Knee arthrodesis using biplanar external fixation and vascularised patella autograft: a novel approach

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Abstract

Background

Knee arthrodesis, though a rare procedure in current practice, remains an option in managing non-reconstructable, non-functional knees, especially if from persistent periprosthetic joint infection (PJI). It is even more of an option because of the continuous rise in the need for total knee arthroplasty with the inevitable increase in complications, including periprosthetic joint infection. The union rate of knee arthrodesis is largely determined by both mechanical and biological stability across the bone contact surfaces. This study aimed to determine the pattern of bone union in knee arthrodesis when a pedicled vascularised patella autograft was integrated into the knee fusion and stabilised with biplanar external fixators. The secondary aim was to determine the functional outcome using this procedure.

Methods

A retrospective descriptive study of knee arthrodesis was done at a single-centre tertiary hospital using vascularised patella autografts and biplanar external fixators. The study period reviewed was from January 2014 to December 2023, and it included adults 18 years and above.

Results

A total of eight knee arthrodesis surgeries were included in this study. The mean age at arthrodesis was 58.5 years (SD 12.2; range 42–74). Six (75%) patients were male. Indications for arthrodesis were persistent periprosthetic joint infection (38%), tuberculosis of the knee (25%), and chronic osteomyelitis (25%). Complications occurred in one individual. At six weeks postoperative follow-up, the fusion rate at the patellofemoral and the patellotibial bone surfaces was 63% (n = 5), and no fusion was observed at the tibiofemoral surfaces of all eight patients. At 12 weeks postoperative follow-up, complete fusion across all bony surfaces was noted for all eight patients. The mean external fixation duration was 12.5 weeks (range 11–13). The mean postoperative lower extremity functional scale score increased from 32 (range 21–42) at six weeks to 46 (range 38–53) at 12 months. There was complete eradication of infection post-arthrodesis in all cases.

Conclusion

Fusion rate across the patellofemoral and patellotibial bone surfaces preceded that across the tibiofemoral surface. This finding suggests that this novel technique can enhance the fusion rate of knee arthrodesis by optimising the biology around the knee in a mechanically stable environment.

Level of evidence: 3

Keywords: knee arthrodesis, vascularised graft, patella autograft, biplanar external fixator, fusion rate

Introduction

Historically, knee arthrodesis was used as a limb-preserving procedure primarily in the management of septic arthritis, tuberculosis (TB), poliomyelitis, and other end-stage arthritis. Its use has since evolved into a salvage procedure for non-reconstructable and non-functional knees.[1] The 15-year cumulative incidence of knee arthrodesis following total knee arthroplasty (TKA) is reported to range from 0.21% to 0.31%. Despite the rarity of this procedure, the most typical indication remains recurrent periprosthetic joint infection (PJI) and irreparable knee extensor mechanism. Extensive soft tissue deficiency and severe bone loss are other common reasons for knee arthrodesis. However, close to half of these patients may have multiple indications for arthrodesis.[2]

The decline in knee arthrodesis is linked to advances in TKA techniques as well as the extensive gain witnessed in managing PJI. Also, improvements in managing infectious diseases, such as newer anti-tuberculous chemotherapy and the effective global polio vaccination, have further reduced the incidence of arthropathy with a decreased need for knee arthrodesis.[1] The demand for TKA in the United States is predicted to peak above 140% by 2050.[3] A similar projection in Denmark, however, predicted that the continuous rise in TKA may plateau in 2030 or 2035.[4] Therefore, with the inevitable

complication of PJI, knee arthrodesis is likely to remain a vital tool in the arsenal of the knee reconstruction surgeon for years to come.

The choice for knee arthrodesis is complex and is usually delayed in clinical practice, often only made following repeated debridement and eventual bone loss, which affects the functional outcome and the rate of the bony union seen in these patients.[5] Knee arthrodesis with a modular intramedullary nail for persistent PJI was found to be an acceptable alternative to the hinged TKA, as knee arthrodesis produced a significant reduction in pain with an associated high PJI remission rate. The improvements in the pre- and post-arthrodesis pain, functional outcome and quality of life were found to be similar to the hinged TKA group. Though the walking distance was decreased in the knee arthrodesis group, the patients, however, demonstrated a high patient satisfaction rate (88.5%), given that the goals of treatment to eliminate pain and ensure limb preservation were achieved.[6] A similar result from a separate study indicated good post-arthrodesis infection control, good functional score and improved pain scores, but demonstrated poor patient satisfaction with the procedure.[7]

