RESEARCH ARTICLE

Total Knee Arthroplasty in End-Stage Knee Osteoarthritis with Tibia Stress Fractures – A Propensity Score Matched Comparative Study

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Abstract

Objectives: Knee osteoarthritis (KO) is a leading contributor to disability years, with a prevalence ranging from 22% to 39%. Tibia stress fractures (TSFs) are well-described for end-stage arthritis patients undergoing TKA. Literature is ambiguous, with a wide range of management options. This study primarily aims to compare and determine the clinical, functional, and radiological outcomes of TSFs in end-stage KO treated with TKA by propensity score-based matching.

Methods: It is a retrospective, single-center, comparative study conducted at University Teaching Hospital. The institutional medical records (IMRs) database was inquired. The TSF group included all patients of end-stage KO who underwent primary TKA with TSFs, and the TKA group included matched patients without TSF. Cases were 3:1 (TKA: TSF) propensity score-matched (PSM). The primary outcome was a PSM comparison of patient-reported outcome measures (PROMs) and 1-year Postoperative Complications and Adverse Events (POCAE). PROMs included the knee society score (KSS), patient satisfaction (PS), and KSS functional activities (FA) score.

Results: Study includes thirty-seven patients. Both groups showed no statistically significant difference in KSS FA and KSS PS scores. At the final follow-up, MCID for KSS FA was achieved by 31 patients (96.9%) in the TSF group compared to 92 patients (95.83%) in the TKA group. MCID for KSS PS was achieved by 29 patients (90.63%) in the TSF group compared to 91 patients (94.79%) in the TKA group.

Conclusion: End-stage KO patients with coexisting TSFs who undergo primary TKA with stem/ plate fixation as per fracture location may expect favorable PROMs, POAECs, radiological outcomes, and rates of achieving the MCID at a minimum 2-year follow-up. Accurate management of such cases results in excellent outcomes and minimized revision rates. All patients achieved complete bone union. These results were comparable to the PSM control group.

Level of evidence: III

Keywords: End-stage arthritis, Knee osteoarthritis, Propensity matching, Tibia long stem, Tibia stress fracture, Total knee arthroplasty

Introduction

Knee osteoarthritis (KO) is a significant cause of pain and deformity and a leading contributor to disability years, with a prevalence ranging from 22% to 39%.[1] The overall incidence of tibia stress fractures (TSF) in patients with KO ranges from 0.84% to 1.4%.[2,3] Stress fractures occur either due to continuous abnormal stress over the normal bone or everyday stress on an abnormal bone over a prolonged period.[4] Loss of dynamic balance between repetitive micro-trauma and healing between the tension and compression sides of the tibia overwhelms the healing process, resulting in stress fracture.[5,6] This process is exaggerated in KO with significant deformity.[7] Deformity related to end-stage KO leads to uneven loading and prolonged repeated atypical stress on the tibia, further

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worsened by osteoporosis in elderly patients, giving rise to cumulative microdamage and stress fracture.[2] Many management options are available for treating KO with associated TSF.[3-11] Given the diversity of treatment options, this study primarily aims to determine the clinical, functional, and radiological outcomes of TSFs in end-stage KO treated with TKA by propensity score-based matching [Figure 1, 2].

Materials and Methods

Study design

The University teaching hospital conducted a retrospective single-center propensity score-matched (PSM) comparative, STROBE-compliant study. Institutional review board (IRB) approval has been taken [AIIMS/IEC/2022/4085].

Patient selection

Study retrospectively inquired consecutive patients with end-stage KO Kellgren Lawrence stage 4, both with and without TSFs, who underwent primary TKA from 1st January 2015 till 30th June 2021, with a minimum of 2-year follow-up, in the institutional medical records (IMRs) database with prospectively collected data. Exclusion criteria included patients with post-traumatic arthritis, inflammatory arthritis, post-septic sequelae, revision surgery, and unwillingness to consent. All patients were telephonically contacted to request their physical attendance for the final follow-up.

The collected data was categorized into two groups. The test group (TSF) included all patients of end-stage KO with TSFs who underwent primary TKA, and the control group (TKA) included matched patients of end-stage KO without TSF who underwent TKA.

