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Review Article

Current Concepts on Unicompartmental Knee Arthroplasty

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Abstract

Unicompartmental knee arthroplasty (UKA) represents a treatment option to address knee pain deriving from either the medial or lateral compartment of the knee. Compared to total knee arthroplasty, UKA offers the advantages of preserving native bone stock, offering less surgical exposure and risks, and better restoring native knee kinematics. The UKA is a specialized procedure that has its best outcomes in the hands of an experienced surgeon who performs UKA repeatedly and with proper patient selection. In this review, we discuss current concepts for both medial UKA and lateral UKA with regard to indications, isolated knee compartment osteoarthritis clinical and radiographic work-up, surgical approaches, and patient outcomes, as well as analyzing the differences between fixed-bearing and mobile-bearing implant designs.

Keywords: Fixed bearing, mobile bearing, osteoarthritis, partial knee arthroplasty, unicompartmental knee arthroplasty

Introduction

In 1968, Ahlback reported that 85% of knee osteoarthritis clinical cases had isolated medial compartment degeneration.[1] This landmark study led to the conceptualization of a unicompartmental knee arthroplasty (UKA), which became a reality in the 1970s with the introduction of the first UKA prostheses that resemble modern UKA implants. Compared to total knee arthroplasty (TKA), UKA offers the advantages of reduced surgical exposure, conservation of native bone, not sacrificing the cruciate ligaments, reduced perioperative morbidity, quicker postoperative recovery, more native knee kinematics, as well as improved cost benefit when performed in the ideal candidate. These qualities make UKA an attractive treatment option in patients with isolated compartment knee osteoarthritis.[2]

Since the 1970s, the UKA prosthesis design and its kinematics have undergone iterations and refinements with the goal of improved clinical outcomes.[1,2] Despite these advancements, there still remains uncertainty around both medial UKA and lateral UKA with regard to their indications, survivability, bearing design, and more. In this review, we aim to discuss these topics to provide clarity on the current concepts regarding UKA.

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Unicompartmental Knee Arthroplasty Indications

The indications for UKA have evolved over time since its introduction in the 1970s. Traditionally, the primary indications were isolated compartment osteoarthritis and spontaneous osteonecrosis of the isolated knee compartment.[2] However, initial high rates of complications narrowed the patient selection criteria as Kozinn and Scott in 1989 described UKA indications to be a patient with an age >60 years old, weight <180 pounds, no heavy labor occupation, least possible baseline pain, preoperative range of motion of 90° or more, <5° flexion contracture, and a coronal angular deformity <15°. Contraindications included osteoarthritis in the other knee compartments, inflammatory arthropathy, chondrocalcinosis, and cruciate ligament deficiency.[3] These traditional indications severely limited the selection criteria for UKA and were based on fixed-bearing (FB) implants only and were more instinctually based than evidence based.[4,5]

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With the improvements in clinical knowledge, surgical technique, and implant design over time, the current indications for UKA have expanded to consider UKA in patients with an increased body mass index (BMI), younger age, patellofemoral joint osteoarthritis, and anterior cruciate ligament (ACL) deficiency.[2,5]

A high BMI representing a strict contraindication to UKA was initially based on the fact that overweight patients subject an increased load on the UKA implant compared to normal weight patients, which predisposes to aseptic loosening.[2] Berend *et al*. found that a patient's BMI >32 kg/m^2 significantly predicted UKA failure and a need for revision in their retrospective study assessing 79 FB UKAs.[6] Bonutti *et al*. reported that patients undergoing FB UKA with a BMI >35 kg/m^2 had significantly more revisions than patients with a BMI <35 kg/m^2, and the mean time to revision was 33 months.[7] On the other hand, Hamilton *et al*. assessed UKA in patients <180 lbs to patients >180 lbs and discovered no significant difference in survival of the implant or functional outcome scores at 15-year follow-up.[8] Moreover, a meta-analysis by van der List *et al*. of 31 studies found no elevated risk for revision or substandard outcomes in patients with a BMI >30 kg/m^2.[9] With these results, a UKA has become considered an option by some surgeons in patients who do not strictly meet the traditional 180 lbs weight limit. However, these patients need to be consulted regarding the preoperative risks and varying research on the survivorship of UKAs in patients with a high BMI.[5]

Regarding patient age, the initial cutoff of <60 years old derives from the concept that younger patients are more active, which predisposes them to implant wear and loosening.[2] UKA in youthful patients often is challenging because this patient population often have high expectations to return to activity with their UKA. Thus, a successful UKA by normal standards may lead to dissatisfaction due to the reality–expectation mismatch and the potential need for revision.[5] There are data that both support and oppose the use of UKA in patients <60 years old. Parratte *et al*. assessed 35 FB medial UKAs in patients <50 years old and found a calculated 12-year survival rate of 80.6% and concluded that polyethylene wear remains a major concern in this patient population.[10] Registry joint data from Australia and Sweden also found a similar 81% survival rate at 7-year follow-up in patients who were <55 years old.[11,12] On the other hand, Walker *et al*. found that 93% of patients <60 years old were able to return to full activity with only a mere revision rate of 2.5% with a minimum follow-up of 2 years.[13] Furthermore, Greco *et al*. found a 96% survival rate at 6-year follow-up and an 86% survival rate at 10-year follow-up in patients <50 years old who received a medial UKA mobile-bearing (MB) implant.[14] A meta-analysis found that an age <60 years old was associated with a higher revision rate, but these patients had improved functional outcome scores compared to patients >60 years old.[9] Hamilton *et al*. found no significant difference in the survival rate at 15-year follow-up for UKAs when comparing patients <60 years old versus >60 years old.[8] Overall, recent data tend to support UKA in patients <60 years old; however, these patients need to be consulted preoperatively regarding expectations and the potential risk of a higher revision probability with substantial activity.[5]

Patellofemoral arthritis (PFA) was initially a contraindication due to the notion that a UKA should only be considered in patients with isolated unicompartmental arthritis. However, this contraindication has been challenged by recent evidence. For instance, Berend *et al*. reported UKA survivorship in patients with PFA (97.9%) versus patients without PFA (93.8%) via a Kaplan–Meier analysis and found no significant difference at 70-month follow-up.[15] Moreover, van der List *et al*. also found no significant difference in revision rate or functional outcome scores for UKA in patients with PFA compared to patients without PFA.[9] Further work has delineated that there may be a difference regarding UKA outcome with PFA between FB and MB implants. Hamilton *et al*. reported comparable functional outcome scores and revision rates at 10-year follow-up in patients with a UKA MB implant and PFA versus patients with UKA MB implant without PFA.[8] However, Berger *et al*. demonstrated that advancing PFA in UKA FB implants was the main reason for failure at 15-year follow-up.[16] Thus, literature is developing the support of UKA in PFA patients, but this literature is more promising regarding UKA MB implants compared to UKA FB implants.

Finally, ACL deficiency also has traditionally been thought of as a UKA contraindication due to the initial high failure rates in these select patients.[17] However, recent work has called this contraindication into question. Boissonneault *et al*. assessed UKA in ACL-deficient patients versus ACL-intact patients and at 5-year follow-up actually demonstrated improved functional outcome scores in the ACL-deficient group and only had one revision in this group due to arthritis development in the lateral compartment.[18] Moreover, van der List *et al*.'s meta-analysis found that ACL deficiency did not result in increased UKA revision rates.[9] Some authors had advocated for concomitant ACL reconstruction at the time of UKA in ACL-deficient knees. Mancuso *et al*. assessed concomitant ACL reconstruction with medial UKA and reported that the ACL reconstruction group had an increased rate of implant survival compared to isolated UKA in ACL-deficient knees.[19] With these results, ACL deficiency does not necessarily eliminate the indication for UKA for some surgeons.

Medial Unicompartmental Knee Arthroplasty and Lateral Unicompartmental Knee Arthroplasty

Medial UKA and lateral UKA both represent treatment options for medial and lateral compartment knee osteoarthritis, respectively. While the decision to perform either a medial UKA or lateral UKA is made prior to surgery, the knee compartments are assessed intraoperatively with direct visualization, and if

there is extensive arthritic change involved, one may convert to performing a TKA intraoperatively.[20]

Medial unicompartmental knee arthroplasty

An individual presenting with osteoarthritis isolated to the medial compartment often presents with anteromedial joint line knee pain. However, this finding is not necessary for diagnosis, as pain can occur in any knee compartment or in the knee diffusely because of reactive synovitis. These patients generally present with a varus deformity, which a surgeon should determine if it is correctable with valgus stress testing with the knee flexed at 20°. In addition, knee range of motion, mechanical knee alignment, ligament testing, gait analysis, and the presence of an effusion should all be assessed.[2]

The standard knee radiographs, including anteroposterior, lateral, merchant/sunrise, and Rosenberg views, should be ordered. The lateral view provides insight into ACL deficiency with anterior tibial subluxation or evidence of posterior tibial wear. The merchant view can provide insight into the arthritic change of the patellofemoral joint.[2] A special radiographic view that can be ordered is the valgus stress view. This view can determine if a varus deformity of a patient is correctable and also provide insight into if there is any lateral compartment arthritic change. To obtain a valgus stress view, a patient's knee is flexed to 20° and a valgus force is applied. If the lateral joint compartment sustains a length of >5 mm and the mechanical varus alignment corrects to within 3° of neutral, then a surgeon can indicate an UKA.[21] Advanced imaging such as computed tomography (CT) and magnetic resonance imaging (MRI) only have niche roles concerning UKA. A CT is generally only ordered to aid in robotic UKA, and MRI is useful in the diagnosis of spontaneous osteonecrosis of the knee in suspected patients, in which UKA can be a potential treatment option.[2]

For a medial UKA, the medial parapatellar approach is employed. The incision needs to be extensive enough to allow visualization of the medial compartment, but not too extensive, so the medial soft-tissue release can be kept to a minimal. The axial tibial bone cut should be just beneath the arthritic joint in parallel with the tibial slope to preserve as much native bone as possible. Moreover, the sagittal tibial bone cut should be made near the medial tibial spine to increase the tibial implant surface area without compromising the ACL's integrity. If there is a varus deformity, one should not overcorrect it, as this will cause increased stress on the medial soft tissues and excess joint contact forces in the lateral compartment. The femoral component needs to be positioned in the middle or marginally lateral on the medial femoral condyle to ensure proper articulation between the femoral and tibial UKA components. Finally, care during impaction and bone cuts should be taken to reduce the risk of iatrogenic fracture.[2]

The survivorship of medial UKAs has demonstrated success with survivorship rates generally around 90% or above in cohort studies with at least 10-year follow-up.[2] For example, Pandit *et al*. found a 94% survival rate at 10-year follow-up and a 91% survival rate at 15-year follow-up in their series of 1000 medial UKAs that were of a MB implant design.[22] Moreover, Lisowski *et al*. demonstrated a 90.6% survivorship rate at 15-year follow-up, and Foran *et al*. found a 90% survivorship rate at 20-year follow-up in medial UKAs of a FB implant design.[23,24] Further cohort studies have demonstrated similar rates ranging from a 90.6% to 96% survivorship rate at 10-year follow-up.[25-27]

There are a few potential complications of why a medial UKA may fail and need revision. In their systematic review, van der List *et al*. found the most common reasons for medial UKA failure were aseptic loosening (36%), osteoarthritis development (20%), pain that was unexplainable (11%), instability (6%), infection (5%), and polyethylene wear (4%). The causes for early failure defined as <5 years were aseptic loosening (25%), osteoarthritis development (20%), and dislocation of the bearing (17%). On the other hand, the causes for revisions at >5 years were osteoarthritis development (40%), aseptic loosening (29%), and wear of the polyethylene (10%).[28] Persistent pain that is unexplainable remains another cause for UKA failure and revision. It is estimated that persistent pain is a cause of UKA conversion to TKA in 1.6%–11% of patients.[25,28]

Lateral unicompartmental knee arthroplasty

Lateral UKA is less commonly performed compared to medial UKA and accounts for <1% of the amount of all knee arthroplasties performed.[29] Moreover, medial UKAs are performed ten times more often than lateral UKAs.[20] However, despite the infrequency of lateral UKA, the literature supports its use in the treatment of isolated lateral compartment osteoarthritis.

Similar to the patient presentation of medial compartment osteoarthritis, a patient with lateral compartment osteoarthritis typically has lateral joint line knee pain. Bert described a "one-finger test" in which the patient uses one finger to point to the lateral compartment of the knee to describe the location of his or her pain.[30] However, as discussed, the pain can be located diffusely throughout the knee because of reactive synovitis. In the setting of diffuse knee pain, the history, physical examination, and imaging work-up should be vigilant to ensure that the symptoms derive from the lateral compartment.[20] Essentially the same physical examination and radiographic work-up for the medial compartment discussed earlier occurs pertaining to the lateral compartment. However, the only difference being that the special radiographic image for the lateral compartment is now a varus stress view, as opposed to a valgus stress view.

A surgeon has a choice regarding the approach for a lateral UKA, which can either be done through a medial parapatellar approach or a lateral parapatellar approach. The medial parapatellar approach involves a medial parapatellar arthrotomy as is utilized in the traditional approach to TKA and medial UKA. This approach for lateral UKA offers the advantages of surgeon familiarity, extensibility if needed, and

the capability intraoperatively to convert to a TKA if needed. Moreover, the medial parapatellar approach allows for easy positioning of the tibial component in a little bit of internal rotation, which aids in recreating lateral knee biomechanics. Finally, if a revision is needed to convert a lateral UKA to a TKA in the future, the medial parapatellar approach is utilized. Therefore, an initial medial parapatellar approach avoids jeopardizing the blood supply to the patella, since the primary and revision approaches were both medial.[29]

Alternatively, the lateral parapatellar approach for lateral UKA offers the advantages of direct access to the lateral compartment, a reduced surgical incision, and no need for patellar eversion during the case. The challenges of this approach involve less familiarity leading to increased operative time, difficulty implanting the tibial component in slight internal rotation, and a potential risk of compromising the blood supply to the patella if a TKA revision is needed through a medial parapatellar approach.[29] Both approaches to lateral UKA can offer successful outcomes, as Edmiston *et al*. found comparable functional outcome scores in both approaches for lateral UKA. However, the authors did find a slightly increased range of motion in the lateral approach group, which the others speculated was due to the increased postoperative scarring from the increased extensive incision of the medial parapatellar approach group.[31]

The survivorship of lateral UKAs overall ranges from 72% to 100% according to Buzin *et al*.'s review, and it has improved since the surgery's introduction in the 1970s.[20] Smith *et al*.'s review further categorized lateral UKA survivorship by separating the various studies into FB designs versus MB designs. For lateral UKA MB designs, the survivorship ranged from 82.8% to 98% over a range of 1–9-year follow-up. For the lateral UKA FB designs, the survivorship ranged from 74.5% to 100% over a range of 1–16-year follow-up.[29]

Regarding complications, Ernstbrunner *et al*. performed a systematic review, and the authors found that the most common cause of lateral UKA failure was osteoarthritis development in 30% and aseptic loosening in 22%. Other causes of failure ranged from instability, persistent pain, infection, wear of the polyethylene, and dislocation of the polyethylene bearing. The most frequent cause of early failure was dislocation of the bearing, whereas osteoarthritis development was the most frequent cause of failure later on. Moreover, the authors also found that dislocation of the bearing was the most frequent cause of failure when a MB design was utilized.[32]

Polyethylene-bearing dislocation represents a unique complication of MB implants with a predilection for specifically lateral UKA MB implants due to how the knee kinematics of the lateral compartment work. In the lateral compartment, there is a greater translation of the lateral condyle on the lateral tibia plateau throughout the range of motion to account for femoral rollback and the screw-home mechanism. With this increased translation, there is an increased risk for polyethylene dislocation, especially in MB implant designs.[20,29] For instance, Gunther *et al*. demonstrated a 10% complication rate for polyethylene-bearing dislocation alone at 5-year follow-up, while Walker *et al*. further demonstrated a polyethylene dislocation rate of 8.5% alone at 5-year follow-up.[33,34] Moreover, Burger *et al*. conducted a systematic review and incorporated 28 studies (19 FB implant studies and 9 MB implant studies) for a total of 2265 UKAs. They found that lateral UKA MB designs had a significantly higher revision rate than FB designs, but the clinical scores were similar between the two designs.[35]

Fixed Bearing versus Mobile Bearing

As referenced throughout this review, the two main UKA implant designs include FB and MB. With FB implants, the metal tibial component and the polyethylene inlay are fixated together, only allowing for micromotion throughout the knee range of motion. On the other hand, with MB implants, there is mobility with the polyethylene insert as it is mobile on the metal tibial component, allowing for rotation of the tibial polyethylene during knee range of motion to better mimic natural knee kinematics.[36]

UKA was initially introduced as a FB implant, which was cemented with an all-polyethylene tibial component. However, because of substantial polyethylene wear of this design, a metal-backed polyethylene tibial design was implemented for modern FB implants.[5] The advantages of the FB design include that it is technically less challenging to implant due to its flat tibial surface and that there is a little risk of dislocation of the bearing.[36-39] The disadvantages include that a FB implant is less conforming in knee flexion, which can result in increased loading on specific locations of the polyethylene surface to cause delamination and deformation.[36,40,41]

The MB implant was inaugurated in 1986 by Goodfellow *et al*. to address the polyethylene wear complication associated with FB designs.[42] The MB implant was designed to replicate inherent knee kinematics in addition to permitting an increased amount of conformity among the articular surfaces. This design offers the advantages of improved native knee motion, minimized contact stress, and hence, minimized wear of the polyethylene.[37,38,43,44] The disadvantages include that a MB implant is technically demanding to implant, and there is a requirement of precise implant alignment and ligamentous balancing or else the complications of bearing dislocation and impingement causing polyethylene wear will ensue.[45,46] Due to heightened stress placed on the ligaments, insufficient ACLs and medial collateral ligaments can occur leading to an unstable knee. Thus, a functioning ACL stands as a prerequisite to consider a UKA MB implant.[5]

The debate of which UKA implant design has superior outcomes still remains unclear. Migliorini *et al*. performed a meta-analysis and included 25 studies and had a cumulative UKA patient sample size of 4696 patients with a mean follow-up of 45.8 months (range, 3–180 months). In their analysis, the authors found no significant difference in

range of motion (P = 0.05), various functional outcome scores (P > 0.05), revision rate (P = 0.2), osteoarthritis progression (P = 0.2), aseptic loosening (P = 0.9), deep infections (P = 0.99), or fractures (P = 0.6). The authors concluded that their meta-analysis did not demonstrate one UKA implant design having better outcomes over the other.[36]

Zhang *et al*. also performed a meta-analysis and included 17 studies with a cumulative 2612 patients with an average follow-up ranging from 7 months to 17.2 years. The authors found no significant difference in various functional outcome scores, radiological outcomes, or revision rates between the implant designs (P > 0.05). Moreover, there was no significant difference regarding osteoarthritis development in the contralateral compartment (P = 0.33), continuing pain (P = 0.84), or aseptic loosening (P = 0.45). However, there was a significant difference in the occurrence of polyethylene wear and dislocation of the bearing, with polyethylene wear occurring more often in the FB implant at an average of 8.3 years (P = 0.02) and bearing dislocation occurring more often in the MB implant at an average of 0.6 years (P = 0.03). The authors concluded that one UKA implant design did not have superior outcomes compared to the other, but the two implants have dissimilarities in the mechanism of failure and the timing of this failure.[47]

Peersman *et al*. also conducted a systematic review and meta-analysis including 44 articles and an aggregate of 9463 UKAs, with 4330 patients having undergone a FB implant and 5133 patients having undergone a MB implant. The average follow-up was 8.7 years for the FB implant and 5.9 years for the MB implant. The authors found that the revision rate was 0.90 (95% CI: 0.65–1.21) for the FB implants and 1.51 (95% CI: 1.11–1.93) for the MB implants per 100 component years, which was not substantially different. Peersman *et al*. concluded that there were no differences among the UKA designs with regard to revision rate, and surgeons can proceed with personal preference when selecting an UKA design.[48]

Conclusion

The traditional indications for UKA have been challenged by recent literature, as there is evidence to consider UKA in patients that previously would have been contraindicated for the procedure. More specifically, there is evidence emerging to perform UKA in patients with an elevated BMI, a younger age, presence of PFA, and ACL deficiency. With proper patient selection, both medial UKA and lateral UKA have successful survivorship and complication rates. FB and MB UKA implant designs both represent viable UKA options, each with their own subset of advantages and disadvantages.

