of availability, graft resorption for autografts, and added risk of disease transmission, nonunion, and increased infection risk for allografts make them less favorable options.^{6, 7} Metal wedges and stems and the use of a constrained prosthesis are suggested for better stability and enhanced capability of the prosthesis and prosthesis-bone interface to resist the forces.^{1, 8} There is, however, a resultant higher rate of loosening and failure of the implant.⁹⁻¹¹

In the population under study, most patients would not opt for joint replacement till they reach very late stages of disease and when they are severely disabled, partly because of financial problems, and partly for the ethnic belief of accepting the disability rendered by God! We, therefore, often face many cases with major deformities and large tibial defects. This also coincides with the very poor access to the costly constrained implants, metal wedges, or stems. Such additional implants would triple the cost of the already-expensive knee replacement.

This paper aims to look at the mid-term results of such knee arthroplasties that have received semi-constrained condylar prostheses despite their major tibial defects.

Patients and Methods

The research project was approved by the Ethics and Research Committee of Shiraz Medical University (code: IR.SUMS.REC.1402.238). Written informed consent for the research and its publication was obtained from all the patients.

Among the knee arthroplasty cases of the senior author, (G.H.S), performed for osteoarthritis (OA) in Shiraz Dena Hospital between January 2004 to December 2017, the ones with an initial defect depth of 15 mm and over, on lateral radiographs, and non-contained-tibial-defects of over 50% of medial tibial plateau on anteroposterior view were selected. These cases were measured separately twice by two different observers. They had been all treated by a particular type of total condylar posterior cruciate ligament (PCL) sacrificing prostheses (NexGen Zimmer, Warsaw [IN], USA), all with a uniform technique and post-operative care. The cases with up to 17 years of follow-up were included in the study.

The non-osteoarthritic cases, those with shorter than 6 years follow-up, the knees with none or smaller than 15 mm tibial defects or contained defects, lateral tibial or femoral defects, the ones who had received metal wedges, tibial stems, or other types of knee arthroplasty designs were excluded.

All the cases pre-operatively filled functional questionnaires of The Western Ontario and McMaster Universities (WOMAC) Arthritis Index, which includes pain, stiffness, and physical function items,^{12, 13} as well as the 36-Item Short Form Survey (SF-36) that measures eight scales: physical function, role physical, bodily pain, general health, vitality, social function, role emotional, and mental health,^{14, 15} and Knee Society Score (KSS), which consists of four scales: objective, satisfaction, expectation, and functional activity.^{16, 17}

The cases were called in for radiographic assessment, clinical evaluation, re-filling the above forms, and inquiring about their satisfaction with the surgery. The evaluations were performed under the supervision of two independent orthopedic surgeons (M.J. and A.T.) and orthopedic associate physicians (E.M. and E.N.).

The defects were pre-operatively measured on standing anteroposterior and lateral knee radiographs. The percentage of the defect on the medial tibial plateau and the depth of defect on the sagittal view were documented (figure 1). A probable need for the use of autogenous bone grafting, from removed upper tibial lateral bone or femoral condyle, for defects of 15 mm or more, had been explained to and consented to by the patients.

The defects were managed by the following technique:

A: Removing more bone from the lateral side (if necessary, down to just touching the fibers of the patellar tendon on the tibial tubercle).

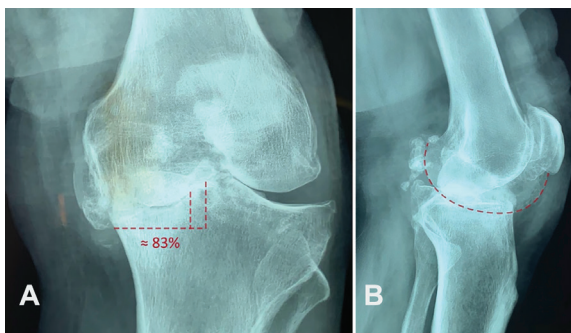


Figure 1: The lateral views of a 67-year-old woman show defects in the tibial plateau. A: 83% reduction of width in the medial plateau. B: The lateral view of the same knee with the depression.

B: Lateralizing the tibial metal component, even using a tibial component one size smaller than its matching femoral component if necessary- provided it would not jeopardize the joint level or upper fibular head.