Matching

Propensity score-matching (PSM) was done to reduce any likely effect of confounding factors. Patients were matched 3:1 (TKA: TSF) using the nearest neighbor PSM without replacement with the optimal matching process.[12] Patients were matched using logistic regression with baseline demographics differences including age, gender, side affected, underlying pathology (osteoarthritis), duration of symptoms, preoperative knee society score (KSS), patient satisfaction (PS), KSS functional activities (FA),[13] Charlson comorbidity index (CCI), American Society of Anaesthesiologists Physical Status (ASA PS) Classification, body mass index (BMI), posterior stabilized procedure, same surgical team, and follow-up duration.[14,15]

Sample size calculation utilizing an a priori power analysis with a 1:3 match ratio to detect 80% power determined 27 patients in the TSF group and 81 in the control group, based on an expected mean difference in the KSS PS of 8 points.[16]

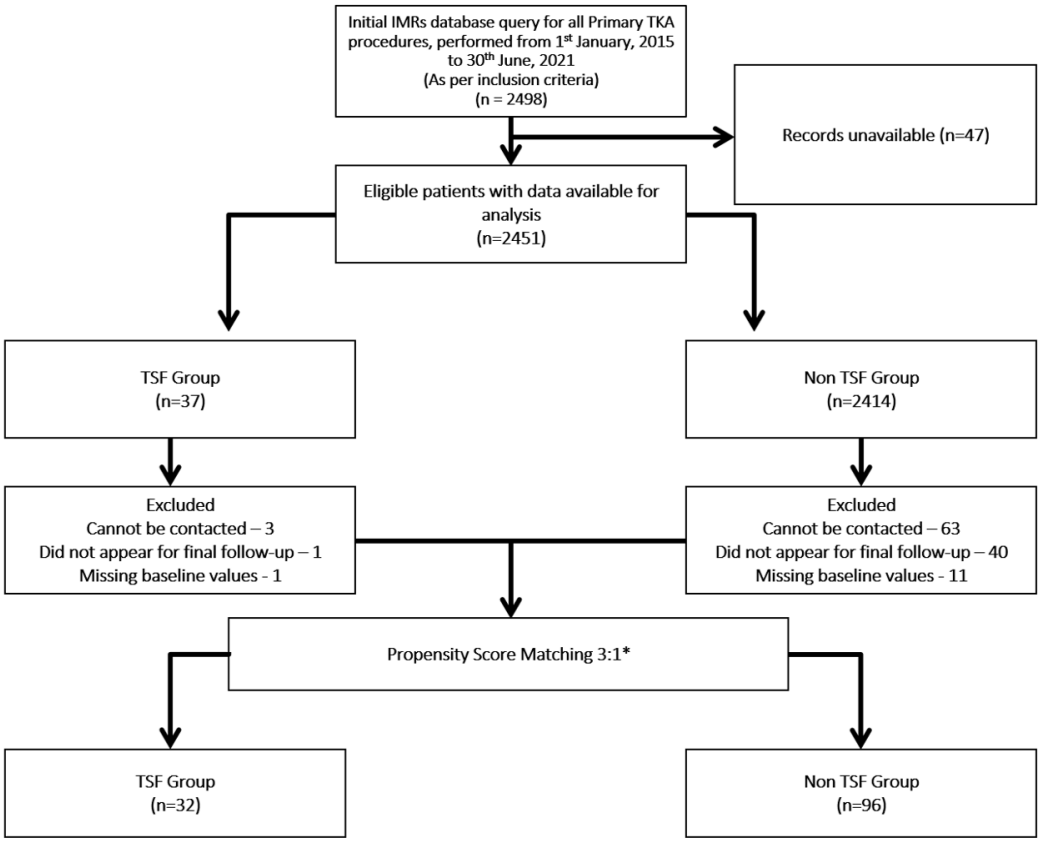

Figure 1.Flowchart delineating patient selection process; * shows the nearest neighbor propensity score matching without replacement based on age, gender, body mass index, side affected, etiology, charlson co-morbidity index, American Society of Anaesthesiologists Physical Status Classification, preoperative knee society score functional activities and patient satisfaction, and a minimum of two-years follow-up duration. (IMR - the Institutional Medical Record; TSF – Tibia Stress Fracture; TKA - Total Knee Arthroplasty)