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Conflicts of interest

There are no conflicts of interest.

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Original Article

The Oswestry-Bristol Classification of Trochlear Dysplasia: Displays Reliability Only for Normal or Severe Dysplasia in the Skeletally Immature

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Abstract

Purpose: Trochlear dysplasia (TD) is one of the several factors that predispose to recurrent instability and long-term morbidity. Subclassification can aid in risk stratification with surgery and comparing case-cohort outcomes. The inter- and intra-observer agreement of the Oswestry-Bristol Classification (OBC) for TD has previously been demonstrated in adults but not in children. We aim to assess the inter- and intra-observer reliability of the OBC in skeletally immature patients. **Methodology:** This was a retrospective review of magnetic resonance imaging scans performed in children presenting with patellofemoral instability or recurrent dislocation. A total of 34 scans were graded according to the OBC by seven orthopedic surgeons in two rounds 6 weeks apart. All reviewers were blinded and scans were randomized. The observations from both rounds were compared for inter- and intra-rater reliability. **Results:** First-round observations showed low–moderate agreement between raters (mean kappa = 0.39). Second-round observations showed moderate agreement (mean kappa = 0.42). However, subanalysis using S statistics found good reliability. There was no statistically significant difference between the two agreement values. Category-wise agreement was excellent for normal trochlea (OBC 1) and moderate to good for severe dysplasia (OBC 4). Reliability was low moderate to poor for mild (OBC 2) or moderate (OBC 3) dysplasia. Intra-observer reliability was good to excellent (mean kappa = 0.73). **Conclusion:** The OBC is reliable in categorizing a normal or severely dysplastic trochlear in skeletally immature children although it fails to adequately differentiate between mild and moderate dysplasia.

Keywords: Classification system, pediatric knee, patellofemoral instability, trochlear dysplasia

Introduction

Patellofemoral instability (PFI) is common, with the annual incidence of acute dislocations being 29–43/100,000.[1] Factors contributing to recurrent instability of the patellofemoral joint include trochlear dysplasia (TD), patella alta, torsional malalignment, genu valgum, foot pronation, and ligamentous laxity.[2] The interaction of these factors is complicated in all age groups, but the presence of TD in patients with open physes increases the risk of recurrent instability up to 69%, especially in children who participate in high-level sports.[3] Persisting instability leads to increased morbidity and ongoing articular damage predisposing to early osteoarthritis.[4]

TD in PFI is present in up to 96% of cases.[5] The first classification scheme to assess TD was introduced by Dejour *et al*., 1998.[6] Originally a three-grade classification, it was later modified in 1998 to four grades based on the morphological appearance on true lateral radiographs and axial computed tomography (CT) scans.[7] In view of the cartilaginous anatomy of the distal femur in the skeletally immature, the use of magnetic resonance imaging (MRI) may be superior to CT although the reliability is poor.[8-11]

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The recently formulated Oswestry-Bristol classification (OBC), based on MRI morphology, is divided into four grades – normal, mild, moderate, and severe, corresponding to the normal, shallow, flat, and convex trochlea.[12] Two studies have evaluated reliability in adults demonstrating good inter- and intra-observer agreement.[12,13] A treatment algorithm based on the above classification has also been advocated by the authors in the adult population.[12] The aim of this study is to assess the inter- and intra-observer agreement of OBC in a skeletally immature population in classifying TD on MRI.

Methodology

The study was undertaken after institutional review board approval (approval code – 310260). A retrospective review of consecutive axial MRI scans of knees of children presenting with first-time or recurrent patellar dislocation was performed. Included patients had available MRI imaging and were skeletally immature with open distal femoral and proximal tibial physes at the time of acquisition, without any previous surgery of the knee. Scans were acquired in 1.5 Tesla or higher strength machines and had axial cuts available. A single axial T2 MRI section was selected for review according to the method described by Carrillon *et al*.[14] and also used by Stepanovich *et al*.,[11] namely the first axial cut of the distal femur, beginning proximally, with complete cartilage cover over the trochlea.

The sample size was calculated according to the confidence interval method described by Rotondi and Donner which was estimated to be a minimum of 18 for alpha error of 0.05 and 80% power of the study.[15] A total of 34 MRI scans were graded for TD by seven orthopedic surgeons with a subspecialist interest in knee surgery (four consultants and three senior fellows) as normal, mild, moderate, or severe as per the OBC [Figure 1]. All reviewers were blinded to patient details and received MRI scans in the form of a 34-slide PowerPoint presentation for evaluation along with a pamphlet describing the OBC.[12] The same scans were then randomized and given back to the same group of surgeons 6 weeks later for repeat analysis. The observations from both rounds were collected and compared for inter-rater and intra-rater reliability.

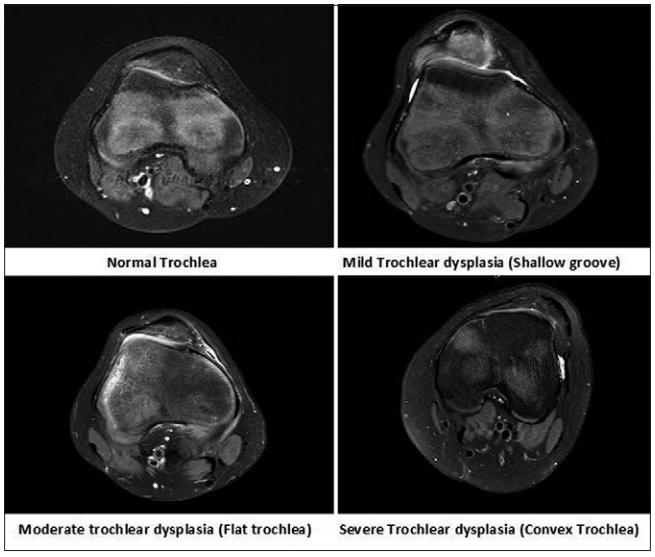

Figure 1: Oswestry-Bristol classification representative axial magnetic resonance imaging images with 100% agreement among all seven oibservers

Statistical analysis

For inter-rater reliability, Fleiss' generalization of the Cohen kappa statistics was used.[16,17] To circumvent inherent paradoxes in kappa statistics, analysis was also done using S statistics.[18] We also calculated the S* statistics (using linear weights) owing to the ordinal nature of the grading system. Kappa values of 0–0.20 were taken to be indicative of poor agreement, 0.21–0.40 as below moderate, 0.41–0.60 as moderate, 0.61–0.80 as good agreement, and 0.81–1.0 as excellent agreement. The intra-rater reliability was calculated as a mean value of agreements of individual observers (calculated using weighted Cohen kappa). All statistical analysis was done using R software (version 4.1.1, Vienna, Austria).

Results

The dataset was first analyzed for the frequency of each category. When all observations were combined, it was found that 6.91% of scans were categorized as "normal," 33.8% were categorized as "mild," 35.4% were categorized as "moderate," and 23.5% were categorized as "severe" TD [Figure 2].

Kappa statistics and S statistics were calculated for both sets of observations. The observations from the first set showed below moderate agreement between the seven raters with a Fleiss kappa value of 0.39 (95% confidence intervals: 0.34–0.44) whereas that from the second set recorded 6 weeks later showed moderate agreement with a kappa value at 0.42 (95% confidence intervals: 0.38–0.46) [Table 1]. There was no statistically significant difference between the two agreement values. The agreement levels calculated using S statistics are also shown in Table 1.

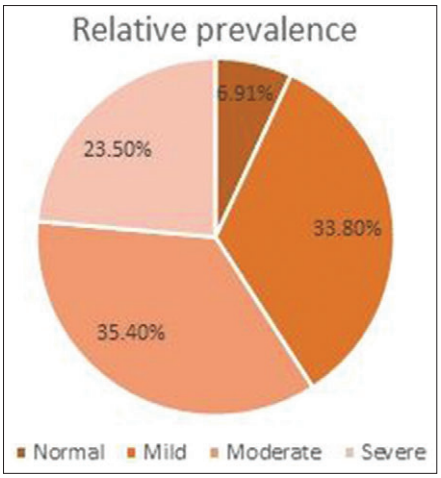

Figure 2: Category-wise prevalence of trochlear dysplasia as classified by the observers (showing mean of both observations)

Category-wise agreement was also measured. Raters were able to agree with "excellent" reliability while classifying as normal trochlea (OBC 1) and moderate-to-good reliability while classifying as severe dysplasia (OBC 4). The reliability was below moderate to poor while classifying as mild (OBC 2) or moderate (OBC 3) TD [Table 2].

The mean intra-observer reliability was "good" for this classification, with all raters showing "good" to "excellent" agreement. The mean kappa value was 0.73 (95% confidence intervals: −0.81–0.65) [Figure 3].

Discussion

Trochlea dysplasia as an isolated entity is poorly understood but is thought to be one of the main contributing factors to instability in both pediatric and adult populations. The majority of patients with PFI will have a dysplastic trochlea and will develop late sequelae of osteoarthritis.[5,19] Surgical failure rates of isolated patellofemoral ligament reconstruction have been unsatisfactory in children with severe dysplasia as compared to those with relatively normal trochlear anatomy.[20] Both pediatric and adult patients with high-grade dysplasia demonstrate persistently positive apprehension test and instability following medial patellofemoral ligament (MPFL) reconstruction.[21,22] Although the use of isolated MPFL in the presence of trochlea dysplasia is still favored by most due to the risk of growth disturbance in the skeletally immature, understanding clearly the degree of dysplasia allows comparison of study outcomes. A reproducible grading of trochlea dysplasia would be useful for clinical trial planning.

Assessment of trochlea dysplasia in the skeletally immature is useful for stratification of the risk of both recurrent instability and in particular the possible failure of isolated MPFL reconstruction.

Table 1: Inter-observer reliability - Fleiss kappa and S-statistics for both rounds of observations

Statistical test	95% CI	
	Round 1 observations	Round 2 observations
Fleiss kappa	0.39 (0.34–0.44)	0.42 (0.38–0.46)
S-statistics (linear weights)	0.65 (0.60–0.70)	0.66 (0.56–0.76)

CI: Confidence interval

Table 2: Category-wise reliability measures for both rounds of observations

Categories	Category-wise kappa values (95% CI)	
	Round 1 observations	Round 2 observations
Normal	0.72 (0.62–0.82)	0.83 (0.74–0.92)
Mild	0.33 (0.27–0.39)	0.23 (0.19–0.27)
Moderate	0.23 (0.18–0.28)	0.17 (0.14–0.20)
Severe	0.67 (0.60–0.74)	0.50 (0.46–0.54)

CI: Confidence interval

This study has demonstrated the reliability of the MRI-based OBC for grading the severity of TD in the skeletally immature; however, accurate quantification and gradation of trochlear morphology in the skeletally immature population still remains challenging. The most commonly used classification scheme is the Dejour classification which was originally based on lateral radiographs and axial CT.[6,7] Several studies have shown this classification scheme to be unreliable, with poor inter- and intra-observer reliability on multiple imaging modalities.[8,10,23] Stepanovich *et al*. studied the utility of Dejour classification in the pediatric population and found it to be unreliable on both radiographs and MRI.[11] They also studied other objective parameters for diagnosing TD, namely trochlear depth index[24] and lateral trochlear inclination,[14] and introduced the medial condyle trochlear offset. These indices are more objective, representing measurements rather than observations, with high levels of sensitivity and specificity;[11] however, they lack simplicity and are time-consuming making them difficult to use in clinical practice. In addition to the lack of cartilage assessment on radiographic modalities, there are also concerns regarding exposure to radiation with the use of CT or plane radiographs in the assessment and surveillance of TD in children. Ultrasonography as a safer means of TD assessment was examined by Nietosvaara, who showed that the morphology of subchondral bone was not representative of the overlying cartilaginous trochlea, the shape of which was changed little from birth to skeletal maturity.[25] Similarly, articular cartilage contour is more representative of trochlear shape than the subchondral bone, and MRI is more useful in the assessment of trochlear morphology in the skeletally immature.[26]

Given that articular cartilage represents the largest anatomical structure in the growing knee (peaking in volume at 9–11 in females and 11 in males),[26] these findings may indicate the superiority of MRI-based classification systems for quantifying TD in children. The OBC is one such recently introduced scheme for classifying trochlear morphology according to severity on axial MRI images.[12] Two previous studies have reported on the reliability of this classification in the adult population. Sharma *et al*. have shown fair-to-good

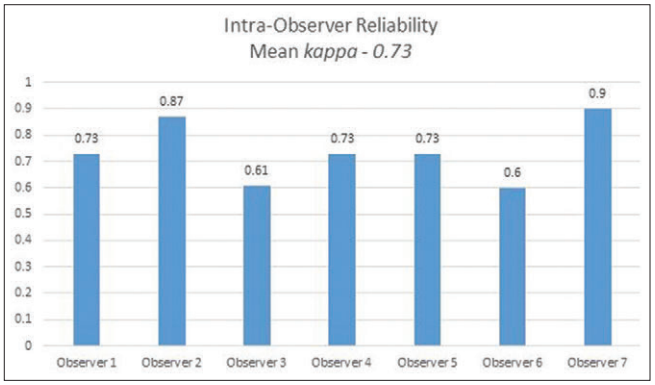

Figure 3: Intra-observer reliability. Mean intra-observer reliability being 0.73 (95% confidence intervals: 0.65–0.81)

inter-observer agreement and good-to-excellent intra-observer agreement with OBC.[12] They also compared the reliability with Dejour classification and found that the OBC is significantly more reliable than on both CT and MRI. Konrads *et al*. also reported excellent inter- and intra-observer agreement while using OBC with a mean kappa of 0.78.[13]

Our study is the first to analyze the reliability of the OBC in children, with a large sample size and with more observers to increase accuracy. Although observers classified normal and severely dysplastic trochlear with excellent reliability, they agreed poorly while classifying into the mild and moderate categories of the OBC. This may be attributed to the lack of an objective radiological parameter or measurement to differentiate between a shallow and flat trochlea in the OBC. Other studies have found similar difficulties in differentiating between the "normal" and "mild" categories.[13] Another possible explanation could be the difficulty in interpreting cartilage on routine rather than cartilage-specific MRI sequences.[27] The clinical application of the mild-to-moderate dysplasia groups on the OBC in children is currently unknown and is rarely used to guide surgical treatment. Simplifying the classification into three groups would improve the reliability without affecting the relevance to clinical practice within the pediatric cohort. Furthermore, surgical reconstruction of TD is rarely undertaken in pediatric patients as in adults due to an open physis and associated complications and has been historically contraindicated in children.[28,29] However, there are reports of trochleoplasty in the adolescent population with open physis with satisfactory results, albeit with a short follow-up.[30] A reliable classification system can aid in developing a management algorithm for pediatric TD with recurrent instability, which is a future research priority.

The limitation of this study is in not comparing the reliability of the OBC with other classification systems for the same set of observers to objectively prove its superiority.

Conclusion

The OBC is reliable in categorizing TD severity in skeletally immature patients, although it is less reliable in distinguishing between mild and moderate categories. Simplicity of application, along with reliability, may make this classification a useful practical tool for those managing the condition and for effective patient counseling.

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Conflicts of interest

There are no conflicts of interest.

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Original Article

Correlation between Clinical Examination, Magnetic Resonance Imaging, and Arthroscopy in Meniscal Injuries of the Knee: A Prospective Cohort Study

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Abstract

Purpose: In comparison to magnetic resonance imaging (MRI) imaging, this study compares the diagnostic efficacy of meniscal injury with clinical examination tests such the McMurray's test, Thessaly test, and joint line tenderness. **Methodology:** Two hundred and fifteen patients having a history of knee injuries with symptoms such as pain, instability, and locking were studied from June 2020 to June 2022 at our institution, for a 2-year period. **Results:** The sensitivity and specificity of McMurray's test for medial meniscus were 84% and 84.21%, respectively. The sensitivity and specificity for medial joint line tenderness were 88.15% and 55.55%, respectively. Thessaly's test for the medial meniscus was 92.10% sensitive and 88.8% specific. The sensitivity and specificity of MRI for medial meniscal injury were 94.87% and 93.75%, respectively. McMurray's test for lateral meniscus had a sensitivity of 84.44% and a specificity of 76.92%. Lateral joint line tenderness for lateral meniscus had a sensitivity of 86.95% and a specificity of 66.66%. The sensitivity and specificity of Thessaly's test for lateral meniscus were 93.33% and 84.61%, respectively. MRI revealed a sensitivity of 93.75% and a specificity of 90% for lateral meniscus injuries. **Conclusion:** Even though MRI is a precise and noninvasive method for detecting meniscal injuries, a thorough clinical examination by a skilled physician has the same diagnostic power as MRI to rule out meniscal injuries. In contrast to previous tests, the Thessaly test can be used as a useful tool to detect meniscal injuries, as we discovered in our study.

Keywords: Joint line tenderness, McMurray's test, meniscal injuries, Thessaly's test

Introduction

Greek term meniskos, which means "crescent," the diminutive of mene, which means "moon," is where the Latin word "meniscus" originates.[1] Each knee has two semilunar, fibrocartilaginous discs called menisci that are situated between the medial and lateral articular surfaces of the femur and tibia.[2] The menisci are particularly crucial for maintaining the cartilage and preventing the onset of degenerative osteoarthritis because they can endure a variety of pressures, including shear, tension, and compression.[3-5] The wedge-shaped nature of the meniscal tissue makes it particularly effective in stabilizing the curved femoral condyles upon contact with the flat tibial plateau.[6]

Meniscal damage typically happens in two separate circumstances. The first is acute meniscal tears, which are seen in young, active people and result from vehicular accidents, falls, and sports-related contact injuries. These tears are caused by a torsional and compressive load put on the knee while the knee is extended from a flexed position. The second one being degenerative meniscal tears which more commonly occurs in older people.[7-9] Meniscal injuries are also commonly associated with anterior cruciate ligament injuries.[10]

History is crucial in determining the diagnosis of meniscal tears.[11] Even though joint pain and a history of popping, catching, locking, or buckling are suggestive of meniscal tears, this information is still not very specific. The frequently used physical examination for the diagnosis of meniscal

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tears such as joint line tenderness, the McMurray's test, and the more recent Thessaly's test have shown inconsistent sensitivity and specificity values in the studies.[12] These tests are known to have a low specificity and sensitivity in various knee diseases, such as anterior cruciate ligament (ACL) ruptures.[13] Plain radiographs are often done routinely to rule out any osseous injuries. With a specificity and sensitivity for identifying meniscal tears as good as 93% and 88%, respectively, and the additional benefit of being noninvasive and using nonionized radiation, magnetic resonance imaging (MRI) remains the imaging method of choice. Our study compares the diagnostic efficacy of three widely used clinical tests – the McMurray's test, Thessaly test, and joint line tenderness [Figure 1] – with results from a knee arthroscopy. According to our theory, MRI diagnosis is more precise than clinical diagnosis.