C: The autogenous structural bone grafting, from the bone taken from a lateral plateau or femoral condyles and addition of local morselized cancellous graft into the remaining crevices- whenever steps "A" and "B" would still leave any part of the tibial component unsupported.

The patients, on their post-operative assessment, after signing the consent for evaluation, underwent knee examination for motion range, stability, clinical alignment, and gait assessment and evaluation of new standing knee radiographs. The patient's symptoms and clinical problems were documented, and the new functional assessment forms (KSS, WOMAC, SF36), were filled by the patients and later compared with their own pre-operatively filled forms. The new standing knee radiographs were meticulously analyzed for radiolucency, limb and component alignment, polyethylene wear, and position change in comparison with the initial post-operative radiographs for alignment and suspected loosening.

Statistical Analysis

The data were analyzed using the R programming language (version 4.2.2.; R Foundation for Statistical Computing, Vienna, Austria). For normal distribution data, the student *t* test or ANOVA was utilized. Non-parametric Mann-Whitney or Kruskal-Wallis for non-normal distributions; and correlations were analyzed with Pearson's and Spearman's rank correlation. A P value less than 0.05 was considered significant.

Results

Out of the 290 patients with 373 primary knee

arthroplasties done with similar prosthesis and similar technique by the senior author in the same period, 103 knees in 84 patients were enrolled in the study with TKA done in the presence of major medial knee tibial defect. Six patients had died, and six others could not attend the follow-up visit due to other health issues. Therefore, 91 knees in 72 patients were studied. The 91 knees included 12 (13.18%) TKA in men and 79 (86.81%) in women, consisting of 19 bilateral, 21 left, and 32 right knees. The mean age at surgery was 65.99 ± 8.66 , with 73.41 years in men and 64.86 in women, and the age at follow-up was 74.27 ± 8.96 . The average period of follow-up was 8.28 ± 2.58 (6-17) years. The patients' original BMI (body mass index) at surgery was 26.66 ± 4.45 (21-41). 70 patients had a BMI of over 32 (32-40), and 21 cases had a BMI of 20 to 31.

Fourteen (15%) knees had received structural autogenous bone grafting for the defect, and 77 (85%) cases were treated without any grafting. The defects in the knees that had required grafting were over 20 mm and had short supra-tubercle bone and mild patella Baja. The 77 knees that were managed without grafting had 15-25 mm defect depths, and 15 had patella-Baja (figures 2 and 3). The thickness of articular surface inserts was 10 mm in 3, 12 mm in 35, 14 mm in 40, 17 mm in 11, and 20 mm in 2 (3.2%, 38.5 %, 44%, 12.1%, 2.2%, respectively). The majority had been thus fitted with 12- or 14-mm articular inserts (82.5%).

All 91 primary knee replacements, including the two that had been revised, were functioning well and had no clinical symptoms of pain, alignment change, or infection.

The number of knees that required revision surgery from this group was two. One was a grafted tibial plateau with a 25 mm defect with resorption of graft and impingement of metallic screw used for graft fixation, which had a slow drift of tibial component and came to revision 5 years post initial TKA. The second revision was in a non-grafted large tibial defect knee replacement that had sustained medial femoral epicondylar avulsion in the initial TKA surgery; and, despite healing of the epicondyle, the screw had produced metal corrosion and resulted in a non-septic femoral component loosening with firm and stable tibia, 4 years post-surgery and required revision surgery.

The pre-operative average SF36 value of 42.4 ± 15.2 improved to 76.9 ± 19.3 , and WOMAC of 58 ± 19.2 changed to 36 ± 21 . The average pre-operative KSS of 32.2 ± 10 changed to 79.4 ± 17.6 postoperatively. These achievements are all statistically significant, $P < 0.001$ for all the amounts (table 1).