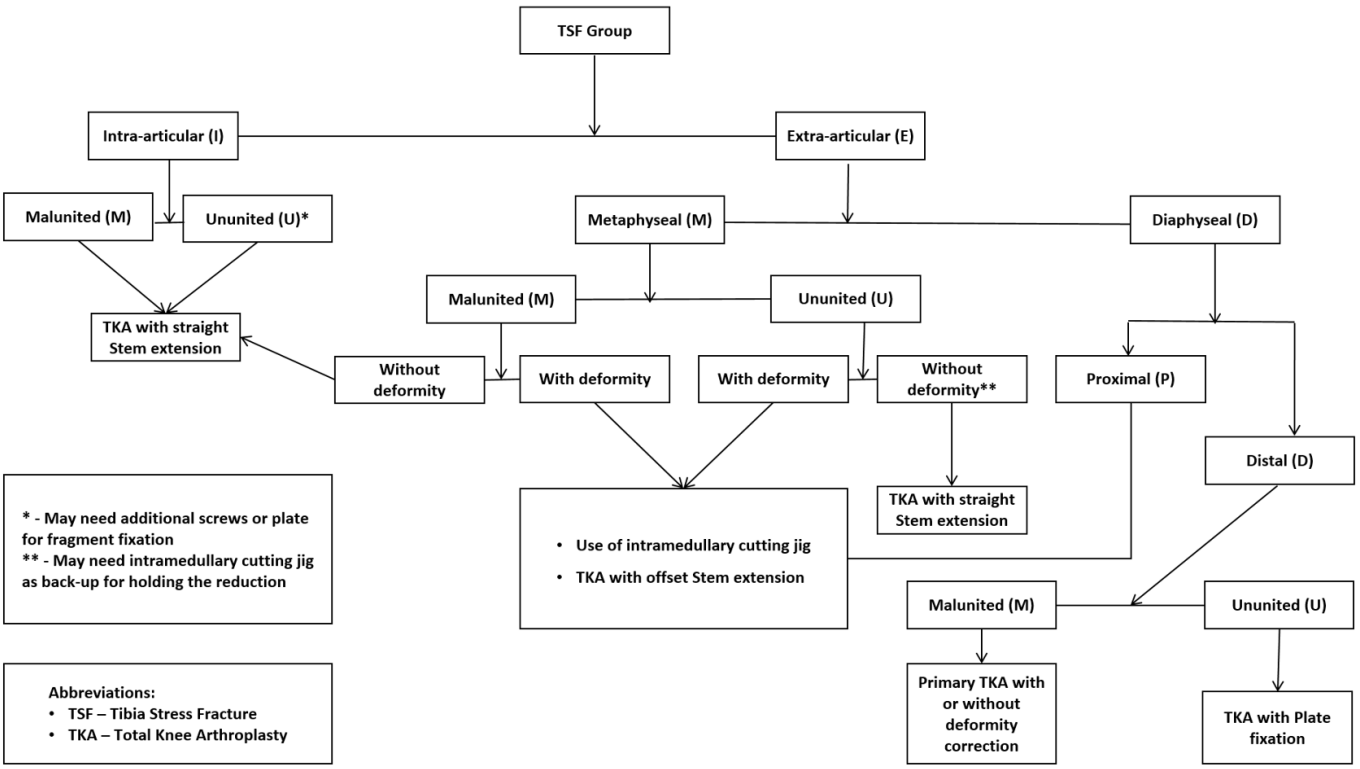

Figure 2. Algorithm-Based Institutional Integrated Classification System (ABIICS)

Outcome

IMRs were reviewed to document baseline demographics, including PSM variables, any history of trauma, surgical details, including date of surgery, procedure done, duration of surgery, intra-operative blood loss, implant details, length of hospital stay, and cause of re-admission or re-surgery. The same surgical team performed all surgeries. A medial parapatellar approach and a posterior stabilized implant were used in all cases. Perioperative care was similar and standardized as per institute protocol.