Comparatively, knee arthrodesis avoids most complications associated with lower limb amputation. Patients who had above-knee amputation (AKA) for PJI had a 50% five-year mortality rate, a higher in-hospital mortality rate, a higher 90-day readmission rate, and increased systemic complication rates compared to those who had knee arthrodesis.[8-10] Furthermore, patients who have an AKA will require higher energy for ambulation than those with knee arthrodesis. The energy expenditure has been estimated to be 0.16 mL/kg/min for knee arthrodesis and 0.20 mL/kg/min for AKA patients.[11,12] Interestingly, microprocessor prosthetic knee amputees have reported better functional outcomes compared to those with mechanical prosthesis and knee arthrodesis. This is because the microprocessor monitors the phases of the gait cycle and provides automatic support for any deficiency in mobility, replicating the normal gait as accurately as possible.[13] Despite its advantages over AKA, knee arthrodesis is associated with significantly higher blood transfusion rates, postoperative infection rates, and a higher cost of surgery when compared to AKA.[10]

Knee arthrodesis is, however, not an elixir as it is generally avoided in ipsilateral hip arthrodesis, contralateral hip/knee arthrodesis, as well as ipsilateral hip or ankle osteoarthritis. This is due to the altered compensatory adaptive biomechanics from the pre-existing pathology. Additionally, functional outcomes after knee arthrodesis are poor if done in obese patients, patients over 62 years of age, and patients taller than 166 cm.[1,14,15]

External fixation carries a low reinfection rate, mainly because of a lack of retained internal hardware that may fester biofilm formations, making it difficult to eradicate persistent infection.[16] A study comparing knee arthrodesis with biplanar and uniplanar external fixation found a 100% fusion rate with the biplanar method compared to 81% in the uniplanar group, and 100% infection clearance compared to 86% in the uniplanar group.[17]

The higher rate of union seen in intramedullary nailing compared to external fixation may be due to the more rigid fixation of intramedullary nails or the lack of surgical expertise in creating an adequate external fixation construct, which is necessary for compression and bone union.[18] Regardless of the fixation method, the outcome of knee arthrodesis depends on the ability to achieve bony union. Therefore, it is important to obtain sufficient contact between the metaphyseal ends of the distal femur and proximal tibia, as well as compression with a rigid fixation technique. A well-united knee after arthrodesis will ensure a pain-free and stable knee, with expected improvement in outcome measures. On the contrary, tibiofemoral pseudarthrosis is associated with instability, malalignment, persistent infection, and significant bone loss.[19,20] A mean four-year follow-up analysis of knee arthrodesis using a monolateral external fixator found a fusion rate of 81%, an infection clearance rate of 86%, and an 82% satisfaction rate, which is indicative of a poorer outcome compared to other techniques.[21] Given that several factors influence fusion rates following knee arthrodesis, the rate of union varies from 38–100% across the literature.[14,22,23]

Pedicled fibula grafts and non-vascularised patella autografts are used in knee arthrodesis as void fillers to achieve fusion in severe bone loss. Our technique, however, relies on the integrity of the blood supply to the patella through branches of the geniculate vessels, especially on its lateral aspect. Therefore, this technique may not be beneficial in patients with vascular compromises to the patella, such as from soft tissue injuries to the knee or avascular necrosis of the patella.[24,25]

A recent study puts the ten-year survival rate at 52%, following knee arthrodesis using modular intramedullary nails. Though this method resulted in a 26% revision rate, none were due to implant failure, and the pain levels at final assessment in the remaining survivals were zero.[26] This study aimed to describe knee arthrodesis with vascularised patella autograft and biplanar external fixation. The secondary aim was to determine if the addition of the vascularised patella autograft would improve the union rate and functional outcome of knee arthrodesis. To our knowledge, no literature currently exists demonstrating the use of a vascularised patella autograft to augment fusion in knee arthrodesis.

Methods

Study design and study population

This single-centred retrospective descriptive study was conducted on data extracted from the medical records and radiographs of adult patients who underwent knee arthrodesis with a vascularised patella autograft and biplanar external fixator at the Arthroplasty Unit of Universitas Academic Hospital, Bloemfontein, South Africa. A consecutive non-probability data sampling method was carried out on the medical records of patients operated on during January 2014 to December 2023. Two orthopaedic surgeons from the arthroplasty unit performed all procedures identified.

A patient was considered a candidate for knee arthrodesis following failed revisions for PJI following TKA, loss of knee extensor mechanism, severe soft tissue, and bone loss.

Exclusion criteria were (i) patients with a body mass index of ≥ 35 kg/m^2, (ii) insufficient clinical records, (iii) knee arthrodesis using other techniques such as unilateral or ring external fixators, intramedullary nails, and plate fixation, and (iv) knee arthrodesis not done by the two arthroplasty unit consultants.

