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Autogenous structural bone graft reconstruction of uncontained significant medial proximal tibial bone defects in primary total knee arthroplasty

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Abstract

Purpose: Tibial bone defects in total knee arthroplasty (TKA) pose a significant challenge for surgeons, potentially causing improper component balancing. We studied the outcomes of autogenous structural bone grafting with screws to address medial proximal tibial defects in primary TKA with varus deformity.

Methods: A prospective study was conducted at Elite Hospital's Orthopedic Department in Sana'a City between 2020 and 2024. Patients with uncontained medial proximal tibial defects 10–25 mm in depth who underwent primary TKA for varus deformity were managed using autogenous structural bone grafts fixed with screws and followed up for at least 40 months. Patients were followed up clinically using the Knee Society Score (KSS). Radiological follow-up was performed to assess bone graft union and implant stability.

Results: The study included 29 patients with a mean age of 59.3 ± 7.2 years. Twenty (69%) were female, and nine (31%) were male. The median BMI was 28.3 (IQR, 26.30–29.30) kg/m². The mean defect depth was 13.2 ± 3.0 mm, with a mean follow-up duration of 55.3 ± 1.3 months. The median (IQR) preoperative KSS increased from 27 (23–34) to 91 (90–93) points at the last follow-up ($P < 0.05$), and the median (IQR) knee ROM improved from 84.0° (67° –109°) to 128.9° (122.1° –140.9°) ($P < 0.05$). Flexion contractures and varus deformities were completely resolved postoperatively ($P < 0.05$). The mean graft union time was 8.2 ± 1 months. The overall complication rate was 13.7%.

Conclusion: The use of autogenous bone grafting fixed with screws to manage large uncontained medial proximal tibial defects in primary TKA with varus deformity is a viable and successful treatment option.

Article Info

Keywords:
Tibial bone defect, Autogenous bone graft, Total knee arthroplasty, Tibial bone defect, Varus deformity, Uncontained defect, Structural bone graft, Screw fixation.

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1. INTRODUCTION

Tibial bone defects in total knee arthroplasty (TKA) represent a significant challenge for surgeons, potentially resulting in improper component balancing [1]. As the frequency of TKA increases annually, current and future scientific research is aimed at solving the issue of bone defect replacement [2]. Arthroplasty surgeons face many challenges, and bone defects, particularly on the tibial side, are a major concern. Bone defects or bone loss can be caused by several factors, such as advanced osteoarthritis, osteonecrosis, infection, trauma, previous osteotomy, and tumors [3]. The management of tibial bone defects is contingent on the size and location of bone loss and various patient-specific factors, including age, functional requirements, and bone quality [1]. Several surgical interventions are available to manage tibial bone defects, including resection of thicker bones, filling of defects with methyl methacrylate either alone or in conjunction with screws, and utilization of bone grafts and

metal augments [1, 4]. If not adequately managed, these defects may result in a compromised bone–implant interface, leading to prosthesis malalignment, postoperative deformity, and an increased incidence of postoperative complications and revision TKA [3]. In cases where tibial defects encompass 50% of the area with a depth exceeding 5 mm, achieving optimal surgical outcomes may prove challenging, necessitating the use of bone grafting [1]. Tibial bone defects are categorized into three distinct types: contained, flat peripheral, and slanted peripheral defects [5]. Bone grafts used to fill tibial bone defects are either autogenous or allogeneic to achieve axial alignment of the prosthesis and stable fixation of the components [4, 5]. We performed osseous reconstruction of a large medial proximal tibial defect with a depth of 10–25 mm using autogenous bone grafts fixed with screws in primary TKA for varus deformity.

2. OBJECTIVE

This study evaluated the outcomes of using autogenous bone grafts fixed with screws for large uncontained proximal medial tibial defects (10-25 mm depth) in primary TKA with varus deformities at Elite Hospital, Sana'a, Yemen, between 2020 and 2024.

3. METHODS

3.1. Study design, setting and patients' involvement

A prospective hospital-based study was conducted at the Orthopedic Department of Elite Hospital in Sana'a, Yemen, between 2020 and 2024. This study aimed to evaluate the outcomes of using autogenous bone grafts fixed with screws to manage proximal medial tibial bone defects in primary TKA with varus deformity. The study was approved by the Institutional Review Committee of the Orthopedic Department, Sana'a University, and all patients provided informed consent for participation. This study included all patients who met the inclusion criteria. The inclusion criteria included patients aged 50 to 90 years with Kellgren and Lawrence grade $\geq$3 (KL4) osteoarthritis, characterized by varus deformity and uncontained medial proximal tibial defects measuring 10–25 mm in depth following the proximal tibial cut. Patients must have completed a minimum of 36 months (three years) of follow-up to be included in the study. Patients with a history of revision knee arthroplasty, valgus osteoarthritis, rheumatoid arthritis, infection, defects following tumor resection, significant distal femur defects, or neuropathic knee arthritis, and those who underwent metal augmentation were excluded from the study. Patients lost to follow-up were also excluded.