The primary outcome was to determine the clinical, functional, and radiological outcomes of TSFs with KO treated with TKA by PSM. Functional outcomes were assessed using patient-reported outcome measures (PROMs) and 1-year Postoperative Complications and Adverse Events (POCAE). PROMs were assessed using the KSS PS and KSS FA score at Preoperative, 3-months, 6-months, 1 year, 2-year, and final follow-up (with a minimum of 2 years).[13] The rates of patients achieving minimal clinically important difference (MCID) were calculated for the primary outcome of 1-year KSS PS and KSS FA, ensuring clinical relevance to the outcomes assessed. MCID was calculated by a distribution-based method to minimize bias, as per Norman et al.[17-19] The MCID baseline for KSS was considered 4.1 for FA and 2.2 for PS.[16] 1-year POCAE was noted per Healy et al.[20] Radiological outcomes were assessed using the Modern Knee Society Radiographic Evaluation System by an independent reviewer pre- and post-operatively.[21]

The secondary outcome was to assess bone union at the fracture site and survivorship. Bone union was evaluated by two independent reviewers 6 weeks apart, clinically by the absence of any local bony tenderness with painless full-weight bearing walking and radiographic continuation of the bony cortex on anteroposterior and lateral view radiographs of the knee joint and full-length scanogram of both lower limbs on final follow-up. The interclass coefficient (ICC) was calculated, and a mutual consensus resolved disagreements. The study also looked for the implant survivorship. Survivorship was defined in terms of patients who underwent revision surgery. Also, the study looked for any subset of cases where plate osteosynthesis was preferred over the long tibia stem.

Algorithm-Based Institutional Integrated Classification System (ABIICS)

All selected patients in the TSF group were classified per ABIICS [Figure 2, 3 and 4]. ABIICS was routinely used in our institution for decision-making in TSF cases and was initially conceptualized based on the anatomic location of TSF. Classification is essentially defines the TSFs in Knee arthritis as follows:

1. 1st alphabet: Association of fracture with the joint: Extra-articular (E) or Intra-articular (I).
2. 2nd alphabet: Site of involvement where applicable:

Metaphyseal (M) or Diaphyseal (D). Diaphyseal can be Proximal (P) or Distal (D) based on whether TSF is in the upper half (P), at the junction (D), or lower half of the tibia (D).

3. 3rd alphabet: Status of fracture union: Ununited (U) or Malunited (M). Ununited was defined as a visible fracture line with a break in trabeculae. Malunited were those with continuous trabeculae and persistent deformity.

4. Modifiers: The status of fracture union has been further sub-classified for a better definition of the treatment algorithm and has two modifiers: "With Deformity" or "Without Deformity" – conceptualized based on previous similar literature.[7,22]

So, the categories of stress fractures requiring treatment with TKR can be enumerated as follows [Figure 3]

1. IU: Intra-articular Ununited
2. IM: Intra-articular Malunited
3. EMM: Extra-articular Metaphyseal Malunited
4. EMU: Extra-articular Metaphyseal Ununited
5. EPDM: Extra-articular Proximal Diaphyseal Malunited
6. EPDU: Extra-articular Proximal Diaphyseal Ununited
7. EDDM: Extra-articular Distal Diaphyseal Malunited
8. EDDU: Extra-articular Distal Diaphyseal Ununited