Variables

The collected data included patient demographics, indications for knee arthrodesis, and complications of the procedure. Radiologic assessment of bone union between the patella, distal femur and proximal tibia surfaces, as well as the tibiofemoral surface, which was done every six weeks until the 24 weeks postoperative period, were analysed. Information regarding the Lower Extremity Functional Scale (LEFS) score at six weeks and 12 months post-surgery was also obtained. The LEFS score consists of 20 questions which assesses different aspects of activities of daily living. Scores range from a minimum of 0 to a maximum of 80. The higher the score, the less the level of functional limitation. Scores 0–20 signify severe functional limitation, 21–40 moderate functional limitation, 41–60 mild-moderate, and 61–80 mild functional limitation.[27,28]

Surgical technique

The patient is placed supine on a radiolucent theatre table and a limb tourniquet is applied. Pre-incision intravenous tranexamic acid is administered. Intravenous antibiotic is given after specimen collection for microbiology and histopathology tests. A medial parapatellar approach is used, extending from the suprapatellar pouch to the tibia tubercle. The pre-existing hardware is explanted. A full-thickness skin flap is developed over the anterior patella, and the quadriceps tendon and patella ligament are reflected off the tubercle. Care is taken to preserve the lateral attachments to the patella and its genicular blood supply. This is vital to the success of this technique. A posterior capsulectomy is then performed to allow unimpeded posterior bony contact. Extensive debridement of the bone surfaces and the intramedullary compartment is carried out to ensure that no residual infection is left behind. The tibiofemoral surface osteotomies are then carried out. The TKA cutting blocks may be used for better accuracy in obtaining coronal and sagittal alignment. However, this can also be done freehand. As was the case in one of our patients, we used the computer navigation system to achieve good end-to-end cuts due to his severe malunion (*Figure 1*). We generally aim for 5° valgus, 0–10° external rotation, and 10–15° of flexion (if limb length discrepancy is a concern, we generally fuse the knee in extension). We routinely wash with saline pulse lavage before temporarily fixing the knee with two crossed Steinmann pins in the desired arthrodesis position. The patella articular surface is denuded of cartilage and sclerotic bone, and the anterior surfaces of the distal femur and proximal tibia are decorticated with a shallow trough shaped out of them into which the patella is situated. This may be done with an oscillating saw.

An Orthofix® monorail external fixator is applied anteromedially with hydroxyapatite-coated pins and compressed under direct visualisation. The Steinmann pins are removed, and the patella is fixed with two large fragment screws angled into the femur and tibia, respectively (*Figure 2*). Following a layered soft tissue closure, a longer Orthofix® pelvic external fixator is applied anterolaterally at 90° to the first external fixator, neutralising the long lever arm of the lower extremity and completing the sagittal and coronal plane stabilisation (*Figure 3*). A flow diagram summarising the key steps in our technique is presented in *Figure 4*.

Postoperative management

Patients were allowed to weight bear, as pain permits, with appropriate walking aids. Radiographs were taken postoperatively to confirm alignment and hardware placements. Patients were discharged and followed up with repeat radiographs done at six weeks, 12 weeks, and 24 weeks postoperatively. The radiographs were assessed for union at the patellofemoral, patellotibial and tibiofemoral bony surfaces at each visit. We defined bony union as the presence of a bridging callus on at least two radiographic views across a joint in the backdrop of clinically diminished pain and improvement in weight-bearing. Radiologic assessment for bone union was done independently by both arthroplasty unit consultants. We removed the shorter compression external fixator once we saw evidence of tibiofemoral union. The longer neutralising external fixator was then removed about 12 weeks after the index surgery.