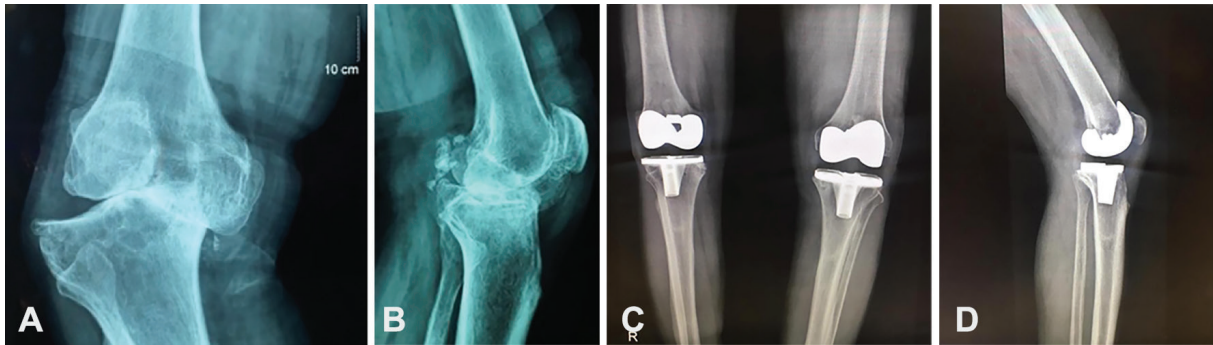


Figure 2: A 75-years-old man with knee osteoarthritis, subluxated knee, and major tibial defect on the right side was managed without a metal wedge or stem, but only with the lateral placement of tibial component and use of tibial plate size 3 instead of size 4 plate to match the size of D femur. A and B: Pre-operative Knee Radiographs show about two-thirds of the medial plateau is depressed with about 17 mm of depth, with good supra-tubercle bone stock. C and D: Post-operative radiographs with reconstruction of the tibial defects. The right side required about 2 cm lateral placement of the tibial component.

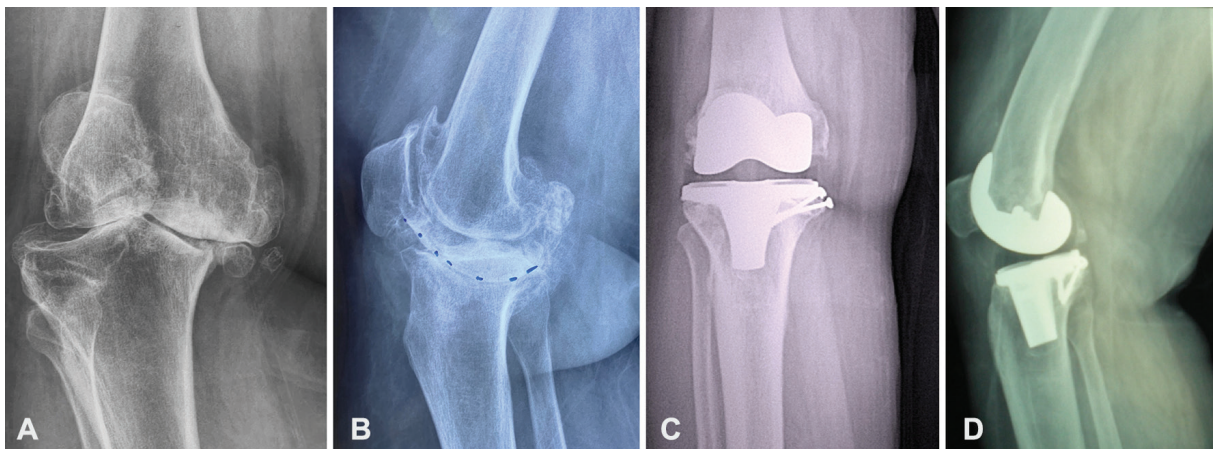


Figure 3: A 70-year-old lady with a BMI of 37 showed severe osteoarthritis with a major tibial defect and rim fracture of the plateau. A and B: the defect of the medial tibial plateau shows the depth of depression better on the lateral view. C and D: Antero-posterior and lateral radiographs with right tibial plateau reconstruction and use of bone autograph.