3.2. Perioperative care and evaluation

History taking, physical examination, and radiological imaging were performed, and the same surgical team performed the surgery. Data were collected using a prepared questionnaire from patient records, including demographic data such as age at the time of surgery, sex, occupation, and primary diagnoses. Second, preoperative data, such as patellar tracking, active and passive range of motion (ROMs), varus angles, and associated deformities such as flexion contracture, were evaluated. Lateral ligament laxity and mediolateral instability were also assessed. Body mass index (BMI) was evaluated, and patients were categorized according to the World Health Organization (WHO) classification as underweight (BMI < 18.5 kg/m^2), healthy weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obesity class I (30–34.9 kg/m^2), class II (35–39.9 kg/m^2), or class III ($\geq$40 kg/m^2) [6]. Standing knee anteroposterior (AP) radiographs, lateral plain radiographs, and skyline views were obtained to verify the diagnosis of advanced arthritis and to evaluate the characteristics of the bone defects. A preliminary assessment of the depth of the bone defect from the anticipated proximal tibial cut was conducted using preoperative AP radiography (**Fig. no. 1 and 2**). Long-film weight-bearing radiography was performed to assess the anatomical and mechanical axes and quantify the degree of varus deformity by measuring the anatomical femorotibial angle (aFTA). Third, intraoperative data, such as the dimensions, size, severity, and location (site) of the tibial bone defect, the Anderson Orthopedic Research Institute (AORI) classification (type T2 A/B), and the type of implant were collected [7]. During the follow-up period, all patients were clinically and radiologically evaluated for the use of analgesia, low-molecular-weight heparin (Clexane), antibiotics, postoperative ROM, instability, wound status, and time to bone graft union. In addition, early and late postoperative complications, such as hematoma, infection, DVT, graft fracture, graft failure, bone graft nonunion, loosening, periprosthetic fracture, revision, and rehabilitation were assessed. Weight bearing was allowed without limitations. Patients underwent clinical and radiological follow-ups at intervals of 6 weeks, 3 months, and 6 months, followed by annual assessments, (**Fig. no. 3**). Finally, functional outcomes were evaluated using the Knee Society Score (KSS) preoperatively, at three years of follow-up, and at the last five-year follow-up during the study period [8–10].

3.3. Statistical analyses:

Statistical analyses were performed on the verified patient data collected using a pre-designed questionnaire. The data were analyzed using the R program (version 4.4.3). Categorical variables are represented as proportions, whereas continuous variables are described as

the mean ± standard deviation for normally distributed data or as the median and interquartile range for non-normally distributed data. Comparisons of preoperative and postoperative continuous data were conducted using either the paired samples t-test or Wilcoxon signed-rank test. The effects on functional and radiological outcomes were evaluated using the Mann–Whitney U test, Student's t-test, one-way analysis of variance (ANOVA), or the Kruskal–Wallis H test. Statistical significance was set at < 5% level.