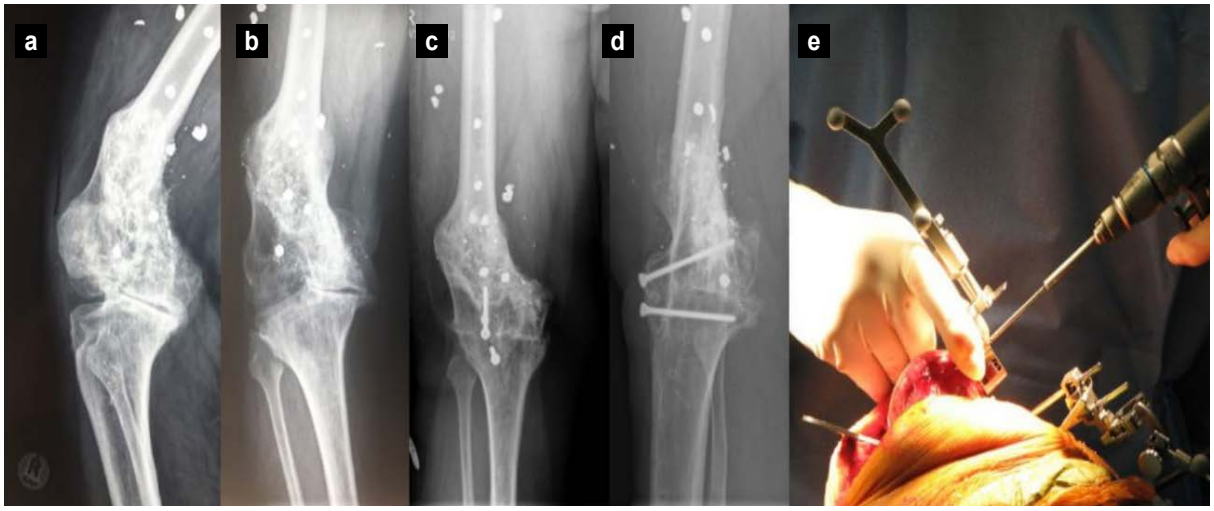

Figure 1. Radiograph gunshot knee, showing: a, b) distal femur malunion; c, d) post-arthrodesis alignment; e) done with computer-assisted osteotomy

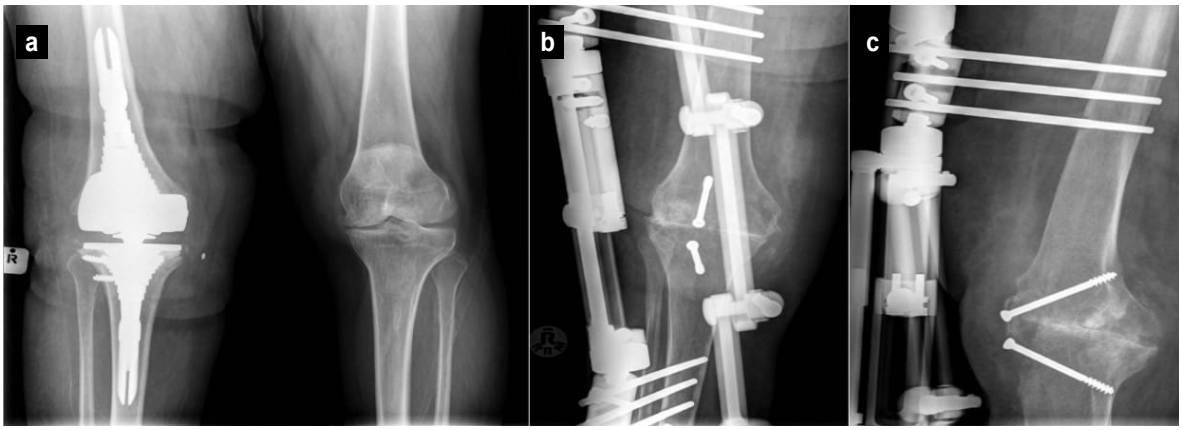

Figure 2. Radiographs of patient with a) persistent periprosthetic knee joint infection; b, c) 12 weeks post-arthrodesis with biplanar external fixation and vascularised patella autograft fixed with large fragment screws

Figure 3. Intraoperative images, a and b, showing the biplanar external fixation construct in a compression and neutralising mode at a 90° plane to each other