Methodology

Following approval by the institutional ethics committee, 215 patients with a history of knee injuries and symptoms such as pain, instability, and locking were studied at our hospital for 2 years, from June 2020 to June 2022.

Inclusion criteria included adult patients with a history of injury to knee with symptoms such as knee pain, instability, and locking. Patients with prior surgery of index knee; patients having fractures or bony injuries, such Segond fracture/tibial spine avulsion fracture, collateral injuries, degenerative tears, and features of arthritis in plain radiographs; cases having equivocal clinical findings and/or inconclusive MRI scan; and patients being treated nonoperatively were excluded from the study [Figure 2].

After taking a full medical history, patients underwent a clinical examination by a senior orthopedic surgeon with more than 20 years of expertise using the McMurray's, Thessaly's, and medial and lateral joint line tenderness tests to look for meniscal lesions. All clinical examinations were performed once the joint haematoma was subsided; MR imaging was done at least 3 weeks later from the time of injury.

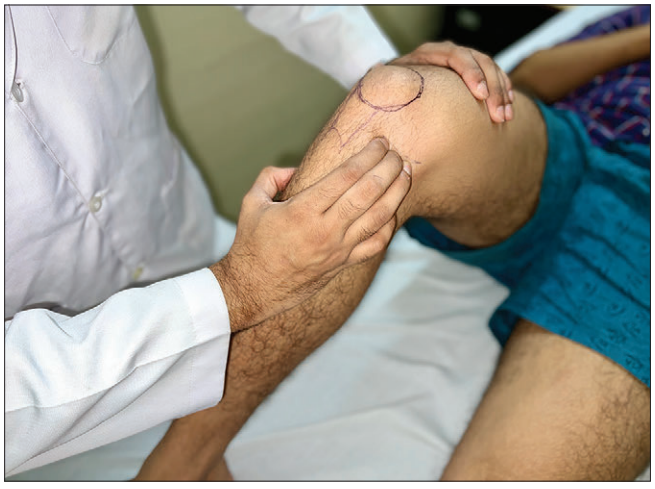

Figure 1: Right knee joint line tenderness being elicited

McMurray's test

The medial meniscus was tested by fully externally rotating the tibia on the femur [Figure 3] or fully internally rotating the tibia on the femur [Figure 4] while the lateral meniscus was tested. To gradually axial load increasingly posterior parts of the menisci, the identical exercises were carried out with progressively greater degrees of knee flexion. There is no valgus or varus tension. The joint line is felt both medially and laterally during the motion. A thud or click that occasionally can be heard but is always felt is thought to be a positive test result.[14]

Thessaly's test

The subject stands on one leg while being supported by the examiner, who holds both of their palms. The patient now extends his knee to a 20° flexion while rotating his body and thigh in both internal and external directions. Thessaly test being performed for right knee by rotating the body internally in flexed knee position. When rotating the thigh, the patient will feel pain over the medial or lateral [Figures 5 and 6] joint line, which indicates a meniscal tear.[12]

After receiving a clinical evaluation, the patient had an MRI of the index knee. A 1.5 Tesla scanner was used to conduct the MRI. Using the Lotysch *et al*.[15] grading system, two radiologists who were unaware of any clinical symptoms separately reported the MRI image. A definite Grade 3 aberrant signal intensity reaching the articular surface led to the diagnosis of a meniscal tear. Meniscus tears in Grades 1 and 2 that did not extend to the articular surface were not considered. Overall, both inter-observer and intra-observer agreements for the parameters used to perform the MRI assessment were high ($P < 0.01$).

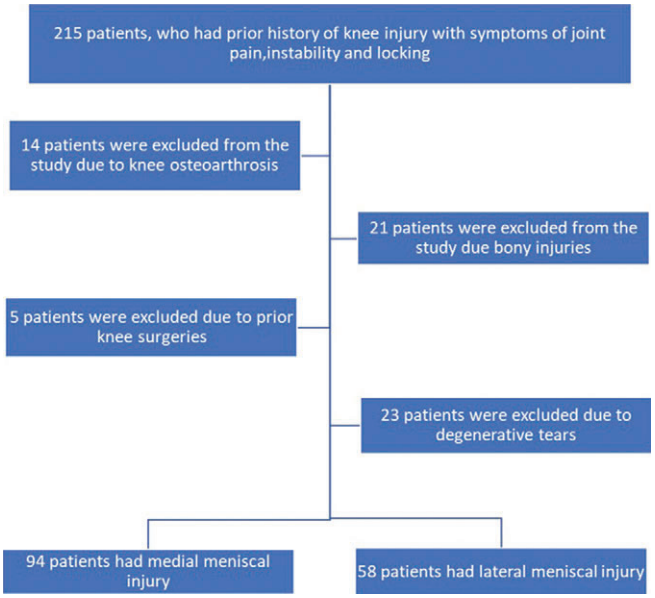

Figure 2: Flowchart depicting inclusion and exclusion criteria for the study

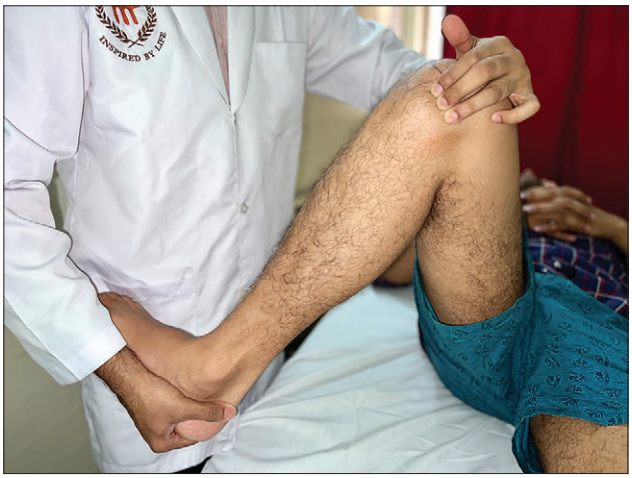

Figure 3: Right knee McMurray's test being performed for medial meniscus

Figure 4: Right knee McMurray's test being performed for lateral meniscus

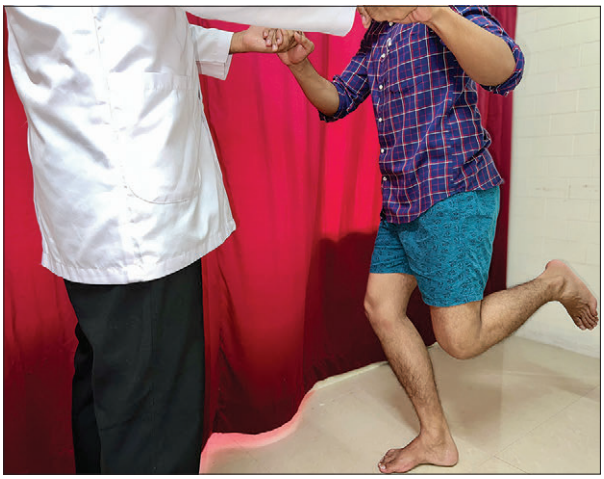

Figure 5: Thessaly test being performed for right knee by rotating the body externally in flexed knee position

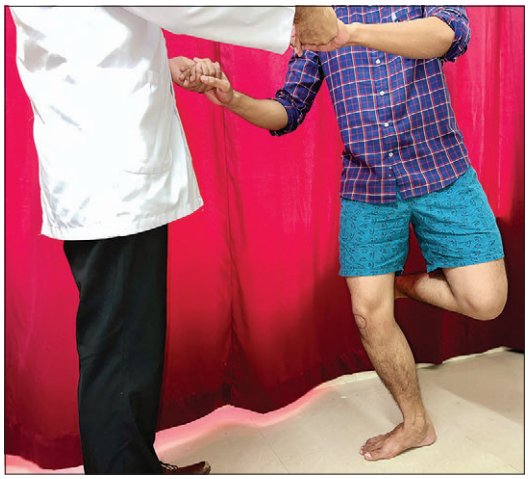

Figure 6: Thessaly test being performed for right knee by rotating the body internally in flexed knee position

Knee arthroscopy was performed on each patient who was a part of the study. An orthopedic surgeon with more than 10 years of expertise in knee arthroscopic surgery performed all arthroscopies. The usual anteromedial and lateral ports were employed. The procedure was carried out while under regional anesthetic. A minimum of 25 days and a maximum of 50 days passed between the time of injury and arthroscopy, with an average of 40 days. The results of arthroscopy, MRI, and clinical examinations were recorded and compared. Regarding arthroscopy as the gold standard, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of clinical examination findings and MRI were evaluated.

Results

Medial meniscus injuries

Ninety-four patients had a clinical detection of a possible medial meniscus injury, out of which 68 were males and 26 were females. Forty subjects sustained injury due to sports injuries. Thirty-four of them had met with a road traffic accident and 20 subjects gave a history of trivial fall. Patients ranged from 21 years to 50 years of age, with 78% (73/94) of them being 35 years old and younger. Forty-eight patients underwent partial meniscectomy and 26 underwent meniscal repair and 20 had intact medial meniscus on diagnostic arthroscopy. Out of 94 patients, 24 patients had associated ACL injuries [Table 1].

Sixty-three patients had a true-positive McMurray's test (diagnosis confirmed at arthroscopy). Twelve patients had false-negative results (negative clinical test with meniscal tear verified during arthroscopy) while three patients had false-positive results (positive clinical examination with no meniscal tears at arthroscopy). Sixteen patients had true-negative results. The sensitivity and specificity of McMurray's test were both 84.21% [Table 2].

In 67 cases, joint line tenderness was true positive. At the arthroscopy, the diagnosis was confirmed. Joint line tenderness

tests on 8 patients resulted in false-positive results (positive clinical examination with no meniscal tears at arthroscopy) and false-negative results (negative clinical test with meniscal tear confirmed at arthroscopy). Ten patients had true-negative results. Joint line tenderness was 88.15% sensitive and 55.55% specific [Table 2].

Seventy patients had a true-positive Thessaly test (arthroscopy verified the diagnosis). Six patients had false-negative tests (negative clinical test with meniscal tear confirmed during arthroscopy), while two patients had false-positive tests (positive clinical examination with no meniscal tears during arthroscopy). Sixteen patients had true-negative results. Thessaly test's specificity was 88.88%, while its sensitivity was 92.10% [Table 2].

MRI analysis revealed 16 true-negative, 70 true-positive, 6 false-negative, and 2 false-positive patients. MRI has a 93.75% specificity and a 94.87% sensitivity [Table 2].

Lateral meniscus injuries

There were 58 patients with a probable lateral meniscus tear clinically diagnosed, out of which 41 were males and 17 were females. Twenty-four subjects sustained injury due to contact sports. Twenty-one of them had met with a road traffic accident and 13 subjects gave a history of slip and fall. Patients ranged from 21 years to 45 years of age, with 88% (51/58) of them being 37 years old and younger. Twenty-seven patients underwent partial meniscectomy and 20 underwent meniscal repair and 11 had intact lateral meniscus on diagnostic arthroscopy. Out of 58 patients, 17 patients had associated ACL injuries [Table 1].

Thirty-eight patients got genuine-positive results on the McMurray test (the diagnosis was confirmed after an arthroscopy). Seven patients had false-negative tests (negative clinical test with meniscal tear verified during arthroscopy), while three patients had false-positive tests (positive clinical examination with no meniscal tears during arthroscopy). Ten patients had true-negative results. The test developed by McMurray showed an 84.44% sensitivity and a 76.92% specificity. A 92.68% PPV and a 58.82% NPV are shown in Table 3, respectively.

Forty individuals had true positives for joint line tenderness. At the arthroscopy, the diagnosis was confirmed. Joint line tenderness tests were performed on six patients who tested false negative (negative clinical test with meniscal tear verified during arthroscopy) and four patients who tested false positive (positive clinical examination with no meniscal tears during arthroscopy). Eight patients had true-negative results. Joint line discomfort was 86.95% sensitive and 66.66% specific [Table 3].

Forty-two patients had a true-positive Thessaly test, and an arthroscopy confirmed the diagnosis. Three patients had false-negative results (negative clinical test with meniscal tear verified during arthroscopy), while two patients had false-positive results (positive clinical examination with no meniscal tears during arthroscopy). Eleven patients had true-negative results. Thessaly test had a 93.33% sensitivity and an 84.61% specificity [Table 3].

Forty-five true-positive, 3 false-negative, 1 false-positive, and 9 genuine-negative individuals were identified by MRI analysis. MRI had a 93.75% sensitivity and a 90% specificity. A 75% NPV and a 97.82% PPV are shown in Table 3.

Table 1: Demographic data of the study

Characteristics	Parameter	Medial meniscus (*n*=94)	Lateral meniscus
Sex, *n* (%)	Male (*n*=54)	68	22 (53.66)
	Female (*n*=24)	26	19 (46.34)
Age	Range (years)	21–50	
Mechanism of injury, *n* (%)	Sports injury	40	0
	RTA	34	18 (43.9)
	Trivial fall	20	23 (56.1)
Radiculopathy, *n* (%)	Right	12 (32.4)	24 (58.5)
	Left	25 (67.6)	17 (41.5)

RTA: Road traffic accident

Table 2: Summary of results of medial meniscus injuries

Medial meniscus injury	McMurray's test	Joint line tenderness	Thessaly test	MRI
Sensitivity (%)	84.21	88.15	92.10	94.87
Specificity (%)	84.21	55.56	88.89	93.75
Positive predictive value (%)	95.45	89.33	97.22	98.67
Negative predictive value (%)	61.53	52.63	72.72	78.95

MRI: Magnetic resonance imaging

Table 3: Summary of results of lateral meniscus injuries

Lateral meniscus injuries	McMurray's test	Joint line tenderness	Thessaly test	MRI
Sensitivity (%)	84.44	86.95	93.33	93.75
Specificity (%)	76.92	66.66	84.61	90
Positive predictive value (%)	92.68	90.90	95.45	97.83
Negative predictive value (%)	58.82	57.14	78.57	75

MRI: Magnetic resonance imaging

Discussion

The average yearly incidence of meniscal tears is 60–70/100,000, with a male-to-female ratio ranging from 2.5:1 to 4:1. According to our research, the male-to-female ratios for the medial and lateral meniscus are, respectively, 2.6:1 and 2.4:1.

Trauma is more likely to be the source of meniscal disease in younger patients, while degenerative meniscal tears are more prevalent in older people. In our study population, the most common mechanism of injury was contact sports (40 for MM; 24 for LM) followed by road traffic accident (34 for MM; 21 for LM) and least common was slip and fall/no specific injury (20 for MM; 13 for LM).[7-9]

There have been several studies which have compared the accuracy of tests of meniscal injury with varying results. A meta-analysis of 18 studies indicated that the combined sensitivity and specificity for McMurray's, Apley's, and joint line tenderness were, respectively, 70% and 71%, 60% and 70%. They concluded that no one physical examination test seemed to reliably diagnose a torn tibial meniscus and that the worth of a history and physical examination was uncertain.[16] In a prospective research including 160 patients, Fowler and Lubliner[11] discovered that the McMurray's test had a sensitivity of 29% and a specificity of 95%, and that joint line tenderness had a sensitivity of 85% and a specificity of 29.4%. Data on the diagnostic accuracy of these show a wide range in accuracy, most likely as a result of variations in research design, performance, and test interpretation.

The McMurray test is among the primary clinical tests to evaluate for a meniscal tear. McMurray first described the test in 1928.[14] Several studies showed various modifications for McMurray test with better validity. This study used a modified version of the McMurray test by adding axial compression with no varus or valgus stress on the knee joint. It has been shown that the modified McMurray test has better diagnostic accuracy than its original version.[13,17,18] In our present study, the sensitivity for McMurray's test was found to be 86.3% for medial meniscus and 84.44% for lateral meniscus. The specificity in our study was 84.21% for medial meniscus and 76.92%. The wide range of specificity and sensitivity in various studies can be explained by the methodology of test conducted. We used clicking/pain as positive test criteria. The original McMurray's test only thud or click felt by examiner was considered positive.

Joint line tenderness test in our study was found to have 88.15% sensitivity for medial meniscus and 55% specificity. For lateral meniscus, the sensitivity was found to be 86.95% and specificity of 66.66%. Joint line tenderness has a high sensitivity for meniscal injuries, but specificity is low. This is in line with various other studies which have evaluated joint line tenderness.

Thessaly test was originally described by Karachalios *et al*.[19] Since then, the diagnostic accuracy has been the subject of numerous investigations.

Harrison *et al*.[20] tested the Thessaly diagnostic against arthroscopy in a retrospective study involving 116 individuals and concluded that it is a reliable and valid diagnostic for the detection of meniscal tears. A sensitivity of 90% and a specificity of 98% were discovered by Harrison *et al*.[20] Goossens *et al*.[21] studied 593 patients with a sensitivity of 64% and a specificity of 53% for Thessaly test. In our study, Thessaly test was found to have 92.1% sensitivity for medial meniscus and 88.89% specificity. For lateral meniscus, the sensitivity was found to be 93.33% and specificity of 84.61%.

MRI was found to have 94.87% sensitivity for medial meniscus and 93.75% specificity. For lateral meniscus, the sensitivity was found to be 93.75% and specificity of 90%. Overall among the 3 clinical tests, Thessaly test had the highest sensitivity (92.1% and 93.33%) and specificity (93.75% and 90%). This test can be used independently with high accuracy to diagnose meniscal tears. MRI in comparison has a better diagnostic accuracy than all 3 clinical tests and can be used independently or as a confirmatory test following the clinical tests.

The sensitivity and specificity of meniscal tests are greatly reduced when there are other knee injuries present, such as anterior cruciate injuries, according to a few studies comparing their validity.[22] Since ACL were not included in our study, their diagnostic efficacy could not be discussed.