3.4. Surgical procedure:

The surgeries were performed under general or spinal anesthesia, respectively. A standard medial parapatellar approach was used with routine steps to prepare the tibia and femur. Soft tissue release was subsequently performed to obtain a balanced correction of the deformities. The proximal tibia was displaced anteriorly to sublux-ate the knees. Subsequently, the tibial cut was made through the non-deficient lateral tibial plateau, which was used as a reference for the tibial cut, using a special stylus adjusted to 10 mm, with either intramedullary or extramedullary alignment guides. The tibial cut was performed using an oscillating saw, taking 8–10 mm with an anteroposterior inclination of 0–3 °from the nondeficient lateral tibial plateau, leaving a defect in the medial tibial plateau. Autogenous structural bone graft blocks harvested from proximal tibia or distal femur bone cuts were used to address the medial tibial plateau defect. First, the concave and irregular surface of the defect was smoothed by minimally removing bone with an oscillating saw, exposing healthy, bleeding bone to achieve good integration and healing with the graft. After the tibial bone was irrigated with pulsatile normal saline, the prepared surface was then dried. The depth of the defect was also measured. The graft was shaped using a bony rongeur, positioned over the flattened defect, and secured with Kirschner wires (K-wires). The K-wires were replaced with 3.5 mm cortical screws to ensure that they did not interfere with the tibial component keel or the stem. The protruding graft was excised using an oscillating saw to create a flat upper tibial surface. Before cementation, the interface between the bone graft and tibia was filled with an autogenous impaction bone graft to prevent cement extrusion into the interface of the bone graft. Trial prosthesis components were inserted to evaluate the position, size, prosthesis fit, tissue and bone gap balancing, and restoration of neutral mechanical alignment, which impact bone graft survival and prosthesis loosening. The definitive prosthesis was inserted using a standard cementation technique. Posterior-stabilized (PS) total knee arthroplasty (TKA) with a standard tibial component was performed in all cases. Patelloplasty was conducted by excising osteophytes with a nibbler and denervating the patella through circumferential cautery (patellar circumcision). Effective hemostasis was achieved after tourniquet release, followed by soft tissue closure after suction drain placement.

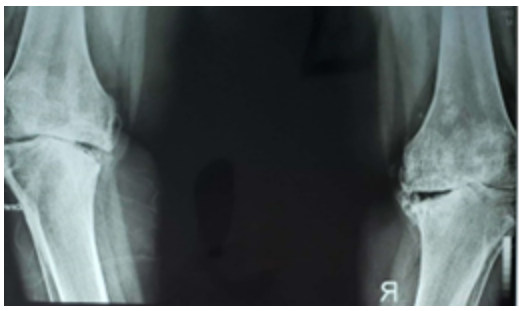

Figure 1. Preoperative right and left standing AP radiographs showing affected both knee joints with varus deformities and medial proximal bone defects.

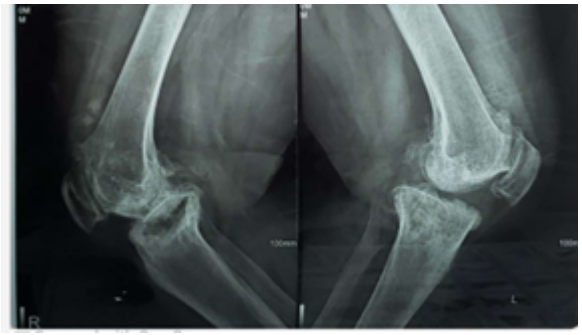

Figure 2. Preoperative right and left standing lateral radiographs showing affected both knee joints with posterior osteophytes and patellofemoral osteoarthritis.

4. RESULTS:

4.1. Demographic data

The study included 29 patients, including 27 (93%) patients < 70 years and two (7%) patients ≥ 70 years, with a mean age of 59.3 ± 7.2 y. Among the patients, 20 (69%) were female and nine (31%) were male. The median (IQR) body mass index (BMI) was 28.3 (26.30–29.30) kg/m². Regarding BMI, most patients were classified as overweight (66%), followed by 0normal BMI (17%), obesity class I (10%), and obesity class II (7%); no patients were found in obesity class III (Table 1).

Primary TKA was performed on the left (69%) and right (31%) knees of the patients. The majority of patients (97%) presented with a preoperative anatomical femorotibial angle (aFTA) between 10° and 25° varus, whereas only one patient (3.4%) had a deformity greater than 25° varus. Additionally, a substantial proportion of patients (69%) exhibited a preoperative flexion contracture greater than 10°, whereas 31% had a milder contracture of ≤10°. The mean bone defect depth, as measured intraoperatively, was 13.2 ± 3.0 mm, indicating moderate tibial bone loss before arthroplasty. The

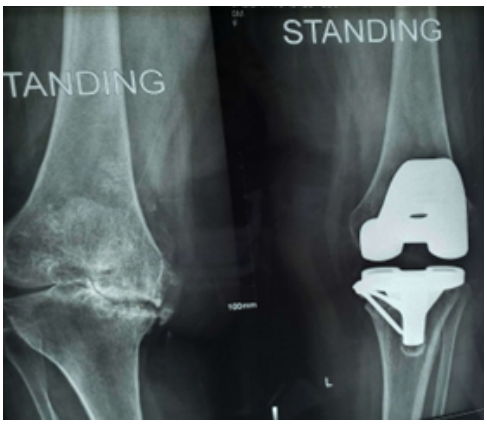

Figure 3. Postoperative right and left standing knee joints X-rays AP view at follow-up. It showed right left knee joint TKA with bone graft reconstruction fixed with three screws to address medial tibial bone defect.

median thickness of the polyethylene insert was 12 mm (IQR, 8-12 mm). The average operative time was 73 ± 28 min. The average follow-up period was 55.1 ± 3.2 months.