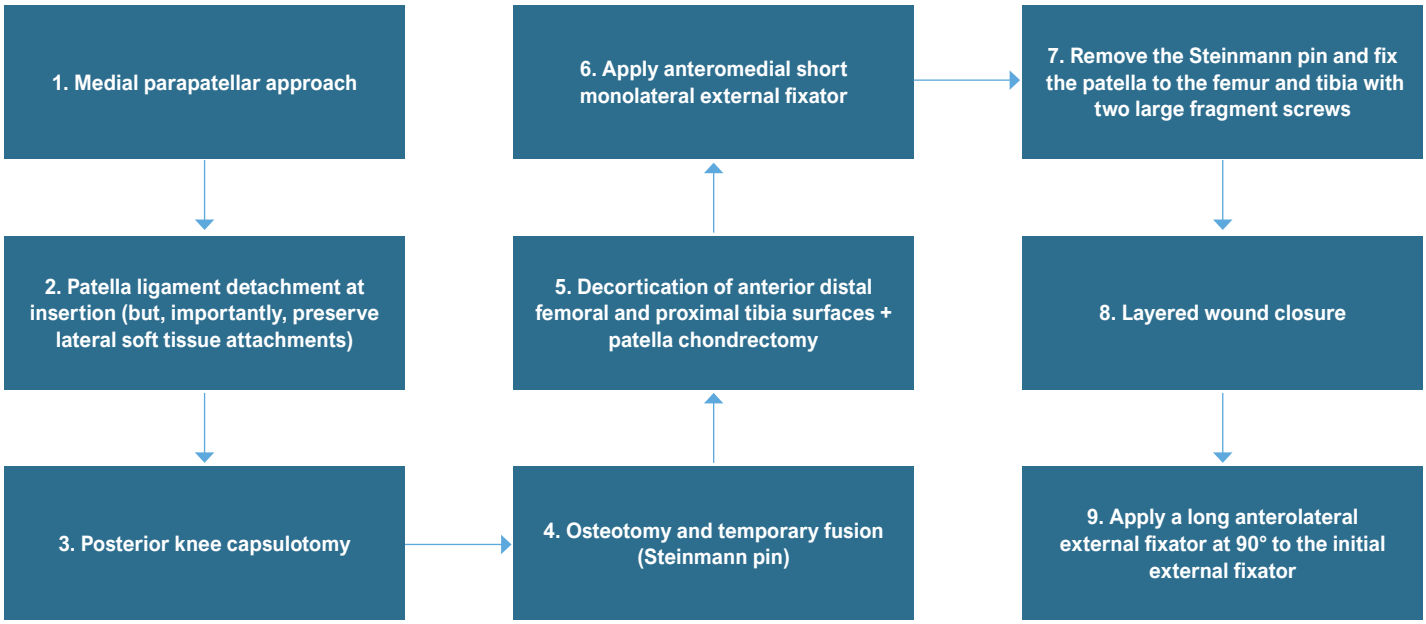

Figure 4. Flow diagram demonstrating knee arthrodesis with a vascularised patella autograft and a biplanar external fixator

Statistical analysis

Data were analysed by the Department of Biostatistics, Faculty of Health Sciences, University of the Free State, using SAS version 9.4 (SAS Institute Inc., USA). Categorical data were summarised using frequencies and percentages. Continuous variables were described using the mean and standard deviation or median and interquartile range when variables were normally distributed and skewed. Chi-square or Fischer's exact test (categorical data) was used to explore the association between the variables. A statistical significance was set at $p < 0.05$. Robust Poisson regression was used to model the relationship between outcome variables and explanatory variables. In a non-linear study such as this,

Table I: Patient study demographics and characteristics for knee arthrodesis (n = 8)

Patient	Sex	Age (years)	Comorbidities	Indication for knee arthrodesis	Previous management
1	M	61	Psoriasis, hypertension	Chronic osteomyelitis	Multiple debridement
2	M	64	Diabetes mellitus 2, hypothyroidism	Recurrent PJI	Failed revision arthroplasty
3	M	74	None	Recurrent PJI	Failed revision arthroplasty
4	F	42	HIV infection	Chronic extensor mechanism loss with tibia plateau malunion	Managed conservatively
5	M	73	None	Chronic osteomyelitis from an old gunshot injury	Multiple debridement
6	M	44	HIV infection	Post-tuberculous arthritis; multidrug resistant	TB chemotherapy
7	M	50	HIV infection	Post-tuberculous arthritis; multidrug resistant with draining sinus	TB chemotherapy
8	F	60	Hypertension	Recurrent PJI	Failed revision arthroplasty

M: male; F: female; PJI: periprosthetic joint infection; HIV: human immunodeficiency virus; TB: tuberculosis

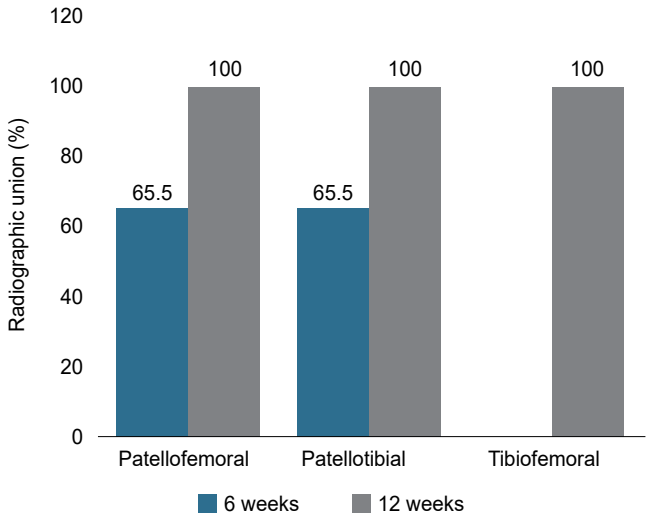

Figure 5. Radiographic union rate across bone contact surfaces at 6 weeks and 12 weeks post-surgery (n = 8)