Table 1: Comparison of pre-operative and post-operative clinical scores

Variable	Pre-operative	Post-operative	P value*
KSS	32.2±10	79.4±17.6	<0.001
SF36	42.4±15.2	76.9±19.3	<0.001
WOMAC	58±19.2	36±21	<0.001

*Comparison was made using a paired *t* test with the significant level at $P < 0.05$. KSS: Knee society score; SF-36: 36-Items short form survey; WOMAC: Western Ontario and McMaster Universities Arthritis Index

The best subjective improvements were observed, sequentially, in the limb appearance, distance of walking, lack of need for cane(s), stair climbing, participation in social and family gatherings, and return to work and sporting activities. The issues that had not improved and were the source of some unhappiness in 10 cases included the ability to sit on the carpeted floor, use flat toilets, and kneel for daily prayers.

The knee range of motion at follow-up averaged 85 degrees (arc of flexion: 0-110 degrees). Good knee stability was subjectively present in 88 knees (97%) and clinically confirmed in knee examination in 81 knees (89%). Knee mediolateral asymptomatic instability in manual testing was 10-14 mm

in nine (three from the grafted group and six from the non-grafted group) and 17 mm in one patient. Occasional mild patellar discomfort in stair climbing was stated in five cases with no need for medication and no clinical evidence for impingement or maltracking.

The radiographic assessments revealed pre-operative severe defects in lateral views of over 20 mm in 69 and 15-25 mm in 22 knees. The anteroposterior radiographs, being more difficult to measure, showed medial plateau defects of 30% to 45%. The post-operative radiographic mechanical alignment, however, showed 7-10 degrees of varus in 10 knees and zero in the rest. Except for the two revised cases, there was no alignment change in the final radiographs

compared with the original post-surgical radiographs. A change in the position of the tibial component with resorption of medial tibial bone was observed in one of the two cases that required revision. Radiolucency of 2 to 3 mm under the medial tibial component that was non-progressive and without symptoms was observed in 10 cases. Evidence of wear in the polyethylene was suspected on radiographs in two grafted knees, with no clinical or radiographic symptoms or loosening and no progression within 5 years.

The knee arthroplasty survival (still functioning with no clinical or radiographic loosening issues) was observed in 89 (98%). All the patients were fully satisfied with their knees and limb alignment.

The comparison of the 14 knees that had required grafting with the 77 non-grafted knees in the functional scoring systems and subjective satisfaction status showed no significant difference. Besides, no statistical correlation between the gender at surgery, size of defect, and post-operative clinical and functional knee scores ($P=0.69$, $P=0.87$, $P=0.63$, respectively) was observed. Grafting or non-grafting also did not correlate with gender type, side, or bilaterality of TKA ($P>0.999$, $P=0.57$, $P=0.33$, respectively). There was also no linear relationship between BMI and functional scores (table 2). Functional post-operative knee score and WOMAC and post-operative SF36 and WOMAC ($r=-0.69$)

showed a strong negative correlation ($r=-0.62$), indicating an inverse relationship in the postoperative assessment of the mentioned parameters (table 2).

Discussion

The medium-term experiences of 91 primary TKA in 72 patients with varus osteoarthritic knees with large medial tibial defects of 15 to 25 mm depths that were managed with a semi-constrained prosthesis, without any metal wedges or stems, were studied. The tibial defects were managed with extra tibial cuts and adjustment of tibial component position in all and the addition of structural autograft only in 14 knees. In 8.28 (6-17) years of follow-up, 98% survived revision with $KSS=79.4\pm 17.6$ and maintained well-functioning knees. Significant improvement in outcome measurements, compared with the pre-operative status, was seen in all the cases ($P<0.001$), even in the two revised knees. No radiographic loosening, alignment change, or clinical instability was detected. The tibial plateau reconstruction without bone grafting and the ones that had autologous bone grafting had similar functional results and radiographic outcomes.

Severe varus deformity in long-standing knee osteoarthritis, especially in overweight patients, may produce large medial and posteromedial tibial plateau defects. The use

Table 2: Correlation matrix of the different scoring systems used in the evaluation of TKA before and after surgery