4.2. Comparison Between Preoperative and Final Follow-up Parameters:

The median KSS improved significantly from 27 (IQR, 23–34) points preoperatively to 91 (IQR, 90–93) points at the last follow-up ($P < 0.001$). The median flexion–extension ROM increased significantly from 84.0° (IQR, 67–109°) preoperatively to 128.9° (IQR, 122.1–140.9°) at the final follow-up ($P < 0.001$). In addition, varus malalignment was significantly corrected from 25° (IQR, 2–30°) preoperatively to 0.0° (IQR, 0–0°) at the last follow-up ($P < 0.001$). The flexion contractures significantly improved from 25° (IQR, 9°–29°) preoperatively to 0.0 °(IQR, 0°–0°) at the last follow-up ($P < 0.001$; Table 2).

4.3. Complications:

This study revealed an overall complication rate of 13.7%. Two patients (7%) had deep infection, and staged revision surgeries were required. In addition, one patient (3.4%) experienced a delayed graft union. Additionally, one patient (3.4%) had persistent medial joint pain, which might have been due to pes anserine bursitis.

4.4. The association preoperative variables and the final follow-up Knee Society Score (KSS):

At the final follow-up, most variables (age, sex, and preoperative deformities) were not significantly associated with KSS. However, the p-values for BMI and surgical

Table 1. Characteristics of the Patients

Characteristics	Value (n = 29)
Age, years (n, %)	
< 70	27 (93%)
≥ 70	2 (7%)
Age, years (mean ± SD)	59.3 ± 7.2
Gender (n, %)	
Male	9 (31.0%)
Female	20 (69.0%)
Classification (n, %)	
normal BMI (18–24.9)	5 (17%)
Overweight (25–29.9)	19 (66%)
Obesity class I (30–34.9)	3 (10%)
Obesity class II (35–39.9)	2 (7%)
Obesity class III (≥ 40)	0(0%)
BMI, kg/m2 (median (IQR)	28.3 (26.30 ,29.30)
Side of arthroplasty (n, %)	
Right	9 (31%)
Left	20 (69%)
Preoperative aFTA (n, %)	
10–25° varus	28 (97%)
> 25° varus	1 (3.4%)
Preoperative flexion contracture (n, %)	
≤ 10°	9 (31%)
> 10°	20 (69%)
Tibial bone defect depth	
mean defect depth	13.2 ± 3.0 mm

Table 2. Comparison Between Preoperative and Final Follow-up Parameters:

	Preoperative	Last follow-up	P-value*
KSS			
Median (IQR)	27 (23–34)	91 (90–93)	< 0.001
Range of motion, °			
Median (IQR)	84.0 (67–109)	128.9 (122.1–140.9)	< 0.001
aFTA, °			
Median (IQR)	25 (25–30)	0 (0–0)	< 0.001
0Flexion contracture, °			
Median (IQR)	25 (9–28)	0 (0–0)	< 0.001

side were borderline, suggesting potentially meaningful clinical trends that should be further explored in larger samples or adjusted analyses (Table 3).

5. DISCUSSION:

Total knee arthroplasty (TKA) is a widely accepted surgical intervention for severe knee osteoarthritis (OA). Treating patients with severe knee OA and varus deformity is challenging because of uncontained proximal tibial bone deficiencies [11]. Autogenous structural bone grafts have shown good long-term outcomes for uncontained tibial bone defects measuring 5-10 mm in depth [12]. Chon et al. used autogenous structural and cancellous chip bone grafts for medial proximal tibial defects $\geq$ 10 mm in 40 patients who underwent primary TKA [13]. Yoon et al. reported outcomes when autogenous onlay bone grafts were used in 19 patients with 12-mm-deep uncontained medial tibial defects; the mean KSS score increased from 30 to 92 at the 30.2-month the 52.2-month follow-up [11]. The current study examined autograft bone grafts fixed by screws for 10–25 mm uncontained medial tibial defects in primary TKAs with varus deformities. The results revealed significant improvements in the flexion–extension ROM, KSS, and correction of deformities over 55.3 ± 1.3 months, providing insights for clinical patients with severe varus deformity, who often present with limited knee flexion and flexion contractures due to chronic misalignment and joint deterioration. Evaluating the range of motion (ROM) and flexion contraction among patients who underwent primary TKA for knee varus with a medial tibial bone defect > 10 mm involves analyzing both preoperative and postoperative conditions to assess improvement and surgical outcomes effectively. Preoperative assessment typically reveals reduced ROM and significant flexion contractures, which are critical factors in determining the surgical approach and potential improvements from TKA [14, 15]. The aim of TKA is to restore alignment and improve ROM by correcting varus deformity, addressing medial bone defects, and relieving pain. The current study revealed a significant improvement in ROM and a reduction in flexion contractures from decision making.