Conclusion

A comprehensive clinical examination by an experienced physician has the same diagnostic power as MRI to rule out meniscal injuries, despite the fact that MRI is an accurate and noninvasive method for diagnosing meniscal injuries. In contrast to other tests, we found in this study that the Thessaly test can be utilized as a suitable tool to identify meniscal injuries.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Original Article

"Push and Park" Microdrilling Technique for Chondral Lesions of the Patella: A Technical Note

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Abstract

Background: The most used treatment modality for chondral lesions of the patella, particularly when the lesion is <2 cm^2, is microdrilling. However, reduced working space and mobility of the patella make this procedure technically difficult. To bypass this technical difficulty, we describe a simple technique of "Push and park" for microdrilling of the chondral lesions of the patella. **Materials and Methods:** Patients operated on by this technique in 2021 were followed for 1 year. Patients operated for magnetic resonance imaging-proven International Cartilage Repair Society grade III and IV patellofemoral chondral lesions (PFCLs) that are localized and <2 cm^2 with or without other concomitant knee pathologies were included. The functional outcomes were evaluated using the Tegner Lysholm score and Kujala score. **Results:** Twenty-one patients were included in the study. Of these, 7 cases had isolated PFCL, 8 cases had associated medial meniscal posterior horn root tears, and the remaining 6 cases had anterior cruciate ligament injuries. The mean follow-up period was 14 (±2) months. The average age was 41 (±7) years. We had 12 female and 9 male patients. The Tegner Lysholm and Kujala scores improved significantly in all the patients at 1-year postsurgery (P = 0.035 and P = 0.026, respectively). **Conclusion:** We have described a simple and reproducible technique for microdrilling of difficult-to-access patellar lesions. When used appropriately, the technique can be a cost-effective method of managing the chondral lesions of the patella.

Keywords: Chondral lesions, knee arthroscopy, micro drilling, microfracture, patella

Introduction

Cartilage lesions of the knee are one of the most common conditions encountered in clinical practice. They present as knee pain causing limitation of day-to-day activities. They commonly involve the medial femoral condyle and patellofemoral joint.[1] In an analysis of 25,124 knees, 60% of them had cartilage lesions, of which 36% were patellofemoral chondral lesions (PFCLs) and 34% were medial femoral condylar lesions.[2] In athletes, PFCLs account for 18%–37% of the chondral lesions.[3]

The management options for chondral defects include arthroscopic microdrilling, microfracture (MF), autologous chondrocyte implantation, osteochondral autograft transplantation, and osteochondral allograft transplantation.[1] When compared to the management of tibiofemoral chondral defects, the management of PFCL is quite challenging because of the peculiar anatomy of the patellofemoral joint. There is a high shear force in this joint. Furthermore, the joint space is relatively less, and patellar mobility is limited for arthroscopic management.[4] The most used treatment modality for chondral lesions of the patella, particularly when the lesion is < 2 cm^2, is an MF or microdrilling (MD).[5,6]

However, reduced working space makes this procedure technically difficult. Special instruments such as angled awls or flexible drills are needed or a retrograde approach can be attempted.[7] To bypass this technical difficulty, we developed a simple "Push and park" microdrilling technique for the chondral lesions of the patella. In this article, we have

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described the technique and the results of MD of the patella using the technique.

Materials and Methods

This is a retrospective single-center study from January 2020 to December 2020. Institutional ethical committee approval was obtained for the study. The inclusion criteria are patients in the age group between 18 and 65 years, operated for magnetic resonance imaging-proven PFCL with or without other concomitant knee pathologies such as anterior cruciate ligament (ACL) injury, medial meniscal posterior horn root (MMPHR) tear, and posterior cruciate ligament injury. Only patients who consented to the study were included. Patients with International Cartilage Repair Society (ICRS) classification - grade III and IV cartilage lesions (acute and chronic defects) of the patella that are localized and < 2 cm^2 were included in the study. Patients with larger defects or lesser ICRS grades were excluded from the study. Professional sports people were also excluded from the study. Patients were followed up the next year. The functional outcomes were evaluated using the Tegner Lysholm score[8] and Kujala score[9] for patellofemoral symptoms.

Surgical technique

No special instrument is needed for this technique. Surgeries were performed under spinal anesthesia. The patient was placed in a supine position with a leg support on the side. Parts were prepped with povidone-iodine solution and draped in a sterile manner. Through standard anterolateral and anteromedial portals, the patellofemoral joint is inspected with the knee in extension. Other intra-articular pathologies, if any, are addressed before this procedure. The facet with the chondral defect is identified. The patella is *pushed* to the same side of the lesion by applying digital pressure as we do in the patellar glide test. The unaffected facet of the patella is then *parked* on the femoral condyle on the affected side, with the patella in a tilted position, by the assistant [Figures 1 and 2]. Under arthroscopic visualization, the defect is prepared. This involves the debridement of unstable cartilage. The base is curetted using a ring curette. The rim of the defect is made perpendicular so that it wells the clot formed after MD. MD is then carried out using 1.2 mm K wires introduced percutaneously perpendicular to the defect through the corresponding gutter under arthroscopic visualization. During drilling, to avoid the inconvenience of the drill hitting the operating table, while drilling the lateral facet, the leg can be placed on a bolster [Figure 2] or held high by an assistant, whereas while drilling the medial facet, the leg should be held high by the surgeon against the abdomen [Figure 3]. Drill holes are limited to a depth of 4 mm. Drill holes are made from the periphery to the center of the defect at an interval of 3–4 mm. Saline is then drained out and the portals are sutured without drain. K wires can be marked at 4 mm to accurately drill to 4-mm depth. Central patellar lesions can be difficult to manage – each half should be drilled by gliding the patella to the corresponding side.

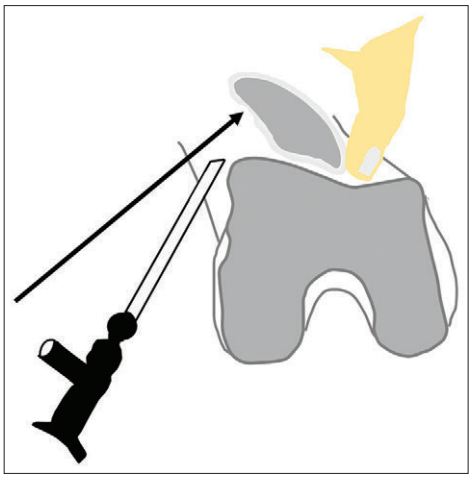

Figure 1: Line diagram explaining the Push and Park micro drilling technique

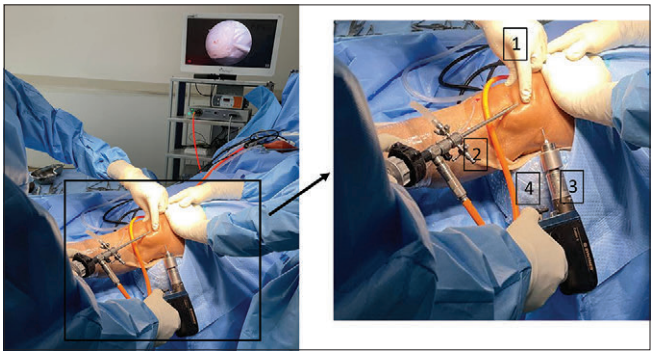

Figure 2: Intraoperative picture showing Push and Park micro drilling technique for the lateral facet of the patella: (1) Assistant pushing and parking the patella. (2 and 3) Surgeon arthroscopically visualizing and microdrilling the lateral patellar facet with the knee in extension, (4) Bolster under knee, helps in positioning the drill

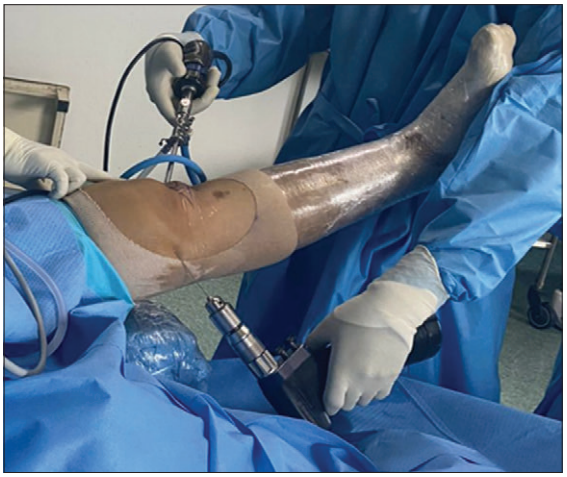

Figure 3: Intraoperative picture showing Push and Park micro drilling technique for the medial facet of the patella - the leg is held high by the surgeon. The assistant is pushing and parking the patella while the surgeon drills under arthroscopic visualization

Statistical analysis

The data were analyzed using SPSS versioin 26 (IBM, Chicago, Illinois, USA). Categorical variables were presented as frequency and percentages, continuous variables were presented as mean ± standard deviation. An independent sample *t*-test was used to measure the association between the Variables at different times. The association between the categorical variables was measured using Chi-square/Fisher's exact test. $P < 0.05$ was considered statistically significant.

Results

Twenty-four patients were operated on during 1 year. Three patients were lost to follow-up. The remaining 21 patients were included in the study. Of these, 7 cases had isolated PFCL, 8 cases had associated MMPHR tears, and the remaining 6 cases had ACL injuries. The mean follow-up period was 14 (±2) months. Eight patients had lesions in the lateral facet, one had a central lesion, and the remaining five had medial patellar facet lesions. The average age was 41 (±7) years. We had 12 female and 9 male patients. The mean preoperative Tegner Lysholm score was 56 (±5). The mean preoperative Kujala score was 53.6 (±8). The postoperative mean Tegner Lysholm and Kujala scores are 94 (±3) and 92.4 (±4), respectively. The Tegner Lysholm and Kujala scores improved significantly in all the patients at 1-year postsurgery ($P = 0.035$ and $P = 0.026$, respectively). The demographic details are listed in Table 1. The outcome scores are *P* values are listed in Table 2.

Discussion

We have described a simple reproducible technique for managing patellar chondral lesions of <2 cm in size. The Kujala scores at the end of 1 year are encouraging. The challenges in MF for patellar lesions are 1. Mobility of the patella compromising the accuracy of the technique and 2. Limited working space of the patellofemoral joint. We have addressed these two challenges by pushing the patella, parking the opposite facet on the femoral condyle, and using percutaneous K wires to drill.

Table 1: Demographic details of patients

Demographics	Numbers
Included patients	21
Male/female	9/12
Distribution of lesions	
Lateral patellar facet	8
Central	1
Medial patellar facet	5
Associated lesions	
ACL tear	6
Medial meniscal root tear	8
Mean age (years)	41±7

Table 2: Outcome scores of included patients

	Tegner Lysholm score	Kujala score
Preoperative	56±5	53.6±8
Final follow-up	94±3	92.4±4
P	0.035	0.026

Kenneth Pridie described the technique of MD as early as 1959 when arthroscopy was not prevalent.[10] His 11-line publication was the start of marrow stimulation methods to treat chondral lesions. Steadman *et al*.[11,12] were one of the earliest to describe the technique of MF for chondral lesions of the knee. They proposed the use of angulated awls (Steadman awls) to create MF in the patella. Even with the use of angulated awls, the procedure is difficult and the accuracy of making Micro fractures can be compromised leading to injury to the chondral base plate and subsequent poor outcomes.

Yip *et al*.[13] described the House on Stilts technique wherein the patella is fixed on the femoral condyles using transarticular K wires in the periphery of the chondral defect. Although this technique solves the problem of patellar mobility, the working space is further cramped by adding transarticular K wires. The femoral chondral damage also cannot be ignored.

There has been a recent increase in the practice of MD when compared to MF. MD was attributed to creating thermal necrosis which led to its decreased popularity. However, in a recent systematic review, Kraeutler *et al*.[14] have concluded that drilling increased the access to the marrow and resulted in higher volumes of repair tissue when compared to MF. Drilling has been found to cause less damage to the subchondral bone when compared to the MF technique. MF causes impaction fracture which obscures the release of marrow.

The place of MD in the treatment algorithm of chondral injuries is limited to correct indications that are described above.[15] The technique is cost-effective and simple. This technique induces the formation of only fibrocartilage. The durability of this tissue for longer periods has been doubtful, particularly when the size of the lesion is larger than 2 cm^2. There are some limitations to our study. This is a retrospective study. The power of the study was not calculated to determine the sample size. The sample size was small, and we did not have a control arm. However, since our study describes only an easier technical modification for MD and did not aim to validate MD as such these limitations could be ignored. Furthermore, in this study, we have had patients only with acute traumatic and degenerative chondral defects of the patella with no considerable malalignments. In young patients with malalignment, correction of malalignment should be considered along with management of chondral defects.

Conclusion

We have described a simple and reproducible technique for microdrilling of difficult-to-access patellar lesions. When used

appropriately, the technique can be a cost-effective method of managing the chondral lesions of the patella.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Original Article

Transcutaneous Electrical Nerve Stimulation Provides Early Recovery from Arthrogenic Muscle Inhibition Post-Anterior Cruciate Ligament Reconstruction

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Abstract

Background: Quadriceps weakness that ensues anterior cruciate ligament (ACL) reconstruction, a common procedure done in sportspersons, is a hindrance in the active rehabilitation and delays return to sport. This weakness of quadriceps muscle is a complex neural phenomenon ascribed to arthrogenic muscle inhibition (AMI). **Purpose:** The purpose of the study was to assess the effectiveness of transcutaneous electrical nerve stimulation (TENS) in AMI post-ACL reconstruction (ACLR). **Methods:** A prospective randomized study involving 60 patients with isolated ACL injury above 18 years of age were included. Patients with osteoarthritis knee, multiligament injury, previous knee surgery, and inflammatory knee pathology were excluded from the study. Patients were divided into Groups A and B (n = 30, each). Group A received TENS therapy with exercises and ice packs, whereas Group B received only exercise and ice packs post-ACLR. All patients were assessed subjectively using Visual Analog Scale score for pain, Lysholm, and IKDC score for functional outcome pre and postoperatively on day 2, 1 month, 3 months, 6 months, and 1 year. Objective assessment was done by measuring thigh girth (10 cm above knee joint line) and isometric quadriceps strength (using David Biofeedback Strength Evaluation Machine) pre and postoperatively at day 2, 1 week, 2 weeks, 1 month, 3 months, 6 months, and 1 year. **Results:** Pain decreased in both groups at 1 month, 3 months, and 6 months, but there was significantly lower pain in Group A in comparison to Group B at 1 month (P = 0.003), 3 months (P = 0.001), and 6 months ($P \leq 0.0001$). There was no pain at 1 year in both the groups. Lysholm score improved in both groups, but there was statistically significantly better Lysholm score in Group A in comparison to Group B at each follow-up. IKDC score improved in both groups, but the improvement in Group A was significantly higher than Group B at each follow-up. No significant difference in mean thigh girth was observed. Mean quadriceps strength was similar in both groups except at 6 months where Group A was better than Group B (<0.001). **Conclusion:** Addition of TENS in ACLR rehabilitation decreases pain and provides better clinical outcome.

Keywords: Anterior cruciate ligament, arthrogenic muscle inhibition, transcutaneous electrical nerve stimulation

Introduction

Weakness of quadriceps is a barrier to active rehabilitation after anterior cruciate ligament (ACL) tear and ACL reconstruction (ACLR).[1] Its consequences being atrophy of quadriceps, abnormality of gait, extension deficit, poor function, knee pain, and dynamic instability.

This quadriceps atrophy is more than a mere local phenomenon. It is a presynaptic reflex inhibition causing failure of quadriceps activation following joint distension that has been ascribed to arthrogenic muscle inhibition (AMI).[2] The injured knee joint causes changes in the discharge of sensory receptors that ultimately leads to the development of AMI. Various mechanisms for such inhibition have been suggested including change in resting motor thresholds of muscle, altered discharge of sensory

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receptors, alteration in spinal reflex excitability, and abnormal cortical activity.

AMI is a source of weakness of quadriceps muscle and prevents effective strengthening of the muscle,[3] resulting in irreversible muscle atrophy and weakness. A greater baseline quadriceps strength may guard against knee pain, loss of patellofemoral cartilage, and narrowing of tibiofemoral joint-space.[4]

Various modalities have been suggested for AMI. These therapeutic strategies for AMI change excitability of motor nerves with disinhibitory mechanisms. Hence, improve activation of quadriceps by directly aiming either joint mechanoreceptors, the peripheral nervous system (PNS) around the joint (Group III and IV afferent nerves), or the central nervous system (CNS).

Transcutaneous electrical nerve stimulation (TENS) is an electrical stimulation method that provides symptomatic pain relief by exciting the sensory nerves and stimulating the pain-gate mechanism. Such stimulation of sensory nerves by TENS activates specific mechanisms of natural pain relief.

There is a paucity of studies with regard to effectiveness of TENS therapy in AMI post-ACLR. This study was undertaken to study the effectiveness of TENS in AMI Post-ACLR.

Methods

A prospective randomized study conducted after institutional ethics approval from 2019 to 2021. Patients with isolated ACL injury above 18 years of age were included in the study. Patients with osteoarthritis (OA) of knee, multiligament injury, history of previous knee surgeries, and those with inflammatory knee pathologies were excluded from the study. Sixty patients with isolated ACL injured underwent arthroscopic ACLR were divided into two groups: A (n = 30) and B (n = 30) using computer-generated random number. During the post-ACLR rehabilitation, Group A patients received TENS along with exercises and ice packs, whereas Group B patients received only exercises and ice packs. Objective assessment was done by the measurement of thigh girth (10 cm above knee joint line) and isometric quadriceps strength (Newton Metre [Nm]) (using David Biofeedback Strength Evaluation Machine) pre- and postoperatively at day 2, 1 week, 2 weeks, 1 month, 3 months, 6 months, and 1 year. Isometric quadriceps strength (Nm) was measured using the David biofeedback machine in sitting position with the upper body and thigh tightly secured by belts and knee angle fixed to 60°. The patients were asked to apply maximum knee extension force by pushing the shin rest upward. Three trials were performed for each subject; best strength reading was recorded.

The TENS group received conventional TENS through a TENS device with a pulse width of 150 μs and pulse rate of 80 Hz for 30 min twice a week for 3 weeks. For TENS therapy, four electrodes were placed around the patella in a crossed mode. Patients were assessed for outcomes at 1 week, 2 weeks, 1, 3, and 6 months and 1 year following arthroscopic ACLR surgery.

Statistical analysis

Data were recorded into Microsoft® Excel Workbook 2019 and exported into SPSS version 23.0 (IBM, Armonk, NY, USA). Quantitative variables were expressed as mean and standard deviation and compared using the Student's *t*-test between two groups. Categorical variables were expressed as frequency and percentages and compared using the Chi-square test. $P < 0.05$ was considered statistically significant.

Results

Out of sixty patients, 47 were male and 13 female [Table 1]. There were 21 right knee ACLRs and 9 left knee ACLRs in Group A and 16 right knee ACLRs and 14 left knee ACLRs in the Group B [Table 2]. There was no loss to follow-up.

There was no significant difference in mean age between groups (P = 0.532). Sex distribution was unevenly matched with a higher female population in Group B. The associated meniscal injuries were baseline matched between the groups.