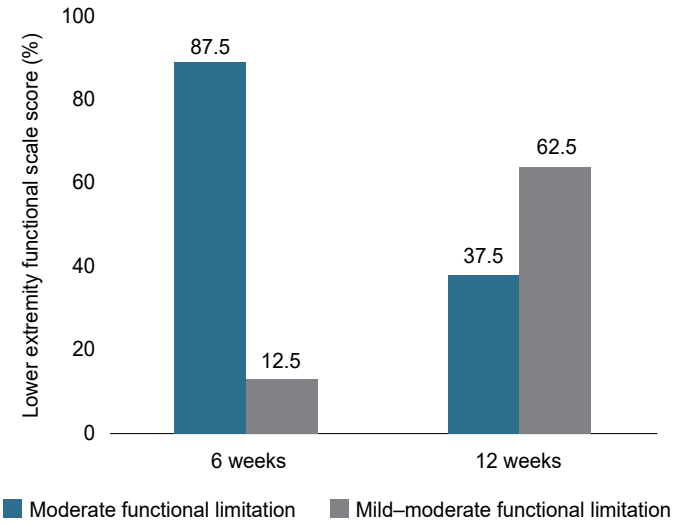

Figure 6. Changes in the Lower Extremity Functional Scale (LEFS) score between 6 weeks and 12 months post-surgery (n = 8)

robust Poisson regression can be used to make risk predictions by assigning statistical weights to each set of data, thereby minimising the effects of outlying variables and hence, modelling the relationship between our outcome variable (complication) and the explanatory variables (age, sex, indications, and bone union).

Results

Patient characteristics

Eight patients met the inclusion criteria and completed at least 12 months of follow-up visits. *Table I* illustrates the characteristics of the patients. The mean age at knee arthrodesis was 58.5 years (SD 12.2, range 42–74). Males made up 75% (n = 6), and females 25% (n = 2) of the study population.

Radiographic and clinical outcomes

Radiological union in the patellofemoral and patellotibial surfaces preceded that across the tibiofemoral joint with a 63% (n = 5) fusion rate at six weeks post-surgery. All eight knees demonstrated a 100% fusion rate across all bone contact surfaces by 12 weeks (*Figure 5*). The mean external fixation duration was 12.5 weeks (range 11–13). The changes in the LEFS scores are depicted in *Figure 6*, with a change in mean score from 32 (range 21–42) at six weeks to 46.25 (range 38–53) at the 12-month postoperative period. There is an improvement in the LEFS score at 12 months follow-up, with more patients reporting mild–moderate functional limitations compared to the six weeks follow-up period.

No residual infection was found post-arthrodesis. The overall infection rate was 13%, with a complication experienced in one patient. The patient developed pin tract sepsis, which resolved with pin tract care and antibiotics. Using statistical modelling, the robust Poisson regression model predicted a low risk of developing complications, irrespective of the patient's age, sex, indication for arthrodesis, and the presence of bone union (*Table II)*.

Discussion

This retrospective study aimed to describe the outcome of the inclusion of a vascularised patella autograft in knee arthrodesis fusion rate with a biplanar external fixator. Most patients (75%) in our study population who underwent knee arthrodesis were male, with a mean age at arthrodesis of 58.5 years (range 42–74). A recent database review of 203 knee arthrodeses found a similar age demographic at arthrodesis (mean age 61 years), but with more than half being female patients (52%).[29] In line with the literature, our findings also demonstrate that failed revision knee arthroplasty for PJI is the most common indication (38%) for knee arthrodesis in current practice.[2,30] Two patients in our study population had knee arthrodesis secondary to advanced multidrug resistance TB knee (*Figure 7*). Though the current move is towards TKA for post-tuberculous arthritis, there is currently no standardised protocol for its management.[31]

Knee arthrodesis performed for chronic osteomyelitis in our study included a patient with methicillin-resistant *Staphylococcus aureus* (MRSA) unresponsive to antibiotics and multiple debridements. The other knee arthrodesis for chronic osteomyelitis occurred consequent to a previous gunshot injury to the knee ten years before presentation to our unit with resistant polymicrobial organisms (*Staphylococcus epidermidis* and *Bacillus* species).