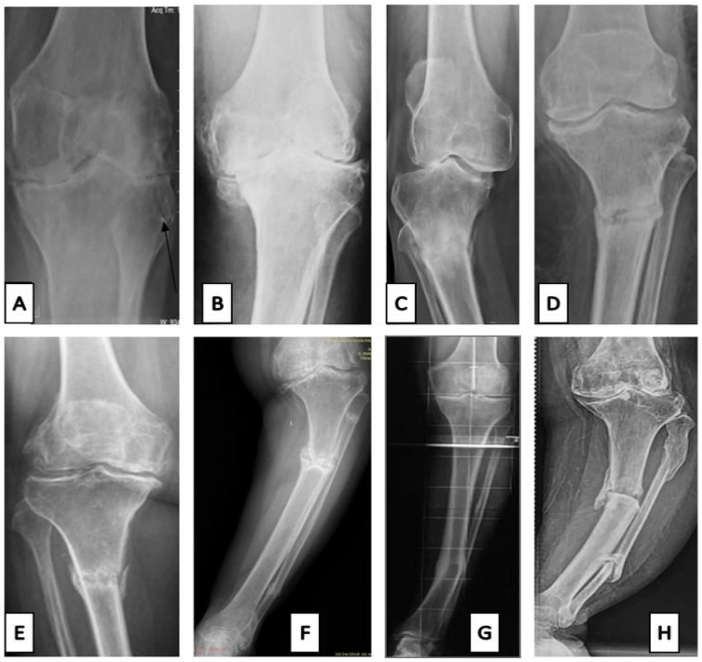

Figure 3. Radiographs of the proposed classification system; A – Intra-articular Ununited (IU); B – Intra-articular Malunited (IM); C – Extra-articular Metaphyseal Malunited (EMM); D – Extra-articular Metaphyseal Ununited (EMU); E – Extra-articular Proximal Diaphyseal Malunited (EPDM); F – Extra-articular Proximal Diaphyseal Ununited (EPDU); G – Extra-articular Distal Diaphyseal Malunited (EDDM); H - Extra-articular Distal Diaphyseal Ununited (EDDU)

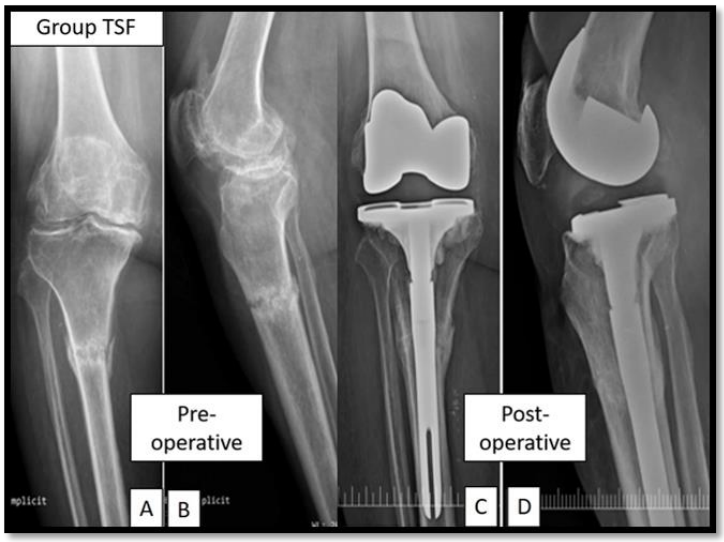

Figure 4. Radiographs of the TSF group; A – Pre-operative AP view with stress fracture; B – Pre-operative lateral view with stress fracture; C – Post-operative AP view with healed fracture; D – Post-operative lateral view with healed fracture

Statistics

All information was collected in an Electronic Data Capture (EDC) system and checked by an independent reviewer. A p-value of <0.05 was considered statistically significant. Statistical analysis was carried out using statistical packages for SPSS software version 24.0 for Windows (SPSS Inc., Chicago, IL, USA). PSM and MCID were carried out using the Matchlt and MCID packages respectively in R software version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Thirty-seven cases of TSFs with end-stage KL grade 4 KO who underwent TKA were enrolled. Since all patients were prospectively called for follow-up, only 32 patients (32 knees) could be contacted and included in the study. Based on a 3:1 PSM comparison, a matched cohort of 96 controls was selected out of 2498 patients [Figure 1]. Baseline demographics are given in [Table 1]. In TKA group, none of the patients had any stem extensions, in contrast to TSF group where press fit stems with hybrid cementing were used. No manipulation and no bone graft was used for the stress fracture in TSF group [Figure 4].