There was no significant difference in pain score between Groups A and B (P = 0.279) in immediate postoperative period. However, pain score improved in both groups at 1 month, 3 months, 6 months, and 12 months with significantly better pain relief was significantly better in Group A in comparison

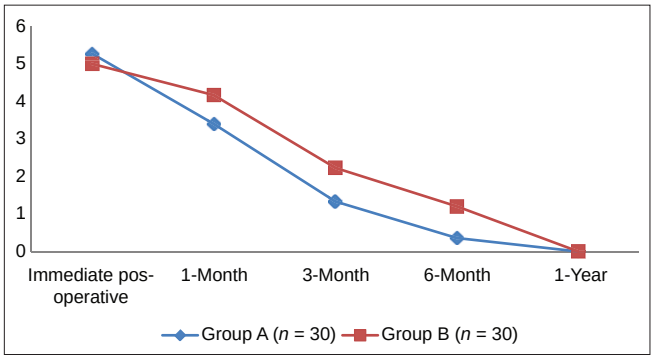

Figure 1: Trend line showing comparison of mean pain score of patients between both groups

Table 1: Patients Demography

	Group-A (n=30), n (%)	Group-B (n=30), n (%)	P
Age (years)			
18–30	18 (60)	22 (73.4)	0.532
31–40	10 (33.3)	7 (23.3)	
>40	2 (6.7)	1 (3.3)	
Mean age (years)	29.40±7.49	27.90±5.97	0.394
Sex			
Male	27 (30)	20 (66.7)	0.028
Female	3 (10)	10 (33.3)	

to Group B at 1 month ($P = 0.003$), 3 months ($P = 0.001$), and 6 months ($P = 0.0001$). There was no pain at 1 year in both the groups [Table 3 and Figure 1].

Lysholm score improved in both groups at follow-up, but there was a significant higher Lysholm score in Group A in comparison to Group B at 1 month ($P = 0.033$), 3 months ($P = 0.001$), 6 months ($P < 0.0001$), and 1 year ($P = 0.0001$) [Table 4]. We also found that 4% patients in Group A had good Lysholm score at 1 month. At 3 months, 46.7% in Group A and 6.7% in Group B had excellent Lysholm score [Table 4 and Figure 2].

The IKDC score improved in both groups at each subsequent follow-up, but there was a significant difference in IKDC score with Group A showing significantly better scores than Group B ($P = 0.001$) at 1 month, 3 months, 6 months, and 1 year [Table 5 and Figure 3].

Thigh circumference improved in both groups at each follow-up. Although no significant statistical difference was found in the mean circumference between both groups at subsequent follow-up, clinically Group A had better values [Table 6 and Figure 4].

The quadriceps strength improved with time in both groups. There was no significant difference in the mean isometric quadriceps strength between both groups at subsequent follow-up except, at 6 months, there was a better score of Group A ($P \leq 0.001$) [Table 7 and Figure 5].

Discussion

It was evident from this study that TENS therapy resulted in clinically better pain control in postoperative period as depicted by significantly better Visual Analogue Scale score at each follow-up till 6 months. This leads to better recovery in terms of measurable and patient-reported outcomes at each time line in comparison to non-TENS group.

The pain reduction was significant after the 1st month postsurgery in the group, rehabilitated with TENS therapy. Pain relief is most important factor that can affect exercise capability, range of motion (ROM), and regaining quadriceps strength. As there was better pain relief, with the addition of TENS to the standard rehab protocol, this group had better rehab milestones than the group rehabilitated without this modality. Although there is convergence of parameters at around a year postsurgery, there is definite evidence of better

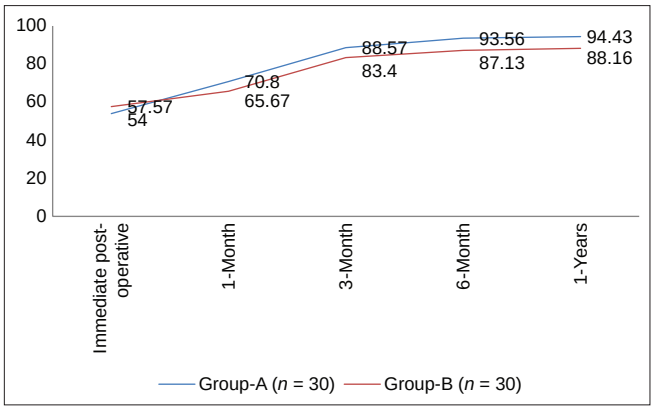

Figure 2: Comparison of mean lysholm score of patients between both groups

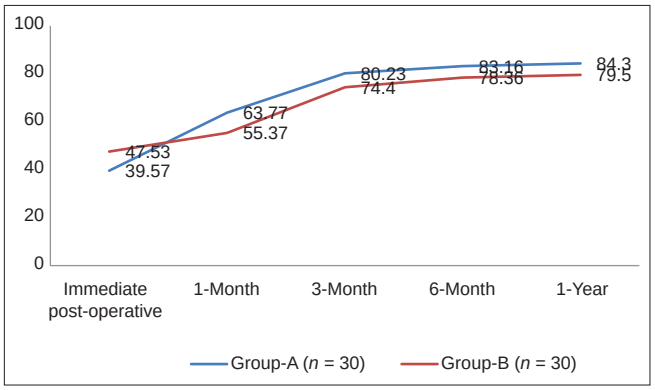

Figure 3: Comparison of mean IKDC score of patients between both groups

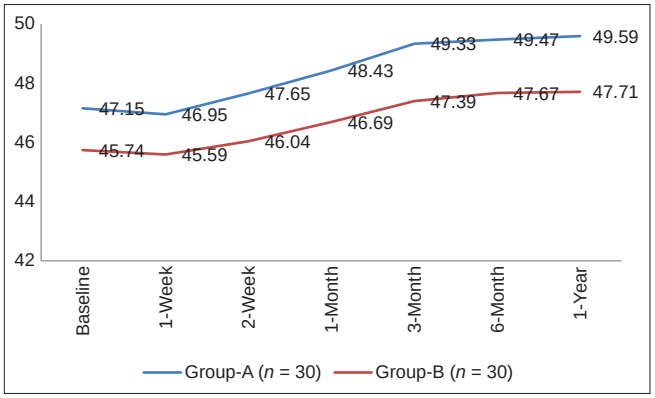

Figure 4: Comparison of mean thigh girth (cm) of patients between both groups

Table 2: Diagnosis distribution of patients between both group

Diagnosis	Group-A (n=30), n (%)	Group-B (n=30), n (%)	P
ACL tear with lateral meniscus tear left knee	1 (3.3)	2 (6.7)	0.523
ACL tear with lateral meniscus tear right knee	1 (3.3)	2 (6.7)	
ACL tear with medial meniscus tear left knee	2 (6.7)	5 (16.6)	
ACL tear with medial meniscus tear right knee	6 (20)	2 (6.7)	
ACL tear left knee	6 (20)	7 (23.3)	
ACL tear right knee	14 (46.7)	12 (40)	

ACL: Anterior cruciate ligament

Table 3: Comparison of mean pain score of patients between both group

Pain score	Group-A (*n*=30)	Group-B (*n*=30)	*P*
Immediate postoperative	5.27±0.98	5.00±0.91	0.279
1 month	3.40±1.07	4.17±0.83	0.003
3 months	1.33±0.92	2.23±1.04	0.001
6 months	0.36±0.55	1.20±0.99	0.0001
1 year	0.00	0.00	-

Table 4: Comparison of mean lysholm score of patients between both group

Lysholm score	Group-A (*n*=30)	Group-B (*n*=30)	*P*
Immediate postoperative	54.00±14.15	57.57±6.68	0.217
1 month	70.80±11.01	65.67±6.69	0.033
3 months	88.57±6.76	83.40±4.78	0.001
6 months	93.56±5.46	87.13±4.29	<0.0001
1 year	94.43±5.06	88.16±4.28	<0.0001

Table 5: Comparison of mean IKDC score of patients between both group

IKDC score	Group-A (*n*=30)	Group-B (*n*=30)	*P*
Immediate postoperative	39.57±8.13	47.53±5.59	<0.001
1 month	63.77±8.72	55.37±5.27	<0.001
3 months	80.23±4.35	74.40±4.86	<0.001
6 months	83.16±2.91	78.36±4.58	<0.001
1 year	84.30±2.64	79.50±4.49	<0.001

Table 6: Comparison of mean thigh girth (cm) of patients between both group

Thigh girth (cm)	Group-A (*n*=30)	Group-B (*n*=30)	*P*
Baseline	47.15±3.63	45.74±3.81	0.149
1 week	46.95±3.69	45.59±3.76	0.165
2 weeks	47.65±3.77	46.04±3.66	0.098
1 month	48.43±3.79	46.69±3.63	0.074
3 months	49.33±3.92	47.39±3.60	0.051
6 months	49.47±3.90	47.67±3.63	0.073
1 year	49.59±3.93	47.71±3.59	0.058

Table 7: Comparison of mean thigh strength (newton meter) of patients between both group

Quadriceps strength	Group-A (*n*=30)	Group-B (*n*=30)	*P*
Baseline	–55.07±18.99	–56.30±14.41	0.778
1 week	–53.30±18.88	–54.97±14.51	0.703
2 weeks	–49.13±18.92	–52.47±14.46	0.447
1 month	–42.33±18.55	–47.50±14.49	0.234
3 months	–32.03±16.64	–36.60±14.15	0.257
6 months	–20.33±12.54	–30.00±13.43	<0.001
1 year	–12.96±9.59	–26.16±13.25	0.06

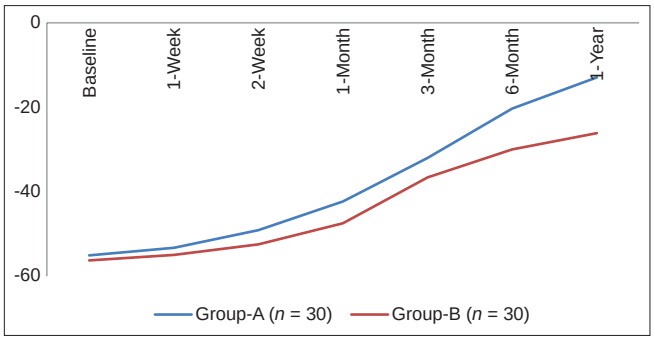

Figure 5: Comparison of mean thigh strength (newton meter) of patients between both groups

early recovery that could be of help to athletes for an early return to sport. Pain could lead to AMI which delays recovery post-ACLR. This makes rehabilitation more challenging, especially in sportspersons where timelines are tight.

Although Forogh *et al*.[5] reported that, adding 35 min of high-frequency TENS to a predefined exercise and mobilization regimen during the first phase (0–4 weeks) of post-ACLR rehabilitation did not lead to any further effect on the improvement of pain. A total of 20 sessions of a considerably longer pulse duration whose intensity was strong, but comfortable was given every day of the week except weekends. This study used a lower number of sessions of a lower pulse duration with adequate time between the sessions. The difference in the protocols could have resulted in different results. Stimulating everyday versus giving time for adaptation may have resulted in different outcomes. This study recorded statistically significant improvements in pain in TENS groups at all points of time after 1st month. Forogh *et al*., in their study, recruited only male participants, whereas this study had female participants in both groups, but a higher number in the group that did not receive TENS therapy. It has been shown that women perceive more pain explained by sex differences in nociception due difference in biological factors of difference in sex hormones responsible for sex differences in pain perception.[5,6]

TENS is known to effect pain relief by the activation of complex neuronal network to result in a reduction in pain. At clinically used frequencies and intensities, TENS activates afferent Aβ-fibers of large diameter.[7,8] This afferent input is sent to the CNS to activate descending inhibitory systems to reduce hyperalgesia.

The relief of pain in Group B could be due to exercise-induced hypoalgesia (EIH). EIH using a variety of exercise regimens has been reported to be in effect in humans. Although many studies have used high-intensity exercise (e.g. aerobic exercise or exhaustive isometric exercise) to produce hypoalgesia.[9] EIH is supposed to activate central opioid systems by increased discharges from mechanosensitive afferent nerve fibers A-δ and IV (C) from skeletal muscles because of rhythmic muscle contraction.[10,11]

The present study recorded a significant improvement in Lysholm score and IKDC score at each follow-up in both groups depicting effectiveness of both methods of treatment. However, in intragroup comparison, Lysholm and IKDC score was significantly better in TENS group at each follow-up. This clinical and statistically significant improvement in group that received TENS therapy as compared to the group that did not, is attributed to the significant pain relief in the TENS group. Pain relief postsurgery is key for patients to undergo and execute an aggressive rehabilitation to achieve musculoskeletal convalescence milestones.

This study recorded statistically significantly improvement in thigh girth and quadriceps strength within each group at subsequent follow-ups, with no statistically significant difference between TENS and exercise group. These findings are in accordance with Hart *et al*.;[12] they compared the effect of TENS and cryotherapy in ACL deficient participants who underwent 2 weeks of quadriceps rehabilitation exercises by measuring quadriceps strength and muscle activation. There was a significant improvement in both groups without a significant difference between both groups. Similarly, this study shows no statistically significant difference between the two treatment groups. However, clinically, the difference was observed, as TENS group showed better mean thigh circumference and recovery of quadriceps strength.

Jensen *et al*.[13] reported that group receiving TENS regained preoperative values of isokinetic strength of flexion and extension, ROM, and leg volume 1 month before patients who were subjected to placebo TENS or no TENS. Recent research[3] has shown improved quadriceps function in patients with OA of knee, following a 4-week course of progressive rehabilitation exercises while wearing TENS versus control subjects wearing placebo TENS devices. Onigbinde *et al*.[14] reported significantly greater quadriceps muscle strength after 8 weeks of TENS in comparison to unstimulated contralateral extremity and the initial ipsilateral value ($P < 0.001$).

Quadriceps weakness is a recognized barrier to effective rehabilitation post-ACL injury and reconstruction.[1] The consequences include extension deficit, gait abnormality, quadriceps atrophy, poor function, dynamic instability, persistent knee pain, and early OA.

Failure to activate quadriceps post-ACLR is not a local phenomenon, leading to atrophy. It has also been noticed simultaneously in both the reconstructed and the contralateral limb.[2] This has been attributed to AMI, a process in which quadriceps activation fails as a result of neural inhibition. The mode of this inhibition is vast and includes altered resting motor threshold of muscle, altered discharge of articular sensory receptors, alterated spinal reflex (Group I nonreciprocal [Ib] inhibitory pathway, the flexion reflex, and the gamma loop),[8] and abnormal cortical activity of brain.[15]

Current literature suggests the use of specific modalities as treatment interventions for AMI that cause alteration in motor excitability by disinhibitory mechanisms.[16,17] There is an improvement in quadriceps by acting upon joint mechanoreceptors, the PNS around the joint (mainly Groups III and IV afferent nerves), or the CNS.[17]

Sensory TENS applied to the knee has been reported to disinhibit the quadriceps motor neuron pool excitability in individuals with artificially effused knee joints.[16] A volitional increase in quadriceps activation post-TENS application was also noticed in OA knee.[3] TENS causes an increase in stimuli to interneurons, thereby elevating motor output to the otherwise inhibited muscle.[3] It has been documented that exercise along with TENS leads to gain in muscle strength and improved gait in patients with knee OA.[4] However, long-term TENS application benefits are yet to be established.

Although we tried to minimize placebo effects in the present study, we acknowledge potential limitations of the no TENS group. The treatment group felt a stimulus, whereas the placebo group did not. We attempted to minimize this limitation by (a) blinding the subject allocation to group, (b) asking subjects not to ask questions regarding the intervention used in the study, (c) instructing subjects that they may or may not feel a stimulus during treatment, (d) treating the other group the same as the treatment group while starting the TENS.

TENS therapy ensued better pain relief and achievement of rehabilitation goals in all cases post-ACLR. The limitations of our study are (a) short period of time for follow-up and (b) small sample size.

Conclusion

Addition of TENS to standard rehab protocol effectively improves pain and functional outcome postoperatively. However, further studies with a higher sample size are required to validate these findings.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Original Article

Safety of a Novel Capsular Closure Device in Hip Arthroscopy for Femoroacetabular Impingement

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Abstract

Introduction: The utilization of hip arthroscopy for the management of femoroacetabular impingement has increased. Capsular closure has been shown to maintain biomechanical stability postoperatively compared to unrepaired capsules. The novel Cap-Fix device (Smith and Nephew, Watford, UK) was developed to aid in capsular closure both by improving the placement of suture and decreasing the number of steps required for capsulotomy. This study aimed to evaluate the safety of the Cap-Fix device for use in capsulotomy and capsular repair following hip arthroscopy. **Materials and Methods:** A retrospective review of 30 patients undergoing hip arthroscopy for the treatment of femoroacetabular impingement (FAI) with capsular repair using the Cap-Fix 45° or 70° Suture Passer was performed. The Hip Disability and Osteoarthritis Outcome Score for Joint Replacement (HOOS JR) and Patient-Reported Outcomes Measurement Information System-Physical Function (PROMIS-PF) measures were used to evaluate patient-reported outcomes at the baseline and the follow-up intervals. Outcomes of interest included complications and patient-reported outcomes at 2-week, 6-week, and 3-month follow-up. **Results:** All patients completed 2- and 6-week follow-up, and 28 (93.3%) completed 3-month follow-up. Two patients experienced complications; one with pain requiring glucocorticoid injection at 6 weeks postoperatively, and another with a 12-mm capsular defect found on 3-month postoperative magnetic resonance imaging requiring repeat arthroscopic debridement, revision labral repair, and capsular plication. By 3 months postoperatively, statistically significant improvement in HOOS JR but not PROMIS-PF scores was seen. **Conclusion:** The Cap-Fix device appears to be safe for use in capsulotomy and subsequent capsular repair during hip arthroscopy for FAI.