Patients with severe varus deformity often present with limited knee flexion and flexion contractures due to chronic misalignment and joint deterioration. Evaluating the range of motion (ROM) and flexion contraction among patients who underwent primary TKA for knee varus with a medial tibial bone defect > 10 mm involves analyzing both preoperative and postoperative conditions to assess improvement and surgical outcomes effectively.

Preoperative assessment typically reveals reduced ROM and significant flexion contractures, which are critical factors in determining the surgical approach and potential improvements from TKA [14, 15]. The aim of TKA is to restore alignment and improve ROM by correcting varus deformity, addressing medial bone defects, and relieving pain. The current study revealed a significant improvement in ROM and a reduction in flexion contractures from a The preoperative median (IQR) ROM was 84.0° (67–109°) and median (IQR) flexion contraction was 25° (9–28°), which improved to a postoperative median ROM of 128.9° (122.1–140.9°) and median flexion contracture of 0° (0–0°) ($P < 0.05$). Similarly, previous studies have shown significant improvements in ROM and a reduction in flexion contracture. Similarly, Chon et al. and Dewidar et al. reported significant improvements in ROM [11, 13]. The ROM of the knee joint improves after TKA and continues to progress over the first few postoperative months following TKA. Maximum improvements in flexion are typically noted at three months, whereas extension improvements plateau at approximately six months post-surgery [15–17]. ROM improvements contribute significantly to patient satisfaction, as they are linked to functionality and QoL [18]. In summary, addressing ROM and flexion contractures in TKA for patients with knee varus with significant me-

Table 3. The association between preoperative variables and the final follow-up Knee Society Score (KSS)

Preoperative variables	Last follow-up KSS Median (IQR)	P-value*
Age. Years		
<70	91 (90–93)	0.861
≥70	91.5 (90.75–92.25)	
Gender		
Male	91 (90–93)	**0.904**
Female	91.5 (90–93)	
BMI classification		
Average Normal BMI	92 (91–92)	**0.0572**
Overweight	90 (90–93)	
Obesity Class I	93 (93–94)	
Obesity Class II	85.5 (84.75–86.25)	
Side of arthroplasty		
Right	93 (90–94)	0.0516
Left	90.5 (89.25–92.25)	
Preoperative aFTA		
10–25° varus	91.5 (90–93)	0.542
> 25° varus	90 (90–90)	
Preoperative flexion contracture		
≤10°	91 (90–92)	0.683
> 10°	91 (89.25–93)	