According to the ABIICS, we had 25 extra-articular and 7 intra-articular tibia stress fractures in arthritic knees [Table 2].

Table 1. Patient baseline demographics

Variable	TSF Group (Mean±SD)	TKA Group (Mean±SD)	p- value
Age (Years)	62.97±7.61 (Range: 42 – 82)	62.66±6.94 (Range: 46 – 78)	0.472
Gender (Women / Total)	24 /32	72 /96	0.062
Side involved (Right)	16	48	ns
American Society of Anesthesiologists Physical Status (ASA PS) Classification	1.59±0.49 I - 7 II - 14 III – 11	1.59±0.49 I - 21 II - 42 III – 33	0.631
Body mass index (BMI) (Kg/M2)	30.28±1.95 (Range: 27.6 – 34.8)	30.46±1.67 (Range: 28 – 34.2)	0.748
Charlson co-morbidity index (CCI)	0.22±0.65	0.22±0.66	0.758
Complaint duration (Years)	4.66±0.83 (Range: 3 – 7)	4.89±0.79 (Range: 2 – 6)	0.89
Preoperative Knee Society Score Functional Activities (KSS FA)	18.41±8.85	18.24±8.08	0.931
Preoperative Knee Society Score Patient Satisfaction (KSS PS)	8.50±4.00	8.65±3.88	0.441
Follow-up (month)	46.25±14.28	45.49±14.04	0.65

ns – not significant

Table 2. Patient particulars as per ABIICS category

ABIICS Category	Number of knees
IU: Intraarticular Ununited	Total – 2 With deformity – 1 Without deformity – 1
IM: Intraarticular Malunited	5
EMM: Extra- articular Metaphyseal Malunited	11
EPDM: Extra- articular Proximal Diaphyseal Malunited	Total – 5 Acceptable angulation – 5 Unacceptable angulation– 0
EMU: Extra- articular Metaphyseal Ununited	Total – 3 With coronal plane deformity –1 With Sagittal Plane deformity –1 Without deformity –1

Table 2. Continued	
EPDU: Extraarticular Proximal Diaphyseal Ununited	3
EDDM: Extraarticular Distal Diaphyseal Malunited	2
EDDU: Extraarticular Distal Diaphyseal Ununited	1

The Mean KSS FA and KSS PS scores pre- and post-operatively, are shown in Table 3 and 4, respectively. There was a significant improvement in the KSS FA and KSS PS at the final follow-up post-operatively compared with preoperative scores. However, no statistically significant difference was noted in comparing both groups [Table 3 and 4]. At the final follow-up, MCID for KSS FA was achieved by 31 patients (96.9%) in the TSF group compared to 92 patients (95.83%) in the TKA group, compared with preoperative scores. MCID for KSS PS was attained by 29 patients (90.63%) in the TSF group and 91 patients (94.79%) in the TKA group. POCAE was noticed in three patients in the TSF group. One patient from the EPDU group had a periprosthetic fracture, for which plate fixation was done. Asymptomatic segmental pulmonary thromboembolism (PTE) and deep vein thrombosis (DVT) of the common femoral vein were noticed in one patient in each EPDU and EDDU group, respectively. Both were managed conservatively. In the non-TSF group, two patients had delayed wound healing; one needed debridement and liner exchange. None of the patients needed revision surgery till the final follow-up. No statistically significant difference was noted in 1-year POCAE comparing both groups [Table 5].

Table 3. Changes in KSS Functional Activities (FA) Score

Timeline	TSF group	TKA group	P – value
Pre-operative	18.41±8.85	18.24±8.08	0.441
Post-operative			
3 months	66.09±6.21	81.31±4.31	0.036
6 months	83.66±5.86	87.75±1.79	0.034
12 months	88.72±1.92	89.81±1.84	0.311
Final Follow-up	90.31±6.11	92.01±3.25	0.271