Keywords: Arthroscopy, capsular closure, femoroacetabular impingement, plication

Introduction

Hip arthroscopy has been demonstrated to provide effective and comprehensive treatment for various presentations of femoroacetabular impingement (FAI).[1] Given the effectiveness of hip arthroscopy, the use of the procedure has proliferated, as evidenced by a 600% increase in procedures performed by the American Board of Orthopedic Surgery examinees from 2006 to 2010.[2] Overall, hip arthroscopy has a relatively low complication rate of approximately 4%; common complications include infection, iatrogenic cartilage and labral injuries, and neuropraxia.[3] Another rare but potentially devastating complication after hip arthroscopy is gross instability, which is estimated to occur in 0.07% of cases.[3] Although less severe, iatrogenic microinstability can also occur, which is considered a possible source of impaired postoperative function that may lead to accelerated cartilage wear and degeneration.[4,5] This has been reported to be an increasingly common clinical problem, accounting for up to 35% of revision hip arthroscopies.[6,7]

Hip joint stability is achieved through the mechanical interaction of static and dynamic stabilizers.[8] In addition to dynamic stabilizer muscles, the labrum, bony morphology of the femur and acetabulum, and capsuloligamentous tissues each play a critical role in maintaining normal hip stability, biomechanics, and range of motion.[9-11] The fibrous hip capsule, which consists of the iliofemoral, pubofemoral, and ischiofemoral ligaments and the zona orbicularis, collectively provides stability through the restriction of

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anterior translation, flexion, extension, abduction, and distraction.[8]

In performing hip arthroscopy, capsulectomy or capsulotomy is performed to access the joint.[12] Historically, satisfactory short-term outcomes were reported in cases where capsular closure was not performed after addressing joint pathology.[12-14] However, contemporary biomechanical and clinical studies have demonstrated the benefits of capsular closure. A recent systematic review of 24 biomechanical studies demonstrated that capsular repair and reconstruction resulted in improvements in maximum distractive force, total range of motion, and torsional stability when compared to capsular release.[15] With regard to clinical outcomes, Looney *et al*. performed a systematic review and meta-analysis of 36 studies encompassing 5132 arthroscopic hip surgeries, to compare differences in patient-reported outcomes between unrepaired and repaired capsules. Across multiple measures, including the Harris hip score (HHS)/modified HHS, hip outcome score (HOS)-activities of daily living, and HOS-Sport-Specific Subscale, capsular closure was associated with significantly superior improvement over nonrepair, after controlling for baseline scores and surgical indications.[16] Another systematic review and meta-analysis of 68 studies and 7241 hips concluded that capsular closure was associated with a lower risk of conversion to total hip arthroplasty following hip arthroscopy.[17] In light of these studies and growing concern around the adverse effects of microinstability, there has been a shift toward increased performance of routine capsular closure in arthroscopic hip preservation surgeries.[17,18]

While multiple approaches to capsular closure have been described,[19,20] this remains a technically challenging aspect of the procedure.[16] To aid in capsular closure, a novel device from Smith and Nephew, Cap-Fix (Smith and Nephew, Watford, UK), has been developed. This device family encompasses both blades for capsulotomy and suture passers for capsular repair. Capsulotomy blades are single use and available as either straight or curved 15° in a single-piece design, while the suture passers are available in 45° or 70° angles and are compatible with multiple suture types. Cap-Fix devices were developed specifically for capsular repair in hip arthroscopy to assist in capsulotomy and improve the placement of sutures for capsular repair, which may decrease the number of steps required to complete the procedure. These potential benefits may streamline both capsulotomy and capsular repair and lead to improved outcomes in these patients; however, there are limited data on the safety of the device. This study aimed to evaluate the safety of the Cap-Fix device for use in capsulotomy and capsular repair following hip arthroscopy.

Materials and Methods

This study was deemed exempt by the Institutional Review Board. Funding for this study was received from Smith and Nephew Inc., (Watford, UK) grant # MAP1040. The study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. A retrospective review of 30 patients undergoing hip arthroscopy for the treatment of femoroacetabular impingement (FAI) was performed. All repairs consisted of multiple passes of a nonabsorbable braided suture. The number of sutures and passes was selected on a per-patient basis to achieve a good closure. All capsulotomies were portal to portal, and no T-capsulotomies were performed. All patients underwent capsule repair using the Cap-Fix 45° or 70° Suture Passer [Figure 1]. Capsule closure was accomplished by passing nonabsorbable tape sutures from the proximal leaf to the distal leaf of the capsulotomy. Passes were either in a simple suture configuration or figure of 8 based on the number of passes needed to close as determined by the surgeon intraoperatively. The capsule was closed from medial to lateral, tying after each set of passes until a water-tight closure was achieved. A minimum of at least two passes were used on all capsules. An intraoperative image of the device being used for capsule closure is presented in Figure 2. A manual review of the electronic medical record was performed to evaluate patient demographics, surgery details, and complications and patient-reported outcomes at 2-week, 6-week, and 3-month follow-up. The Hip Disability and Osteoarthritis Outcome score for Joint Replacement (HOOS JR) and Patient-Reported Outcomes Measurement Information System-Physical Function (PROMIS-PF) measures were used to evaluate patient-reported outcomes at the baseline and the follow-up intervals. Descriptive statistics were performed to summarize patient demographics and complications, and *t*-tests were performed to compare postoperative patient-reported outcome scores versus baseline. Statistical analysis was performed in SPSS version 26 (IBM, Armonk, NY, USA). Statistical significance was assessed at $P < 0.05$.

Results

The average patient age was 37.0 ± 14.7 years, body mass index was 28.5 ± 6.0 kg/m^2, and 23 (76.7%) patients were female. Seven of the 30 (23.3) patients had a history of prior

Figure 1: Cap-Fix 45° (black) and 70° (front) Suture Passers

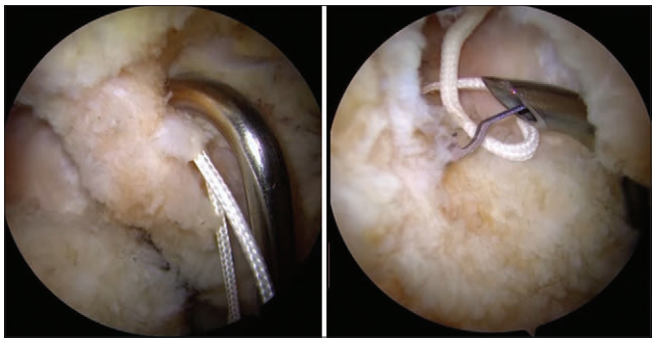

Figure 2: Intraoperative images of the 70° Cap-Fix Suture Passers used to perform anterior capsule closure

surgery on the operative hip. The majority of patients (27, 90%) underwent labral repair, while three patients (10%) underwent labral reconstruction. Pincer resection was performed in 13 patients (43.3%), while cam resection was performed in 26 patients (86.7%). No intraoperative complications occurred.

All patients completed 2- and 6-week follow-up, and 28 (93.3%) completed 3-month follow-up. During the postoperative period, two patients experienced complications (6.7%). One patient presented to the emergency department 4 weeks postoperatively, with a complaint of increasing pain over the prior 2 weeks. Infection was ruled out, and a small effusion was identified on magnetic resonance imaging (MRI); the patient was discharged home uneventfully. At 6-week follow-up, the patient continued to have pain and stiffness which was treated with ultrasound-guided corticosteroid injection. The second complication was a large (12 mm) capsular defect observed on MRI approximately 3 months postoperatively, after the patient presented with ongoing pain. The patient underwent repeat arthroscopic debridement, revision labral repair, and capsular plication. Revision capsular management was performed using #2 Ultrabraid Sutures; four total passes were used to close the anterior and anterior/superior defects. No medical or surgical complications were observed at the 2-week follow-up for the second procedure.

At 6 weeks and 3 months postoperatively, improvements in average HOOS JR scores of 7.0 and 13.9 points were observed, although statistically significant improvement was only observed at the 3-month postoperative time point ($P = 0.032$). An average improvement of 2.8 points in the PROMIS-PF scores was observed at 3 months postoperatively; however, this did not reach statistical significance ($P = 0.266$).

Discussion

Overall, the complication rate observed in the current study was in alignment with previously published results, with only two patients out of 30 (6.7%) experiencing postoperative complications. None of the complications observed in this study were directly device related, and no complications occurred before the 4-week follow-up visit. By 3 months postoperatively, patients demonstrated statistically significant improvement in patient-reported outcomes as measured by the HOOS JR instrument.

Various complications have been reported after capsulotomy and capsular repair, including capsular defects, repair failure, postoperative stiffness, and instability among others. A prognostic case series of 39 patients undergoing hip arthroscopy for FAI who received a postoperative MRI at an average of 12.5 months demonstrated that 92.5% of the capsular repairs remained intact, with 7.5% developing capsular defects but no cases of repair failure.[21] In alignment with this result, 1 (3.3%) patient in the current study experienced a capsular defect requiring subsequent repair. While some defects may be small enough that revision capsular repair may not be required, surgeons should be aware of this potential complication and monitor patient recovery closely to determine if revision is necessary.

Another complication that has been reported is postoperative stiffness.[22] Studies have shown increased thickness of the capsule along the area of the capsulotomy on MRI, with greater thickness in males than females.[21] This increased thickness may contribute to stiffness of the hip joint, leading to gait disturbance and discomfort. While no stiffness was reported in our results, the patient experiencing pain at 4 weeks postoperatively may have been due to some soft-tissue impingement from the capsular repair. Alternatively, symptoms of pain with motion, locking, clicking, or catching may be indicative of microinstability.[17] While difficult to diagnose, microinstability may contribute to decreased satisfaction after hip arthroscopy. Repair of the capsule has been shown to increase subjective satisfaction and lower failure rates in dysplastic populations.[23] While this has been demonstrated for capsular repair as a whole, no studies to date have been performed specifically for repair with a Cap-Fix device. Overall, frank instability is a rare complication of capsular closure; however, previous studies have shown a higher rate of instability-related complications in female patients.[24,25] The shorter period of follow-up in this study may have masked any instability developed after capsular repair. Longer follow-up is needed to determine if this is a significant complication with the use of the Cap-Fix device. The low complication rates observed in this study suggest that the Cap-Fix device is safe for use for this indication.

There are various limitations to this study. As a limited case series performed at a single institution, our results may not be widely applicable to other health-care systems with a larger or more varied population. Since there were no comparisons between Cap-Fix and other similar devices, the direct benefit of Cap-Fix over other devices cannot be determined from these results. The small sample size may also be unable to demonstrate trends in capsular complications that could be seen in a larger population. As stated in the discussion, this study included <1 year of follow-up data. Some complications may not have been detected during the early follow-up period that may be reported with a longer period of follow-up. Further studies into the safety and benefits of the Cap-Fix device should be performed to determine the utility of this novel device in hip arthroscopy.

Conclusion

The Cap-Fix device appears to be safe for use in capsulotomy and subsequent capsular repair during hip arthroscopy for FAI. Surgeons should use their clinical judgment and preference when determining which operative devices to use for these procedures.

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Conflicts of interest

Dr. Petre is a paid consultant for Smith and Nephew Inc. No other authors have relevant conflicts to disclose.

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Original Article

Biomechanical Comparison of Banarji Knot with Various Sliding Locking Knots

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Abstract

Background: The most essential part of arthroscopic shoulder surgery is tying a secure knot. A knot should be a low profile, nonbulky, and more stable construct. In the present research, we have compared the biomechanical performance of the new sliding locking knot-the Banarji knot, with two different sliding locking knots: The Samsung Medical Centre (SMC) Knot and the Weston Knot. **Methods:** Two samples of arthroscopic sliding locking knot, Banarji knot with three and five half hitches were taken. They were named Banarji Knots 1 and 2 in the study. The SMC Knot and Weston Knot were taken for comparison with the Banarji Knot. All knots were prepared with high-strength suture material fiber wire (Arthrex, Naples, FL, USA) and were tested in Bose Testing Machine to evaluate the load to failure of knots taken in the research. The statistical significance was determined using a $P = 0.05$. **Results:** The maximum load to failure was higher with the Banarji Knot, and it showed significantly better performance when compared with other knots taken in this study. The maximum load to failure in Banarji Knot 1 was 23% and 17% higher than SMC Knot and Weston groups, respectively, and that for Banarji Knot 2 was 29% and 22% higher than SMC and Weston groups, respectively. **Conclusion:** The Banarji knot is a low-profile, stronger, and stable knot. The biomechanical properties of the Banarji knot were better, and the load to failure was superior to SMC and Weston Knot.

Keywords: Arthroscopic knot, Banarji knot, double locking, secure knot

Introduction

Creating a stable framework for soft-tissue healing to bone is often necessary during arthroscopic shoulder surgeries. The most widely used fixation technique still necessitates the tying of arthroscopic knots, despite the availability of many alternatives.[1] Procedures for arthroscopic repair depend on the adoption of a secure knot-tying method. An initial sliding knot, followed by a string of half hitches to seal the knot, is often the first stage in the arthroscopic knot-tying process.[2] According to their common properties, the various forms of arthroscopy knots that have been reported[3,4] may be simply categorized. There are locking and nonlocking variations of both types of arthroscopic knots, which may be categorized as sliding or nonsliding.[5]

The outcomes of arthroscopic glenohumeral as well as subacromial shoulder operations have improved with the addition of suture anchors. To successfully re-approximate soft tissue to other tissue, it is necessary, among other factors, to choose an acceptable knot for a specified anchor and given suture material. To prevent knot impingement, an arthroscopic knot ought not to bulky, challenging to tie, or time-consuming.[6]

The security of the arthroscopic knot is essential for arthroscopic surgery to provide successful outcomes.[7] Orthopedic surgeons still need to learn how to make arthroscopic knots, despite the recent rise in the use of knotless suture anchors.[8]

The optimal arthroscopic knot must have minimum friction to facilitate sliding and minimal or no slack after the knot. In addition, a low-profile knot might be preferable. Significant features, such as application ease, ability to slide, reproducibility through arthroscopic cannulas, knot profile,

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ease of lock setting, and dependable initial security, are important for the outcome of arthroscopic rotator cuff repairs and capsulolabral procedures.[9]

A knot must have optimum characteristics for both knot security and loop security to be useful.[1] An ideal lockable sliding knot must be easy to use and should offer both excellent loop and knot security.[10] Loop security refers to the tendency of the knot to juxtapose soft tissue to the bone, whereas the surgeon is tying the knot. The ability of a knot to prevent slippage is known as knot security, which relies on friction dependent, internal interference, and the space between throws.[11] The strength of the finished knot after it has been fastened with three consecutive reversing half-hitch throws is referred to as the knot security.[12-14] According to earlier research, sliding knots need to be secured using 3–5 reversing half-hitch knots on opposite posts.[15]

Despite the variety of knots available, all successful knots must satisfy 2 criteria.

- The knot has to be correctly constructed to prevent the suture from slipping and cutting into itself
- It must be simple to tighten to provide optimum strength.[16]

In this study, we have compared the biomechanical performance of the arthroscopic "sliding locking knot," Banarji Knot[17] with existing sliding locking arthroscopic knots: Samsung Medical Centre (SMC) Knot and Weston Knot, by evaluating knot security and load to failure strength.

Methods

Study design

The material we used was ultra-high molecular weight polyethylene suture material (Arthrex, Naples, FL, USA) fiber wire for the description of the knot and comparative study. Poststrands are placed shorter and loop strands longer to form the Banarji knot [Figure 1a-f]. On over of the poststrand, a loop is made, A double loop is seen once the loop strand is pulled through the post. Once both suture strands have been pulled through the second loop, the knot might be placed by pulling off the poststrand. Pulling the poststrand completes advances, and secures the knot while pulling the loop strand tightens it. The knot is finally tightened with a knot pusher. The biomechanical performance of the Banarji knot was compared with SMC Knot and Weston knot. Two types of Banarji knot, with three and five reversing half hitches, were used for the comparative study, and they were mentioned as Banarji Knot-1 and Banarji Knot-2, respectively. Five samples in each of these knots were taken for the study.

The mechanical tests were performed at Biomechanics Laboratory, Indian Institute of Science, Bengaluru, India, by an independent investigator on a Bose Electro force® 3200 [Figure 2].

A single orthopedic surgeon carefully made each knot, taking care to guarantee optimum loop and knot stability by removing twists, minimizing slack between throws, as well as tensioning the 2 suture limbs. Each knot was knotted with as much initial stress as possible. The specimens were tested by soaking the knots in saline for 5 min.[18,19]

Biomechanical performance

Mechanical tests were performed on a Bose Electro force® 3200[14] (Bose Corp., USA) testing system equipped with two L-shaped metal hooks on which suture loops were mounted [Figure 2].

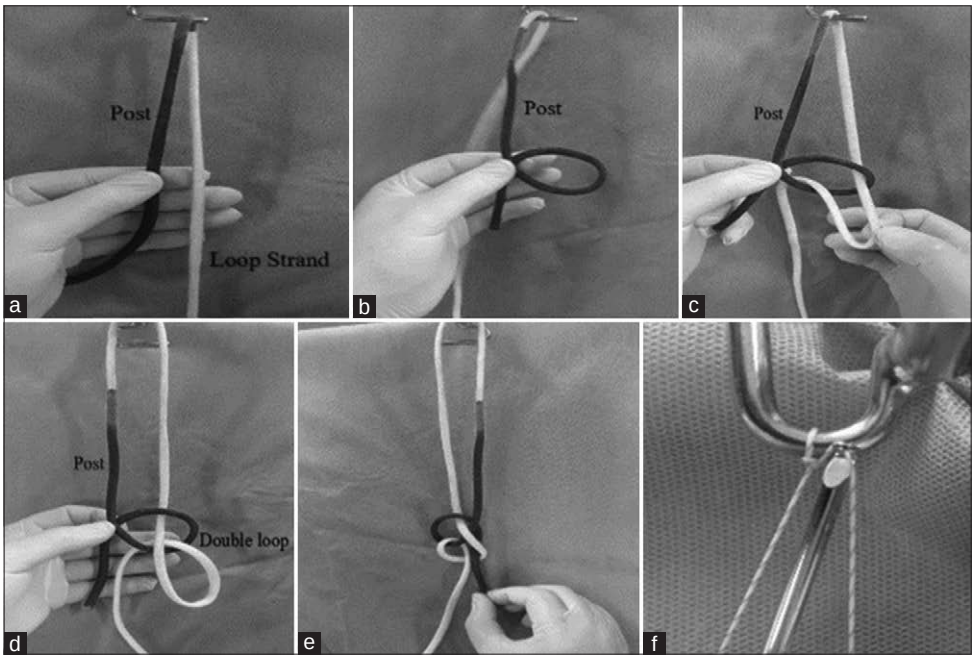

Figure 1: (a-f) Demonstration of Banarji knot

Preload

To eliminate any slack, each suture loop was preloaded to 5N before testing. The top clamp was moved at 0.1 mm/s to stretch the loop until failure.

Load to failure

The construct fails when any one of the following three criteria is satisfied: (1) the knots open up, (2) the suture thread ruptures, and (3) the loop length exceeds 3 mm.[20] The load at failure determines the load at the construct's point of failure. In our experiments, the knots did not open up, nor the suture thread ruptured, and therefore using the third failure criterion, the experiments were terminated when the change in the loop length exceeded 3 mm. The loads were measured using a 220N load cell, and the displacements (changes in the loop length) were recorded at 20 Hz using the machine software.[19,21] The load value when the loop length is increased by 3 mm is referred to as load to failure. A total of 5 samples were tested for each of the four groups. One-way "Analysis of Variance" with the Bonferroni criterion has been performed to test for variations in the results. A $P = 0.05$ was applied to examine statistical significance.[22]

Figure 3 shows the load versus extension results for five samples each in the groups corresponding to SMC Knot, Weston Knot, Banarji Knot 1, and Banarji Knot 2. Each sample is indicated using a different color. The average load to failure was obtained for each of the knots in the different groups in the study and was used to compare the overall strengths of the different groups.

Figure 4 shows the mean ± standard deviation of the experimentally obtained load to failure in each of the different groups in this study. Banarji Knots 1 and 2 showed statistically significant differences in the measured values of maximum load to failure when evaluated to SMC and Weston knots [Table 1].

Results

The results show significantly better performance with Banarji Knots 1 and 2 when compared to conventionally used knots.

Figure 2: Bose electro force 3200 testing machine showing testing of the knot

The maximum load to failure in Banarji Knot 1 was 23% and 17% higher than SMC and Weston groups respectively and that for Banarji Knot 2 was 29% and 22% higher than SMC and Weston groups, respectively. Load to failure and tensile strength were good with the Banarji knot when compared to other knots used.