We found that 63% (n = 5) of patients had experienced bone union at the patellofemoral and patellotibial surfaces, compared to the tibiofemoral surface (n = 0) at the six weeks postoperative period, hence demonstrating that union across the vascularised patella surfaces precedes that across the tibiofemoral joint. At the 12-week radiographic assessment, 100% of the knees had fully united across all bony surfaces. We postulate that this observed early bony union resulted from the pedicled vascularised patella graft providing osteogenic, osteoconductive, and osteoinductive properties, which enhanced bone union. We also put forward that including the vascularised patella autograft increased the bone

Table II. Robust Poisson regression modelling (with complication as the dependent variable) demonstrates the risk of developing complications using this study technique

Variable	Parameter estimate	Standard error	p-values
Age	−0.03	0.03	0.481
Sex	−0.537	0.42	0.431
Indications	−0.43	0.32	0.407
Bone union	−0.09	0.35	0.839

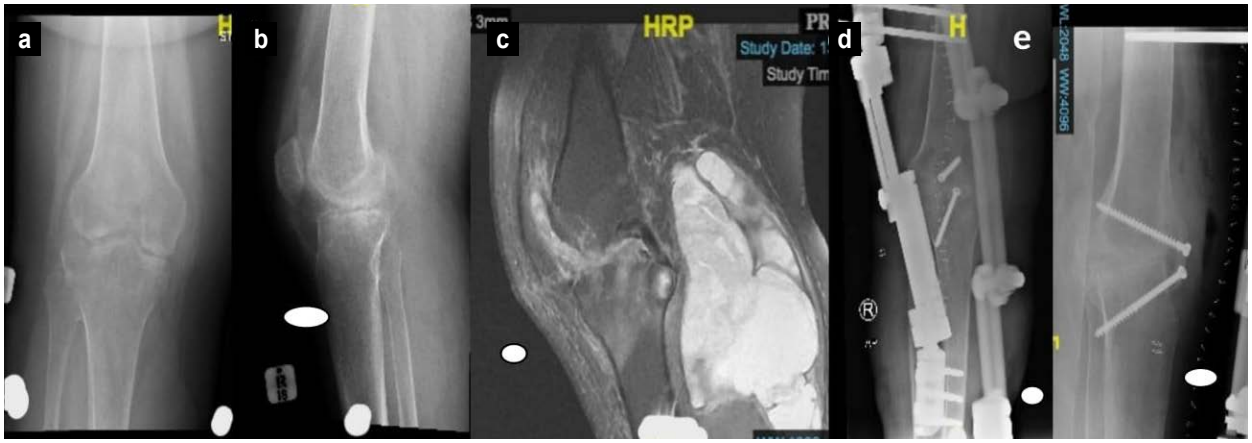

Figure 7. a and b) Anterior-posterior and lateral radiographic images of tuberculosis of the knee; c) T2 weighted sagittal magnetic resonance image view of the same patient; d and e) 6-weeks post-arthrodesis radiographic views

surface area for fusion, which has been identified as a key principle in knee arthrodesis.[30] The use of the patella as an autograft during knee arthrodesis has been reported in the literature, especially in the setting of bone defects to augment bony contact and facilitate healing. A patellectomy is usually done, and the patella is shaped out to fill the bony void during arthrodesis.[32-34] Tekin et al., however, integrated patella autograft into the fusion site by suturing the patella to the femoral condyles, using both the uniplanar and biplanar external fixator.[35] Their method differs from ours in that we used pedicled vascularised patella autograft, preserving the lateral-sided blood supply to the patella – a fact which appears to be unclear in their methodology. We also used two screws for graft compression and stability as opposed to their use of osseous sutures. The uniplanar external fixation for knee arthrodesis is less stable, with double the time to union compared to the biplanar external fixation. The biplanar external fixator and the circular frame have similar biomechanical rigidity and fusion rates. However, the biplanar external fixator has a shorter operative time and better ease of ambulation as no rings are in between the legs.[17,36,37] These key mechanobiological differences are in keeping with Glissan's age-old principles of arthrodesis, and they are pivotal to the success of our technique.[38]

Table III compares the outcome of our technique with some of the existing literature. The biplanar external fixation technique confers the advantage of a two-plane construct, which is more stable than a monolateral construct. Also, stability is directly related to union rate and infection clearance in arthrodesis, which may explain the better union rate observed in our study (100%) and in that by Corona et al. (100%), who also used biplanar external fixators in their arthrodesis in 2021.[17] These findings contrast with those by Corona et al. in 2013, who recorded a union rate of 81% and a 14.2% reinfection rate using a monolateral external fixator.[21] However, although Corona et al. achieved a similar fusion rate to ours, our technique led to a comparatively quicker mean time to union (3 months vs 5.2 months).[17]

The circular external fixator has the advantage of being able to simultaneously correct limb length discrepancies and avoid propagation of infection through the medullary canal. Nonetheless, its high complication rate includes prolonged duration of fixation, pin tract sepsis, fractures, and inconsistent rates of bone union.