Table 4. Outcomes of both groups

Variable	TSF Group(Mean±SD)	TKA Group	p value
Adverse events	0.16±0.37	0.06±0.24	0.45
Delayed wound healing	0.03±0.18	0.03±0.17	0.86
Implant failure	0.03±0.18	NA	---
Infection	0.03±0.18	0.01±0.10	---
Incision to closure duration (minutes)	56.28±14.43 (Range: 36 – 114)	46.90±6.91 (Range: 33 – 64)	0.093
Bone union (days)	24.06±41.91	NA	NA
Hospital stay (days)	5.88±3.72 (Range: 3 – 24)	3.96±1.03(Range: 3 – 7)	0.591
Postoperative Knee Society Score Functional Activities (KSS FA)	90.31±6.11	92.01±3.25	0.271
Postoperative Knee Society Score Patient Satisfaction (KSS PS)	38.19±1.55	38.13±1.47	0.679
Intra-operative blood loss (Milliliters)	146.8±86.1 (Range: 70 – 450)	50.6±22.7 (Range: 40 – 110)	<0.05

ns – not significant/ NA – Not Applicable

Table 5. Postoperative Adverse events of both groups compared

Variable	TSF Group	TKA Group	ABIICS	Management
Peri-prosthetic fracture	1	0	EPDU	MIPPO Anatomic Plate Osteosynthesis
PTE	1	0	EPDU	Conservative
DVT	1	0	EDDU	Conservative

Table 5. Continued				
Cardiac	1	1	EMM	Conservative
Delayed wound healing	1	1	IM	Conservative
Infection	0	1	NA	Debridement and liner exchange
Readmission	1	1	EPDU	Total Adverse Events: 7 in TSF; 5 in TKA group
Reoperation	1	1	EPDU	

The mean tibio-femoral angle (mTFA) improved from 7.5°±3.2° varus preoperative to 2.4°±2.1° in the TSF group. The mTFA in the TKA group improved from 4.6°±2.1° varus preoperative to 2.5°±1.2° at the final follow-up [Table 6].

Mean Fracture Union time was 107±42.16 days with an ICC of 0.8. One patient from the EPDU group who underwent fixation for a periprosthetic fracture needed 249 days for complete union. There was no evidence of any implant failure or revision surgery.

Table 6. Postoperative Radiographic Outcome of both groups compared

Variable	TSF	TKA	P value
Tibio-femoral angle (Degree)			
Pre-operative	7.5°±3.2°	4.6°±2.1°	ns
Final follow up	2.4°±2.1°	2.5°±1.2°	ns
Patellar tilt (Degree)			
Pre-operative	4.2°±2.32°	4.4°±2.47	ns
Final follow up	4.3°±1.67°	4.2°±2.2°	ns
Posterior condylar offset (mm)			
Pre-operative	17.2±0.89	17.4±0.92	ns
Final follow up	17.9±0.74	17.7±0.64	ns
Joint line orientation (Degree)			
Final follow up	0.7(-2 to 2.9)	0.8(-2.4 to 2.7)	ns
Implant position (Degree)			
Coronal Femur Angle	95°±0.12°	94.8°±0.47°	ns
Coronal Tibia Angle	90.3°±1.19°	90.2°±1.32°	ns
Sagittal Femur Angle	2.4°±0.8°	2.5°±0.76°	ns
Sagittal Tibia Angle	87°±1.2°	86°±0.92°	ns

Data presented as Mean and Standard Deviation/ Data presented as Median (min-max), "-"suggests valgus

Discussion

This study primarily compares and determines clinical, functional, and radiological outcomes for TSF patients undergoing TKA [Figure 1-3]. This study comprises 32 cases with 3:1 PSM controls, which, to our knowledge, is only a matched sample size study compared to the existing literature in this category of patients.