dial bone defects involves both surgical correction of mechanical deformities and ongoing postoperative management to optimize knee function and patient outcomes [13, 18]. These outcomes underscore the importance of comprehensive preoperative planning and postoperative care to maximize the benefits of TKA [19]. Compared with alternative methods, bone autografts have distinct advantages, particularly in managing Anderson Orthopedic Research Institute (AORI) type 2A and 2B uncontained defects ranging from 10 to 25 mm in depth in TKA [20–23]. The mean proximal medial tibial bone defect depth (13.2 mm) in the present study fits this indication range, supporting the rationale for selecting a biological technique over metallic augmentation for treating such defects [20, 21]. In addition, autograft bone avoids immunologic reactions and potential disease transmission associated with allograft tissue [11]. However, allografts have been linked to slower union and resorption and an increased risk of mechanical collapse [11]. In contrast, autografts contain viable osteocytes and marrow elements that promote rapid osteointegration [11]. However, the use of autografts is limited by donor volume. Therefore, for extensive defects (>25 mm), hybrid techniques combining autografts with metal augments or morselized allografts may be necessary; however, defect size was not included in this study. The results of the current study demonstrated that structural autogenous bone grafting (ABG) is an effective biological solution for managing large tibial bone defects in total knee arthroplasty (TKA), where bony union was achieved in all cases, with a mean graft union time of 8.2 ± 1 months. These findings are in line with those of several scientific studies indicating successful incorporation and healing of ABGs, with average graft incorporation times ranging from 5 to 10 months [11, 24–26]. These findings are supported by the fact that the union rates for large tibial bone defects $\geq$ 10 mm treated with autogenous bone grafting during total knee arthroplasty (TKA) have demonstrated promising outcomes across various studies, highlighting the effectiveness of the technique for managing large tibial defects in TKA, while preserving bone stock for future revisions and offering a cost-effective solution. The effectiveness of the technique was further supported by significant improvements in knee alignment and knee function scores postoperatively. Additionally, ABG possesses osteoconductive and osteoinductive properties, facilitating effective integration into the host bone without significant complications. Metal augments, cones, and cement-with-screw techniques have been proposed for tibial defect reconstruction; however, each has its limitations. Cement augmentation is appropriate solely for contained defects measuring less than 10 mm [27], whereas metal augmentation is employed to address uncontained defects, particularly those exceeding 10 mm [10, 28–30]. However, anatomical bone reconstruction cannot be achieved with metal augments, necessitating additional bone resection to ensure proper fitting [11, 31]. Furthermore, increased protrusion may lead to persistent knee pain [11, 32]. Metal blocks also contribute to significant bone defects in subsequent revision surgeries [11, 33]. This technique (ABG) also eliminates the need for metal augments and complex fixation devices, simplifying the surgical process and reducing costs, particularly in low-resource settings [1, 11, 24, 34]. Future research should focus on developing enhanced grafting techniques. The complication rates associated with autogenous bone grafting for the management of large tibial bone defects in TKA appear to be favorable when compared to the complication rates associated with allogenic bone grafting [11]. Previous studies have indicated that autogenous grafts achieve a high union rate of approximately 97% with minimal complications [11, 25]. In contrast, allogenic bone grafting is associated with complications such as nonunion [11, 35]. In our study, no significant complications, such as implant loosening or graft nonunion, were reported, with an overall complication rate of 13.7%, except for two cases of deep infection (7%), one case (3.4%) of delayed graft union, and one case (3.4%) of pes anserine muscle. Likewise, the studies by Chon et al. [13], Yoon et al. [1], and Ahmed Dewidar et al. [11] reported no significant complications. These comparable findings from various studies indicate that autogenous bone grafting secured with screws is a safe and effective approach for addressing large tibial defects in TKA, characterized by low complication rates and high success in achieving union [11, 24]. All patients showed improvement in the KSS, with a median preoperative KSS of 27 (IQR, 23–34) and a median postoperative KSS of 91 (IQR, 90–93) at the last follow-up ($P < 0.05$). These findings are consistent with those of some published studies that reported improvements in the KSS from good to excellent [1, 11, 13, 24, 35]. The improvement in the KSS indicates that employing autogenous bone grafting secured with screws to manage substantial uncontained medial proximal tibial defects in primary TKA with varus deformity is a useful and feasible treatment approach for varus osteoarthritis.

6. CONCLUSION:

The use of autogenous bone grafting fixed with screws to manage large uncontained medial proximal tibial defects in primary TKA with varus deformity is a viable and successful treatment. This technique yields significant improvements in functional outcomes, high rates of graft union, and low complication rates.

7. LIMITATIONS:

This study had several limitations. The small sample size and single-center design limit the generalizability of our findings. Although the 55-month follow-up period was suf-

ficient for midterm evaluation, it did not assess long-term implant survivorship beyond 10 years. Additionally, the absence of a comparative control group using metallic augments or allografts limits direct comparisons.

8. AUTHOR CONTRIBUTIONS:

All authors contributed to the conception, design, material preparation, data collection, analysis, reporting, and writing of the manuscript.

9. DECLARATIONS:

9.1. Ethics approval:

This study was performed in line with the principles of the Declaration of Helsinki, the WHO Code for Health, and Article (5) of the Statistics Yemeni Law (28) for 1995. Approval was granted by the Ethics Committee of the Faculty of Medicine, Sana'a University, Yemen.

9.2. Informed consent:

Informed consent was obtained from all the patients included in this study. 9.3 Conflict of interest declaration The authors declare that they do not have any competing interests in this manuscript.

9.3. Author Contributions:

All coauthors contributed to the design and implementation of the research, analysis of the data and writing of the manuscript.

10. AUTHOR DETAILS:

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