	Age	Follow-up time	CKSS pre-op	CKSS post-op	FKSS Pre-op	FKSS Post-op	SF-36 Pre-op	SF-36 Post-op	WOMAC Pre-op	WOMAC Post-op	Articular surface	BMI
Age	1	-0.030	0.210	0.094	-0.011	-0.273	0.086	-0.200	-0.034	0.202	-0.123	-0.029
Follow-up time	-0.030	1	0.454	-0.090	0.034	-0.287	0.160	-0.164	-0.125	0.157	0.084	-0.273
CKSS pre-op	0.210	0.454	1	0.163	0.379	-0.097	0.157	-0.113	-0.295	0.006	-0.125	-0.258
CKSS post-op	0.094	-0.090	0.163	1	0.140	0.471	0.080	0.294	-0.205	-0.480	-0.258	-0.138
FKSS Pre-op	-0.011	0.034	0.379	0.140	1	0.278	0.314	0.163	-0.381	-0.164	-0.173	-0.128
FKSS Post-op	-0.273	-0.287	-0.097	0.471	0.278	1	0.009	0.550	-0.025	-0.623	-0.175	0.064
SF-36 Pre-op	0.086	0.160	0.157	0.080	0.314	0.009	1	0.266	-0.491	-0.167	0.032	-0.169
SF-36 Post-op	-0.200	-0.164	-0.113	0.294	0.163	0.550	0.266	1	-0.158	-0.685	0.111	-0.058
WOMAC Pre-op	-0.034	-0.125	-0.295	-0.205	-0.381	-0.025	-0.491	-0.158	1	0.258	-0.005	0.015
WOMAC Post-op	0.202	0.157	0.006	-0.480	-0.164	-0.623	-0.167	-0.685	0.258	1	-0.026	0.085
Articular surface	-0.123	0.084	-0.125	-0.258	-0.173	-0.175	0.032	0.111	-0.005	-0.026	1	-0.170
BMI	-0.029	-0.273	-0.258	-0.138	-0.128	0.064	-0.169	-0.058	0.015	0.085	-0.170	1

This is a regression analysis test. Pre-op: Pre-operative; Post-o: Post-operative; CKSS: Clinical Knee Society Score; FKSS: Functional Knee Society Score; SF-36: 36-Items short form survey; WOMAC: Western Ontario and McMaster Universities Arthritis Index; BMI: Body mass index

of bone cement to fill the gap is beneficial only for small defects.¹⁸ In case of bone loss of over 10 mm, there is often a need for reshaping, base-plate reconstruction of the tibia with bone grafting, metal augmentations, and possibly, the addition of stem extensions.¹⁹ The restoration of joint line and recreation of symmetry in flexion and extension is needed for good ligament balance and knee joint kinematics. The bone stock reconstruction for tibial defects in primary TKA is more appealing in younger and more physically active patients.

Autogenous bone grafting in non-contained defects has had over 10 years of survival.^{19, 20} Ahmed and colleagues investigated 18 cases to compare grafting for a defect with regular TKA and reported no collapse of the graft or prosthesis subsidence and similar knee scores in 6 years average follow-up.¹⁹ Our grafted cases with 6-17 years follow-up had one revision. We, however, had grafting in defects with depths of 20 mm or more, when the supra-tubercle distance was short and extra bone removal was not justified. We obtained knee scores of 79.4, with a longer follow-up, slightly better than the TKA in the control group of Ahmed and colleagues. Sugita and colleagues used morselized bone grafting in 45 primary TKA cases with over 10 mm defects and found no loosening or subsidence in about 6 years of follow-up.¹⁸ It has been, however, suggested that with more than 40% deficiency of interface of the implant with bone, there would be inadequate support for the bone graft, and then stem extension in addition to some kind of augmentation is needed.^{18, 20} The metal augmentation, however, would produce radiolucent lines at its interface with bone in numerous cases and may be a concern for implant stability in the long-term, besides concern for future possible revision surgery.¹⁸

The tibial defects, concerning knee arthroplasty, have been extensively categorized and studied, in particular, in revision knee arthroplasty.^{21, 22} With the shortcomings in different classification systems, we used the simple measurement of defect height and width on anteroposterior standing and lateral radiographs.²³⁻²⁵

The functional and health-related assessment tools have been used previously in primary TKA.^{1, 3} The generic and disease-specific outcome measures for assessing the results of knee arthroplasty i.e., SF36, WOMAC, and KSS, are some of the most frequently used tools to assess the quality of patients' general health and arthritis status and outcomes before and after TKA.²⁶

The improvement of over twofold in SF36,

WOMAC, and KSS in the present report, is similar to the best records of knee replacement in regular knee osteoarthritis.²⁷

The good survival rate of a semi-constrained total condylar TKA, similar to the one used in the present report, has been studied previously.^{1, 2} A high survivorship of 92% after 10 years for TKA was reported by one multicenter study, and when categorized for different designs, an average of 90% to 95% survival has been observed.²⁸ The present report is about cases with major defects, and 98% survival is commendable.