As per Soundarrajan et al., TKA with a long stem gives excellent functional and radiological outcomes, irrespective of the severity of arthritis associated with TSFs. The KSS and mTFA were similar to our study. But in contrast to our study, it included only proximal TSFs compared to the EDD group of the present study, which needed plating. Also, the study was single-armed and used classification based on tibiofemoral angle grading, but no difference in management or prognosis was concluded based on the grade of stress fractures.[23]

A retrospective comparative study by Gill et al. used long stem extension with TKA for the mobile group, whereas plates were used in addition to long stem extension with TKA in the non-mobile group.[24] However, both modalities are not needed at the same level as per literature, and any one of them will suffice, thereby preserving either periosteal or endosteal blood supply.[6,23,25]

Mullaji et al., mentioned one patient with an ununited stress fracture in the lower half, treated with TKA and patellar–

tendon–bearing cast application until fracture union. Our study also had a similar case managed with TKA and plating. Distal tibia stress fractures are difficult to manage even using an offset long stem extension due to increased chances of leg pain and stem tip periprosthetic fractures given overall varus tibia. The study also mentions one patient with a proximal malunited stress fracture treated with corrective osteotomy and a long stem. However, we did not encounter any such case in our study, and if such is the case, then corrective osteotomy may be needed depending on location and deformity.[6]

In a recent systemic review, single-stage long-stem TKA was sufficient for most TSFs with end-stage arthritis. In contrast, our study mentions a subset of patients with distal tibia diaphyseal stress fractures, which need the use of minimally invasive plate osteosynthesis instead of conventional long stems with TKA. The review also proposed a unified algorithm to guide the treatment of such cases. However, fracture location, which can be crucial in deciding treatment options, was not included, unlike our study, which uses anatomic location.[25]

The strengths in the present study reinforce the reported findings. 3:1 PSM and an a priori power analysis were utilized, thereby increasing the overall strength of the study and making it more applicable, as compared to previous classification and algorithm-based studies, which were non-comparative series of cases. The sample sizes of the study cohorts were adequately representative to detect differences in KSS, diminishing the risk of type II error. Furthermore, using validated KSS PS and FA outcome scores designed to assess outcomes in patients of TKA limits a potential ceiling effect and increases the generalizability of the results. Last, the psychometric tool MCID for KSS was considered.[26] the study also shows that TKA with a long stem is insufficient for all TSFs, especially distal fractures, which may need plate fixation.

Limitations

First, as it was a nonrandomized study, despite PSM, additional confounding variables may have influenced the results, like anesthesia type, postoperative anticoagulation used, patients undergoing medical management for osteoporosis, and physiotherapy protocol, which were not available for all cases and were not assessed. Additionally, since the analysis was based on patients from a single high-volume center with the same surgical team, it may limit the generalizability of the results or lead to non-reproducible findings at other centers. The sample size is not homogenous due to a few cases, thereby leading to selection bias, which propensity-matched controls reduce. An a priori power analysis showed 27 patients as the sample size, but the study describes the results of all 32 follow-up completed patients. This can be explained by the addition of the proportion of attrition, which is generally 20% of the sample size.[27] Another limitation is that the Patient-Acceptable Symptom State (PASS) and Maximum Outcome Improvement Satisfaction Threshold (MOIST) Score were not considered, as neither has yet been validated for the KSS PS and FA. Although no statistically significant differences were found between the PASS and MOIST of the two groups for KSS-PS and FA, whether or not the noted difference in symptom state is acceptable cannot be established. Finally, 100% follow-up was not achieved, and 5 (13.51%) out of 37 patients were excluded, which could have impacted the final comparison analysis between both groups. This is because there were certain baseline characteristic differences between follow-up completed and lost to follow-up TSF patients. Last, as the follow-up was only a minimum of 2 years, longer follow-up and adequately powered prospective multi-center studies could further establish the durability of results and proposed algorithm protocol more intensely.

Conclusion

End-stage KO patients with coexisting TSFs who undergo primary TKA with stem/ plate fixation as per fracture location may expect favorable PROMs, POAECs, radiological outcomes, and rates of achieving the MCID at a minimum 2-year follow-up. Accurate management of such cases results in excellent outcomes and minimized revision rates. All patients achieved complete bone union. These results were comparable to those of a PSM control group of patients who underwent TKA without TSF. The study also mentions a subset of patients with distal tibia diaphyseal stress fractures, which need the use of minimally invasive plate osteosynthesis instead of conventional long stems with TKA.

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Declaration of Informed Consent: Authors declare that there is no information (names, initials, hospital identification numbers, or photographs) in the submitted manuscript that can be used to identify patients.

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