Table III: Outcome of various knee arthrodesis techniques in literature

Study	Country (year)	n	Mean age (years)	Technique	Mean follow-up (months)	Fusion rate	Mean time to union (months)	Reinfection rate	Mean external fixation duration (months)	Complication rate
Mabry et al.[23]	USA (2007)	24	67	Intramedullary nail	13	96%	5.7	8.3%	N/A	38%
Corona et al.[21]	Spain (2013)	21	81	Monolateral external fixator	50.4	81%	–	14.2%	N/A	–
Brown et al.[40]	USA (2020)	17	65	Long intramedullary nail	50	94%	–	–	N/A	47%
Faure et al.[26]	France (2021)	31	67	Modular intramedullary nail	149	–	–	26.1%	N/A	26.1%
Corona et al.[17]	France (2021)	8	70	Biplanar external fixator	38.4	100%	5.2	0	6.1	–
Marwan et al.[39]	UK (2023)	14	63	Circular external fixator	84	92.9%	–	7.1%	13	92.7%
Present study	South Africa (2024)	8	58.5	Biplanar external fixator and vascularised patella autograft	12	100%	3	0	3.1	12.5%

USA: United States of America; UK: United Kingdom

The outcome of our technique appears to be superior to that done with circular frames, as reported by Marwan et al.[39] Though they had a longer follow-up period compared to our study, our fusion rate (100% vs 92.9%), reinfection rate (0 vs 7.1%), mean fixation duration (3.1 months vs 13 months), and complication rate (13% vs 92.7%) appear to be superior to theirs.[39]

The use of intramedullary nails has been widely shown to have a higher fusion rate compared to external fixation in knee arthrodesis. However, their propensity to seed infective microorganisms through the medullary canal partly accounts for their higher rates of persistent infection and septic non-union compared to external fixation. Therefore, our reinfection rate (0%) compared to the intramedullary nail knee arthrodesis by Mabry et al.[23] (8.3%) and Faure et al.[26] (26.1%) was certainly not surprising. Additionally, our complication rate (13%), compared with those of Mabry et al.[23] (38%), Faure et al.[26] (26.1%) and Brown et al.[40] (47%), showed a better short-term outcome, though with similar high fusion rates. We found a slight improvement in the mean LEFS score at the 12-month follow-up (mean 46.3) compared to the six-week mean score (mean 32). This was an improvement from 'moderate functional limitation' to 'mild-moderate functional limitation' with a reported normal population mean LEFS score of 69.[41] A similar study looked at 24 patients who had knee arthrodesis using a uniplanar external fixator and found a mean preoperative LEFS score of 39 which improved to a mean score of 64 postoperatively with an average of 5.4 months to fusion.[42] This contrasted with a post-knee arthrodesis gait analysis study in 15 participants, which found a mean LEFS score of 27.5 at 5.9 years mean follow-up.[43]

The retrospective single-centered nature of our study restricted us to pre-collected data in patient records. This, coupled with the small data size, and short-term follow-up, limits the ability to generalise our findings.

Conclusion

We found that the addition of a vascularised patella autograft resulted in a high union rate and an improved functional outcome in knee arthrodesis done with biplanar external fixation. We also found a high infection eradication rate and a low complication rate in these patients. These short-term findings should apply regardless of the surgeon's fixation method. However, knee arthrodesis should be avoided whenever possible because of its poor functional outcome. Further research aimed at long-term patient satisfaction, functional outcome, and quality of life is encouraged towards validating this body of evidence. We recommend a multicentre collaboration study, given the general rarity of this procedure.

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Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to the commencement of the study ethical approval was obtained from the following ethical review board: The Health Sciences Research Ethical Committee of the University of the Free State (reference no.: UFS-HSD2024/0039/3004).

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed written consent was not obtained from patients included in the study as the Ethical committee approved a waiver of informed consent as this is a retrospective study, with all data, clinical photographs and images adequately anonymised.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

KTL: study design, data capture, data analysis, manuscript preparation
LJE: study design, data review, manuscript revision, patient management, surgery
JFvdM: study conceptualisation, study design, data review, patient management, surgery

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