Discussion

One of the most crucial elements in determining the success of surgery is the arthroscopic knot.[12,20,22] The critical properties of arthroscopic knots to preserve tissue apposition have been determined by many biomechanical investigations.[20,23] These aspects include the inherent qualities of the suture as well as the security of the loop and knot. For the best results of arthroscopic rotator cuff surgery, loop and knot security have been highlighted in several research.[21] We assessed the maximal force at 3 mm of crosshead movement as a measure of knot security, indicating a clinical failure. Numerous studies have shown that the idea of knot security is a crucial fixation characteristic for a range of arthroscopic knots.[1,21] In addition, the knot's capacity to resist loosening over time is crucial because tissue tension has to be maintained until appropriate healing has occurred. Additional crucial factors are the time required to make the knot and how simple it is to operate inside the joint and cannula used.[24]

The maintenance of the structural integrity of the treatment site while healing takes place is a crucial factor in musculoskeletal injuries and surgical repair. Even if the knotted suture never

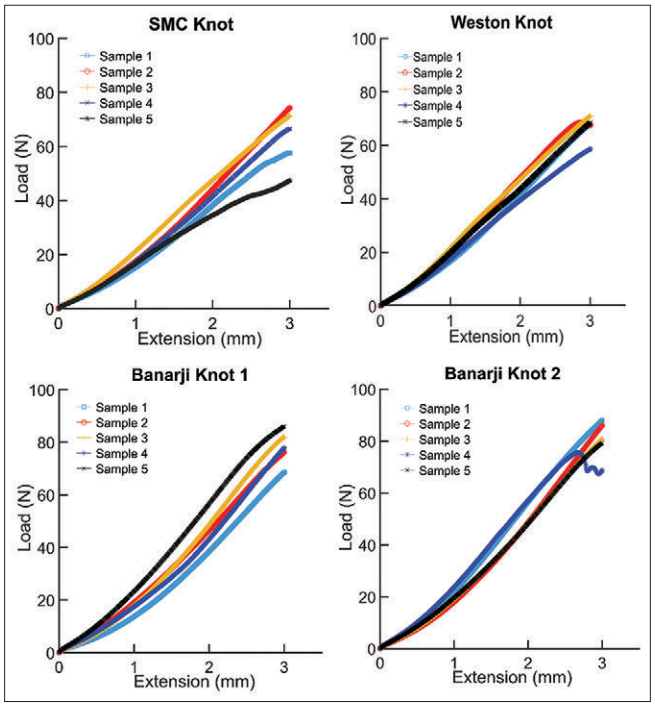

Figure 3: Load versus extension results for five samples of different knots taken. SMC Knot, Weston Knot, Banarji Knot 1 and 2. SMC: Samsung medical centre

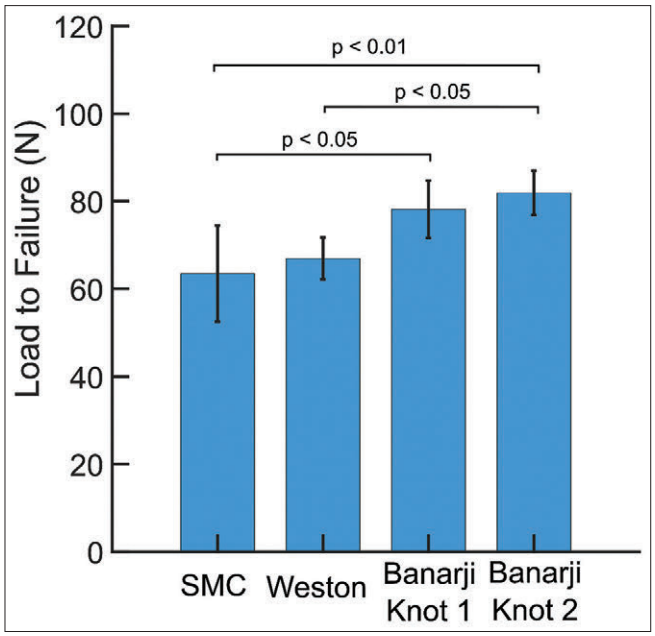

Figure 4: Load to failure of four knots, taken. SMC: Samsung medical centre

Table 1: Result of load-to-failure of each knot configuration

	SMC knot	Weston knot	Banarji knot 1	Banarji knot 2
Load to failure (*n*)	63.47±10.97	66.91±4.79	78.14±6.55	81.91±5.04

SMC: Samsung Medical Centre

breaks, a separation of the tissue of even a few millimeters might be harmful during recovery.[23]

The integrity of a repair construct depends on a surgeon's skill and expertise, regardless of knot or suture creation. Therefore, while creating an arthroscopic knot, it is crucial to take these aspects into account to eliminate such technical variances. Given the large range of alternatives available for arthroscopic knot tying, it is crucial to keep the following factors in mind to achieve the best results. The best arthroscopic sliding knot should fulfill the following five requirements: (1) It should be low profile, (2) It should be easy to throw, (3) It must slide well, (4) It must be easy to set, and (5) It must possess outstanding initial security and holding power.[24]

The Banarji Knot is a kind of sliding locking knot that may be tied during arthroscopic procedures. It may provide biomechanical dependability and is less reliant on the skill or expertise of the surgeon. This surgical knot's dependability was examined biomechanically in comparison to other widely used arthroscopic sliding locking knots. The maximum load to failure in Banarji Knots 1 and 2 were higher than SMC and Weston Knot. Table 1 provides an overview of each knot's load to failure. The Banarji Knot could withstand high tension when compared to SMC Knot and Weston Knot. It has a lesser learning curve and is easily reproducible by the surgeon. Once fastened, it keeps tension effectively and has great knot security. It is extremely good for capsule labral repairs since it is low profile and reasonably easy to tie. In addition, a biomechanical analysis revealed that the Banarji knot was more resistant to failure than the Weston and SMC knots. The Banarji Knot is a fairly simple, double-locking, and readily repeatable knot. Impingement is not a concern since the knot is low-profile and does not generate a bulky knot. It is biomechanically strong has good tensile strength, and high load to failure. The loop strand goes through two loops, making it stronger and raising its tensile strength after it is tightened and secured at different points.

Conclusion

The arthroscopic sliding locking knot-the Banarji knot is simple, easy to tie, relatively less bulky, safe, and stronger, which makes it suitable for most arthroscopic repairs. The biomechanical properties of the Banarji knot are better when compared to SMC and Weston Knot. We are certain that this knot will assist surgeons in reaching improved clinical outcomes.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Dual Organism Periprosthetic Joint Infection Following Total Knee Arthroplasty: A Case Report and One Year Follow-Up

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Abstract

Periprosthetic joint infections (PJI) of the knee are mostly due to a single organism, very rarely, it is due to dual organisms, and even rarer are dual Gram-negative bacilli and fungal infections. Most fungal infections are caused by *Candida albicans;* however, very few case reports are available for nonalbicans *Candida* in immunocompetent patients. We report an unusual case of nonalbicans *Candida* infection with Gram-negative bacilli in the knee joint with no predisposing risk factors. A 59-year-old man reported following mild pain, swelling, and restricted knee movements in a case of a primary total knee arthroplasty. The patient had minimal symptoms but had gross lysis around implants on imaging. His inflammatory markers were significantly high and knee aspiration was turbid, with raised polymorphs without any conclusive staining result. The culture reports revealed a fungal and Gram-negative organism infection. The patient was managed by debridement, prosthesis removal and antibiotic-loaded cement spacer insertion, and culture-specific antibiotics, followed by revision TKA and oral fluconazole therapy. The patient had a good clinical performance at 3 months and 1-year follow-up visits, with a painless range of motion of 10°–90° and there was no evidence of recurrence of infection. Dual Gram-negative and fungal prosthetic joint infection is a rare but serious complication. In the presence of mild clinical symptoms, but extensive lysis around the implant, fungal pathology should be considered irrespective of the immune status of the patient.

Keywords: Dual organism, *Escherichia coli*, nonalbicans *Candida*, periprosthetic joint infection

Introduction

Total knee arthroplasty has changed the life of patients with advanced osteoarthritis. Periprosthetic joint infections are one of the most feared complications, which hamper the results of successful knee arthroplasty. *Staphylococcus* is one of the most common bacteria leading to periprosthetic joint infection, followed by the rising trend of Gram-negative bacteria. Fungal infections are a rare cause of periprosthetic joint infection and *Candida albicans* is the most commonly isolated fungi.[1-3] Very few cases have reported dual organism infection caused by both fungi and bacteria.[3] We report a case of periprosthetic joint infection where the infection was caused by nonalbicans *Candida* along with Gram-negative bacteria in an immunocompetent host. The purpose of the report is to highlight the difficulty in making an accurate diagnosis and the outcome at 1-year follow-up of standardized two-stage exchange arthroplasty on dual organism periprosthetic joint infections.

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Case Report

A 59-year-old patient, a normotensive, nondiabetic, and chronic smoker with body mass index of 23 kg/m^2 reported to our center for the first time in October 2021, following mild pain, swelling in the right knee, and difficulty in walking for the last 4 months. The patient had undergone B/L cemented total knee arthroplasty in 2014 for advanced osteoarthritis knee at another center. He had an uneventful recovery postsurgery with no history of reported or documented intraoperative or postoperative complications. However, the documents pertaining to previous surgery and follow-up were not available.

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The patient on clinical examination had well-healed anterior midline scar of previous surgery, varus deformity in the operated limb, and tenderness along the medial joint line. He had mild swelling in the suprapatellar region and the range of movements of the knee was 10°–90° and painful. The patient was noticed to have a shortening of around 2 cm with varus thrust gait.

Radiographs of the knee revealed loosening of the femoral as well as tibial component, varus collapse on the tibial side, and bone defect in both femur as well as tibia [Figure 1]. Radiograph also revealed bone grafting with screw on the medial side, however, the source of the bone graft could not be identified. It is presumed that the intraoperative bone cuts were used for the augmentation of the defect. Patella appeared to be not resurfaced without any evidence of lysis. Inflammatory markers, i.e., erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP), were 84 mm at the end of 1 h and 135 mg/dl, respectively. Complete blood counts and urine evaluation were normal. Knee aspiration was performed and aspirated material histological and microbiological evaluation showed inconclusive results for KOH staining and Gram staining, however, polymorphs were more than 80% in knee aspirate and synovial fluid white blood cell counts were raised.

Management

In view of the above, the patient was suspected as a case of periprosthetic joint infection and his Musculoskeletal Infection Society Score (MSIS) score was calculated as 8 and the patient was planned for surgical intervention in the form of two-stage revision arthroplasty.

1st stage

Previous incision was used along with a quadriceps snip approach, and loose prosthesis was removed. Six intraoperative specimen cultures were taken (2 from supra patellar site, 1 each from medial gutter, lateral gutter, intercondylar notch, and posterior aspect of knee) and were labeled as per site and sent for Gram staining, Ziehl–Neelsen staining, and KOH staining.

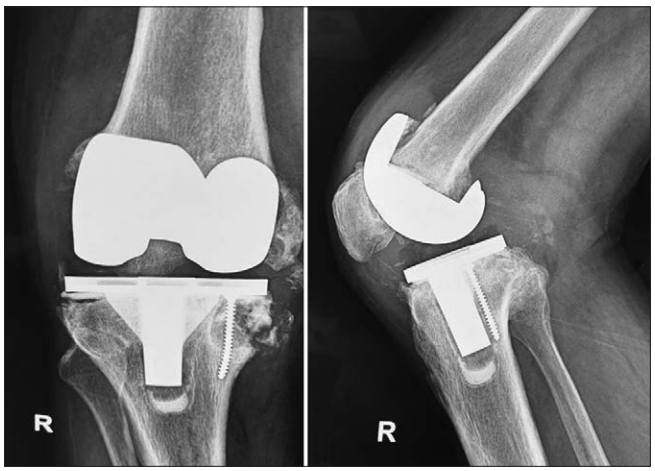

Figure 1: Preoperative radiographs showing extensive lysis and collapse of knee prosthesis

Wound debridement was done; the joint was thoroughly washed with pulse lavage along with povidone-iodine and hydrogen peroxide. Static spacer was made using Steinmann Pins and antibiotic bone cement (40 g PALACOS with gentamycin) laden with 4 g of vancomycin and placed in the knee [Figure 2]. The wound was closed in full extension, and a long knee brace was applied. The patient was started on broad-spectrum antibiotics pending culture reports.

Culture reports from the suprapatellar pouch region were suggestive of nonalbicans *Candida* and *Escherichia coli* species. For fungal etiology, nonalbicans *Candida* was diagnosed on the basis of a negative germ tube test. On further identification of specific fungi, *Candida Tropicalis* was identified based on the pigment pattern on CHROMagar. Based on the culture sensitivity, he was started on intravenous (iv) meropenem + iv fluconazole for 2 weeks, followed by oral fluconazole + cotrimoxazole as advised by the hospital infection control team for a duration of 8 weeks with serial CRP, liver function test, and renal function tests monitoring [Figure 3]. The CRP showed a decreasing trend, and the renal and liver functions were normal at regular follow-up visits.

2nd stage

After 8 weeks, patient's ESR and CRP levels normalized to 23 and 2.64, respectively, and it was decided to perform 2nd stage revision. Previous incision along with quadriceps snip approach was used. Wound debridement was done, and tissues were sent for culture and for intraoperative histopathological examination, and evaluation to look for polymorphonuclear cells presence and counts. Static spacer along with loose cement was removed, and a joint was prepared. Intraoperative staining of tissue samples showed no evidence of infection, hence final decision for implantation was made. There were extensive defects present on both femoral and tibial sides, which were managed by augments (AORI type 2B) [Figures 4]. Final implants along with stems and augments were implanted with PALACOS-G mixed with fluconazole. Postoperative culture reports were negative for fungal as well as bacterial organisms.

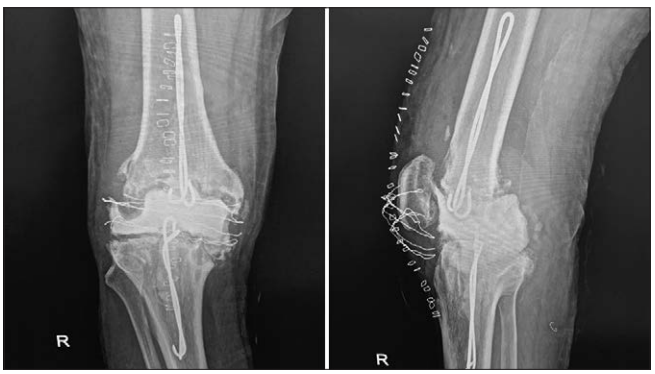

Figure 2: Immediate poststage 1 radiographic images showing the static spacer *in situ*

Postoperatively, the patient was again given a course of iv fluconazole and iv meropenem for 2 weeks. The patient was further given a course of oral fluconazole for 6 months. The patient on the last follow-up at 1 year achieved a 10°–100° range of knee movements with no pain or local signs of inflammation, normal inflammatory markers, and the absence of periprosthetic lucency on radiographs [Figure 5]. The patient is on constant 6-month follow-up where he is monitored clinicradiologically and with inflammatory markers.

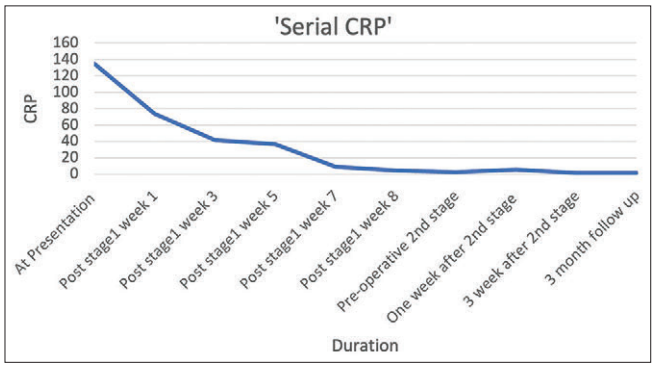

Figure 3: Figure showing serial CRP values. CRP: C-reactive protein

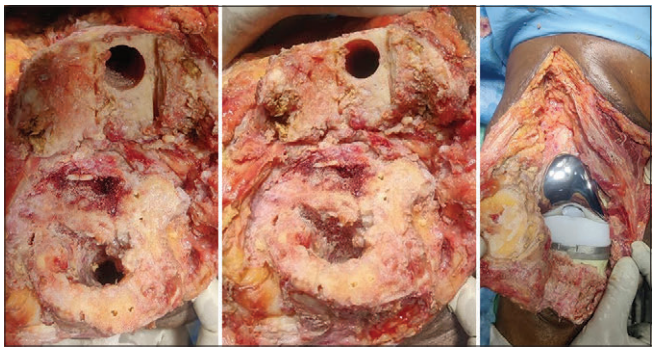

Figure 4: Intraoperative images showing the bone defects and final prosthesis

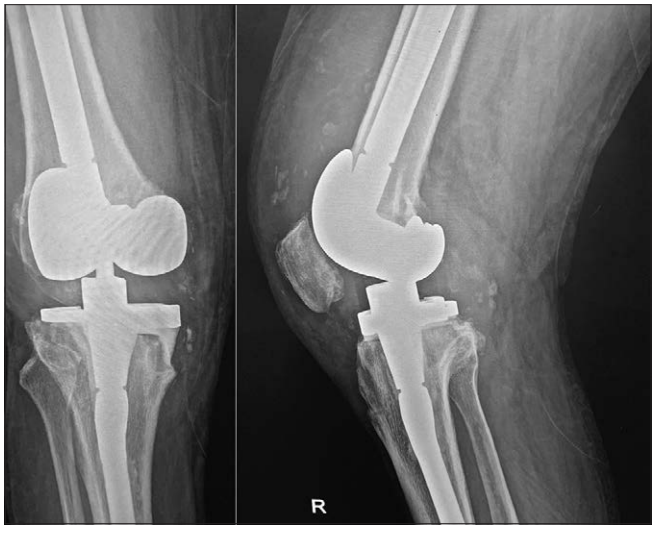

Figure 5: Radiographic images at the end of 1 year

Discussion

Periprosthetic joint infection (PJI) are a difficult problem to manage not only for the patients but also for the treating surgeon and are associated with severe disability and poor outcomes. PJIs in immune-competent patients are mostly bacterial in origin. Fungal infections are rarely the causative agent and are usually not considered in the preoperative period before culture reports because of extremely low incidence.[3-5] Clinical features of pyogenic infections are well described in the literature, with the symptoms being severe pain, disability, and swelling, with or without a discharging sinus. MSIS scoring is presently the accepted scoring system for periprosthetic joint infection and guiding management for the same. PJIs are managed either as a single-stage or two-stage revision, depending on the presentation, however, two-stage revision arthroplasty is still considered the gold standard. The success of two-stage revision arthroplasty has been reported to be 65%–98%.[1-3] In general, in two-stage arthroplasty, implant removal is done, heat-stable antibiotics (vancomycin, tobramycin, etc.) mainly to address pyogenic infection are added to cement spacer in the first stage, followed by final implant placement in the second stage.

Similar to our case, the case reported by Reddy *et al*.[6] had mild knee pain and swelling, with extensive osteolysis noticed on radiographs, which later was confirmed to be of fungal etiology. However, unlike us, they were dealing with a single-organism pathology. This unusual radiographic finding prompted us to consider a wider evaluation to find the possible etiology and it proved to be true, as we had grown fungus on culture. Hence, we presume that if radiograph reveals much greater destruction in the absence of florid symptoms, fungal origin should be kept as one of the possible etiologies.