The large bone defect in the tibia, which in varus deformities is posteromedial and often uncontained, is however, a major challenge and needs special considerations to salvage the situation.⁴ It has to be addressed by auto or allograft bone, tibial augments, sleeves, and cones. The different techniques of compensation for tibial bone defects with autogenous or allograft have been also investigated.^{7, 8, 18-20, 29} The use of wedges or metal augments for tibial defects as suggested by Brand,²⁵ has become a common practice nowadays.^{21, 22} The metal wedge augmentation, supplemented with different length stems for additional metaphyseal or diaphyseal tibial fixation, to decrease the axial and shear forces on a well-aligned and balanced knee implant on a tibial plateau, has been advocated. Such stem use in revision knee arthroplasty for adding stability is a common practice, while its role in primary knee replacement surgery is not very clear.^{25, 29} The increased constraint with the use of stems has been debated.

Rawlinson and colleagues, in a cadaveric study, concluded that stem extenders would decrease the stress on the bone, improving the knee stability of the implant.³⁰ Kharbada and colleagues and some other investigators have recommended the use of stem extenders in cases with bone defect.^{4, 9, 10, 30} Stemmed components have been advocated in overweight patients with over 35 Kg/m² BMI also,⁵ to be only questioned by the comparative study of Parrate and colleagues.¹¹ A more constrained total knee may, however, result in lower survival of the implant.^{9, 10}

To avoid augments or stems that are not easily available in our center and are costly, we had to utilize the patient's bone autograft, take more bone from the lateral tibial condyle -sometimes even down to touching the top of the tibial tubercle- and lateralize the tibial component to use our standard posterior cruciate ligament (PCL) sacrificing prosthesis.

Almost one-third of our referred cases had large defects with major varus and instability

and were often overweight. The effect of high BMI on knee replacement has been looked at by Mohammad and colleagues, who suggested an association with loosening in cemented unicompartmental replacements.³¹ We did not find any difference in functional or radiographic changes related to the BMI level.

Seventy-seven knees (85%) from this group were managed without additional bone grafting, and only 14 knees received bone grafts. A successful outcome was observed in medium- to long-term evaluation with 98% surviving and well-functioning knees. This kind of surgery requires specific attention to soft tissue handling and balancing and is not suitable for very osteoporotic or rheumatoid bones.

The limitations of the present report are its retrospective nature and lack of a control group. A good follow-up period and availability of prospectively collected questionnaires were some of its strengths.

Conclusion

Management of large defects in primary knee replacement in knees with large tibial defects is difficult and often requires defect reconstruction with metal wedges or cones as well as metal-stem augmentation for mechanical support for longer survival of implant - with or without bone grafting. We, however, showed that in situations where such metal augments were not available, the condition was salvaged with lateralization and/or one size down-sizing of the tibial component with a well-balanced PCL-sacrificing semi-constrained total knee implant, and obtained an excellent function and 98% TKA survival in about 8 years follow-up. A prospective randomized study of cases with this magnitude of defect, comparing our suggested defect management in primary TKA with that of metal augments and tibial stem addition would be worthwhile.

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Authors' Contribution

G.H.S: Examining the patients, conducting surgery, and writing the manuscript; M.J: Tabulation of functional scores, analyzing the data, literature search, and writing the manuscript; A.T: Examining the patients, assessing, and measuring the radiographs, literature search for writing the manuscript; E.N:

Collecting and analyzing the data, comparing the original functional scores with the follow-up scores, part of statistical analysis and writing; E.M: Collecting the data, gathering the patients' information, examining the patients, obtaining patients' consents for the study, and writing the manuscript. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of Interest

Gholam Hossain Shahcheraghi, as the Editorial Board Member, was not involved in any stage of handling this manuscript. A team of independent experts was formed by the Editorial Board to review the article without his knowledge.

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