Extensive osteolysis and the absence of florid symptoms led us to manage the case in two-staged procedure and we were at an added advantage as we could add an antifungal agent in the cement at the time of final revision. A possible additional intervention of adding an antifungal agent in the cement spacer can be considered if a patient has a similar clinicoradiological picture, which we realized retrospectively on analyzing our case.[7]

There is limited information on the treatment of knee infections caused by fungi. The literature review revealed a paucity of conclusive therapy for such cases. Various authors had used different rationales with varying duration. For *Candida*, amphotericin B is the gold standard but is nephrotoxic and may not be useful for long-term administration. In our case and the one managed by Reddy *et al*.,[6] fluconazole was used, in view of fewer side effects on long-term usage. In both cases, fluconazole proved to be effective in treating primary *Candida* infections. However, the presence of dual organisms complicated our scenario, as we not only had to consider tackling two organisms at a time but also consider the long-term effects of culture-specific antibiotics. Even with dual infection, our patient went on to have an uneventful and

acceptable recovery with complete subsidence of infection with no drug-induced side effects.

The present report provides insight into the management of a difficult situation of dual organism infection. With the rampant increase in joint replacement surgeries, we are also entering into an era of PJIs, with guidelines coming into the practice and the management of this dreaded complication. We had some significant learnings from the present case, which should be pondered upon and imbibed by every arthroplasty surgeon, to have a successful outcome. It is rare to find dual organism infection in an immunocompetent patient. Most of fungal infection in literature has been suggested by hematogenous spread.[3] A symptom-free long duration between index surgery and the onset of symptoms suggests that infection at the time of initial surgery is a low probability. We hypothesize that there could be two reasons for the infection, the first being a tobacco chewer patient might have had an episode of low immunity because of poor oral hygiene during the last few years and we presume this to be the source from which he acquired dual infection and second the graft used during the primary arthroplasty could be an allograft and a potential source of fungal infection. However, dental evaluation at the time of final implantation had no evidence of active dental caries or poor dental hygiene.

The lessons which we learned were as follows:

1. Consider fungal etiology for periprosthetic joint infection in immune-competent patients when clinical signs and symptoms are disproportionate to radiological features
2. In the management aspect, adding an antifungal agent to the spacer can be considered it shall act as an added advantage if the culture grows fungal organism
3. Our case also tells the importance of cumulative team effort in such a rare and difficult case with the involvement of orthopedic surgeon, clinical microbiologist, and hospital infection control team.

The limitations of our case study were as follows:

1. Considering the onset of infection of 7 years, our case had a short follow-up of only 1 year
2. There is a possibility of recurrence in the future after a dormant phase, as we are not sure of the reason of the infection.

Conclusion

Fungal and bacterial infection is a rare but serious complication, which should be considered in patients irrespective of immune status. We feel that resection arthroplasty with delayed implantation under antifungal and antibacterial cover is a valid treatment option, however, more studies are needed to lay down guidelines for managing such cases effectively.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Diffuse Tenosynovial Giant Cell Tumor of the Wrist with Joint Destruction and Invasion

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Abstract

A 54-year-old man took antitubercular drugs for 1 year for right wrist pain, swelling, and restriction of movements, with no improvements. Magnetic resonance imaging wrist reported multiple nodules and soft-tissue mass with intraosseous erosions involving carpal bones, distal radius, and ulna. Resection of the mass, excision of the distal ulna, and wrist arthrodesis were done. The histopathology confirmed a diffuse tenosynovial giant cell tumor (TSGCT). No postoperative radiotherapy or systemic therapies were given. The patient remained symptom-free at 2 years of follow-up. Diffuse TSGCT with joint destruction and invasion of the wrist is rare. Therefore, a high index of suspicion is required before considering the most common infective etiologies in the wrist.

Keywords: Fusion, good outcome, intra-articular invasion, tenosynovial giant cell tumor, wrist

Introduction

Tenosynovial giant cell tumor (TSGCT) involves the synovium, bursae, tendon sheath, and rarely joints. It can affect any location but is predominantly seen in fingers and tendons around the wrist. TSGCT usually occurs in the fourth and fifth decades of patients and has different types of presentation.[1,2] The nodular forms are common in females; the localized form predominantly affects fingers and diffuse forms affect larger joints such as the knee (75%), hip, ankle, or shoulder.[1-3] Nodular forms are slow growing, extra-articular, and involve a tendon sheath, which presents as a painless mass. Pain, swelling, and restriction of movements are seen in intra-articular forms. Radiographs reveal cystic erosions in diffuse type, especially in the hand and hip. Magnetic resonance imaging (MRI) delineates the lesion, extent, and location and is considered the preferred diagnostic modality. It characterizes the soft-tissue mass with homogeneous uptake and gradient-echo detects hemosiderin deposits.

Macroscopically, TSGCT is often multinodular, pedunculated, whitish, or yellowish-brown (hemosiderin deposits) and measures 1–6 cm. Histopathological evaluation predominantly exhibits histiocytes, varying proportions of multinuclear giant cells with variable mitosis and positive for CD68.[1,2] Diffuse forms of TSGCT are aggressive and destructive and have intra-articular locations with erosions and cysts. They involve larger joints such as the knee, hip, ankle, and elbow. Tuberculosis, monoarticular rheumatoid arthritis, synovial chondromatosis, and hemophilia are differential diagnoses. TSGCT has a great diversity of anatomical, clinical, diagnosis, and biological behaviors and is challenging to treat. In such cases, complete resection of the lesion and histopathological evaluation are considered the best intervention modality in symptomatic patients.

We report a rare presentation of diffuse TSGCT eroding the carpal bones, distal radius, and ulna and invasion into the surrounding tissues in a 54-year-old man diagnosed with wrist tuberculosis based on MRI findings.

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Case Report

A 54-year-old man presented to the clinic with severe right wrist pain, swelling, and restriction of movements for 1 year. There was no history of early morming stiffness, trauma, low-grade fever, asthenia, weight loss, night sweats, anorexia, multiple joint pain and swelling, chronic cough, sinus discharge, or skin lesions over the right wrist. The patient had no pulmonary tuberculosis in the past and was not a diabetic. Based on the X-rays and MRI, he was diagnosed elsewhere with tuberculosis wrist and was getting antitubercular drugs. There was no improvement. Clinical examination showed multiple diffuse tender warm swellings over the dorsum of the wrist with severe joint restriction. The radiographs showed diffuse osteopenia and multiple intra-articular cystic erosions involving the distal radius, ulna, and carpal bones without calcification [Figure 1].

MRI revealed extensive encapsulated multilobulated soft-tissue masses in the dorsum of the wrist arising from the extensor tendons with diffuse erosions involving intra-articular distal radius, ulna, scaphoid, lunate, triquetrum, and capitate with multiple intraosseous cysts [Figures 2 and 3]. Laboratory results such as complete blood count, liver and kidney function tests, coagulation profile, antinuclear antibody testing, antistreptolysin O level, RA factor, and anti-cyclic citrullinated peptide were normal except C-reactive protein was 15 mg/L (normal range 0–5 mg/L) and erythrocyte sedimentation rate was 25 mm/h (normal range, 0–15 mm/h).

Considering the persistent symptoms and the inconclusive clinical-radiological features, the wrist was explored under supraclavicular anesthesia and tourniquet control. Multiple nodules (pedunculated and sessile), whitish to yellowish brown masses infiltrating the extensor retinaculum, extensor tendons (2–6th compartment), and wrist capsule were noted. The carpal bones (scaphoid, lunate, triquetrum, and capitate), distal radius, and ulna were eroded and invaded by these yellowish-brown masses [Video 1]. Approximately 10 mL of reddish-brown joint fluid was aspirated. Multiple large yellowish nodules invading the distal radius and distal ulna medullary cavity were removed. Few rice bodies were seen and excised. The distal ulna was wholly eroded, and the ulna was cleared free of the lesion by a proximal osteotomy approximately 5 cm from the distal radius [Figure 4]. The aspiration, rice bodies, debrided tissues, and bones were sent for microbiology and histopathological examination (bacterial culture, bacterial and fungal smear, acid-fast staining, and Cartridge Based Nucleic Acid Amplification Test for tuberculosis. The carpal bones were debrided, and the soft-tissue mass eroding them was removed. A proximal row carpectomy was done and used as a bone graft. The distal radius and the distal carpal rows were cleared of the articular surfaces, and wrist fusion was done using a 10° dorsal tilt wrist arthrodesis locking compression plate (LCP) and screws. The extensor carpi ulnaris tenodesis was done to provide stability and prevent distal ulna translation. Postoperatively, the patient was encouraged active finger mobilization and immobilized in a volar wrist splint for 6 weeks. Splints were removed afterward. The radiographs confirmed the wrist fusion 12 weeks after surgery, and all daily activities were started [Figure 5].

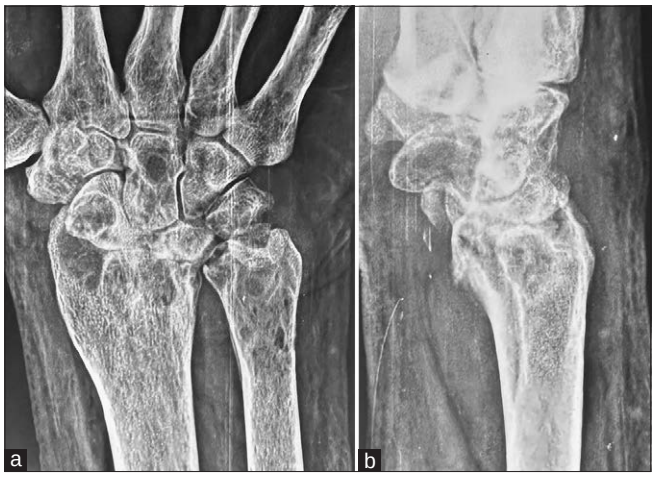

Figure 1: Anteroposterior and lateral radiographs of the right wrist. (a and b) show multiple cysts and erosion in the carpal bones, distal radius, and ulnar with reduced joint space

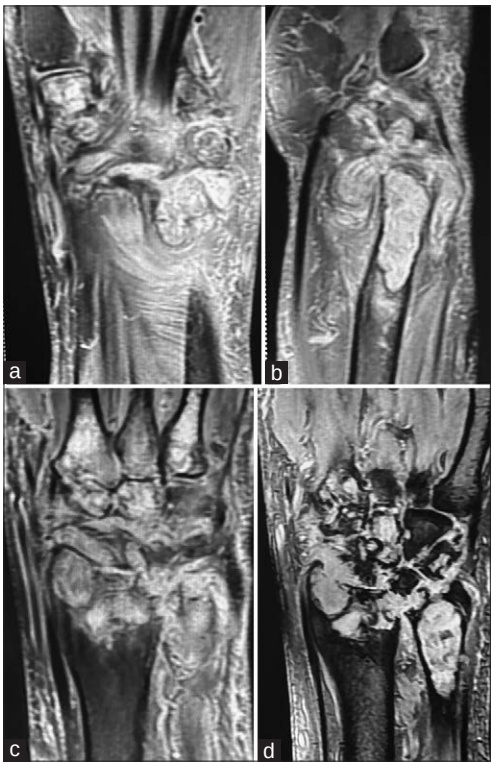

Figure 2: Coronal T2-weighted fat-saturated magnetic resonance imaging (MRI) images (a, c, and d) and Sagittal T2-weighted fat-saturated MRI images, (b) show extensive encapsulated multilobulated soft-tissue masses in the wrist involving the extensor tendons with diffuse erosions involving the distal radius, ulna, scaphoid, lunate, triquetrum, capitate, and the corresponding joints with multiple intraosseous soft-tissue component

The microbiological evaluation was negative for tuberculosis and fungi. The histopathology section found a papillary configuration of synovial lining with underlying stroma showing cleft-like spaces, dense inflammatory infiltrates predominantly lymphocytes with multinucleated giant cells, hemosiderin-laden macrophages, and few congested vessels, confirming the diffuse type of TSGCT [Figure 6]. The antitubercular drugs were stopped. No postoperative radiotherapy, nonspecific anti-inflammatory treatment (antitumor necrosis factor [TNF] alpha), or colony-stimulating factor (CSF)-CSF1 receptor/1R inhibitors were given. The patient was pain-free, the DASH score was 11, grip strength was 50% better than the preoperative value, and a high degree of patient satisfaction at 2 years of follow-up. The hand and elbow range of movements was good [Figures 7 and 8]. There were no complications or recurrence noted.

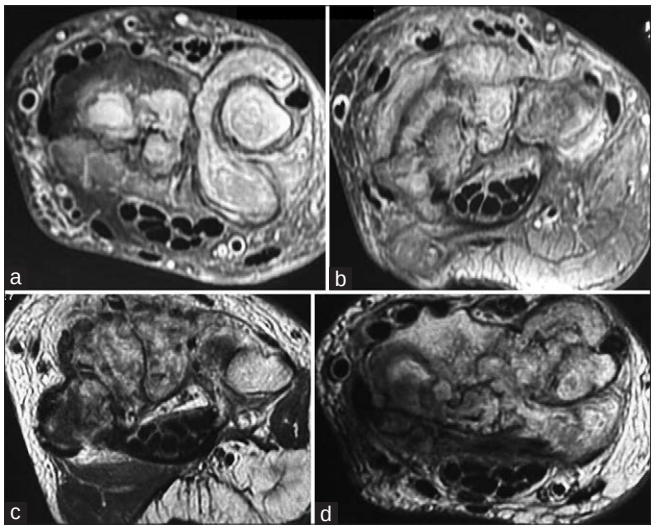

Figure 3: T2-weighted fat-saturated axial magnetic resonance imaging (MRI) (a and b) and T2-weighted images MRI, (c and d) show the dorsal to the volar extension of the lesion around the distal ulna with diffuse erosions into the medullary cavity of the radius and ulna

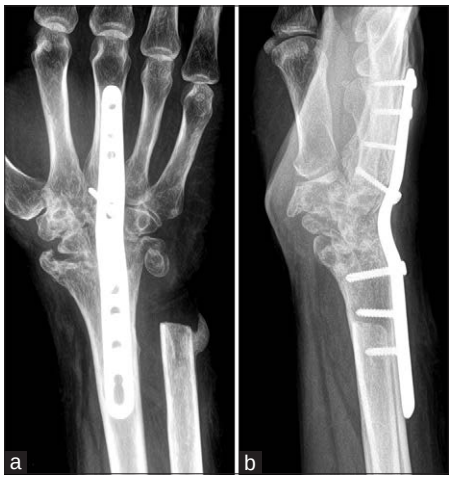

Figure 5: Postoperative radiographs (a and b) of the wrist arthrodesis

Discussion

Diffuse TSGCT of the wrist with joint destruction and invasion is rare, and no literature exists on its management. This report describes the challenge in diagnosing TSGCT in the wrist and effectively treating it with an arthrodesis. However, intra-articular

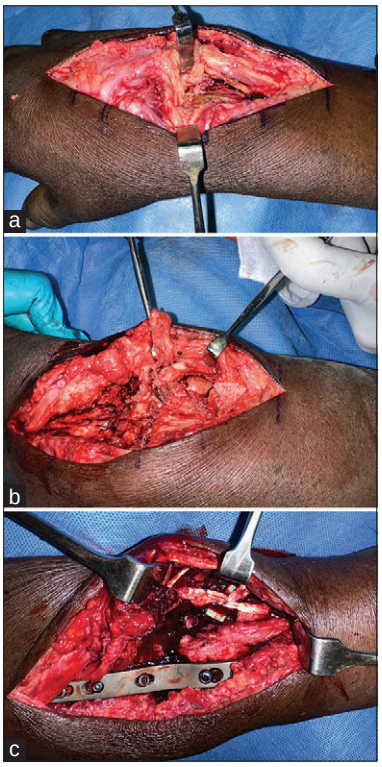

Figure 4: (a) The intraoperative picture shows multiple nodules involving the extensor sheath and capsule, (b) Intra-articular and intraosseous extension lesions involving the distal radius and ulna. (c) Wrist arthrodesis

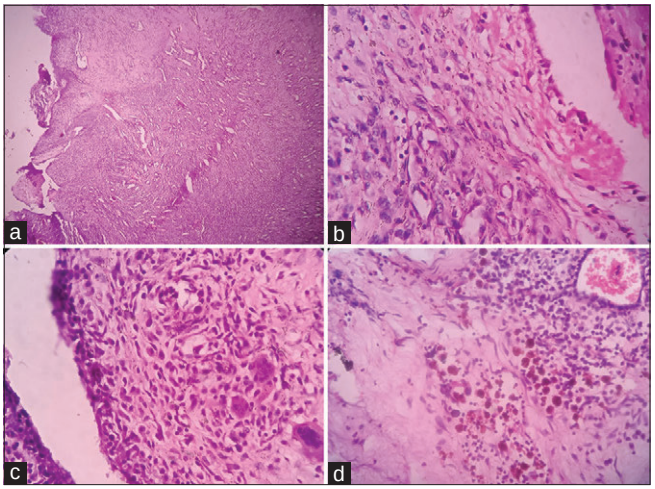

Figure 6: The histopathology section (H and E stain) found a papillary configuration of synovial lining with underlying stroma showing cleft-like spaces (a-c), inflammatory and spindle cells (b) dense inflammatory infiltrates predominantly lymphocytes with multinucleated giant cells (c), hemosiderin-laden macrophages (d), and few congested vessels, confirming the diffuse type of tenosynovial giant cell tumour

invasion is seen in the knee, hip, ankle, and shoulder, presenting as severe joint restriction, swelling, and pain.[1,2] Chondrolysis and intraosseous extensions are also seen in the hip, and mostly, these TSGCTs progress to osteoarthritis.[1] The symptom progression is slow and may take 10 months to 10 years, especially in extra-articular and tendon sheath forms.[1,2]

Diffuse TSGCT is challenging to treat because of the intraosseous extension and 21%–50% recurrence.[2] Open or arthroscopic synovectomy and resection of all pathological tissue are done for intra-articular lesions in the knee. In addition, dislocation is done for hip lesions. Stiffness and recurrences are inevitable.[1,2] Fusion is recommended for the diffuse type of involvement in the foot and ankle.[1-3] Little is known about the management of diffuse TSGCT of the wrist.

Our case had painful swelling and wrist joint restriction for 1 year with no improvements from antitubercular drugs. The symptoms and the clinical-radiological features could not differentiate the pathology from tuberculosis or inflammatory etiologies.[4-7] Tuberculosis of the wrist is rare and has the same clinical presentation (pain, swelling, and restriction of joint motion). MRI will show synovial thickening, fluid collection in the tendon sheath, intercarpal and radiocarpal joint erosion, and osteomyelitis.[8,9] Rarely, the sinus tract is seen in children, directing the diagnosis to infective etiology (tuberculosis).[7] It is difficult to differentiate tuberculosis from diffuse TSGCT based on the MRI findings. This was the possible reason he was getting antitubercular drugs elsewhere. The persistence of symptoms made us rethink and evaluate.

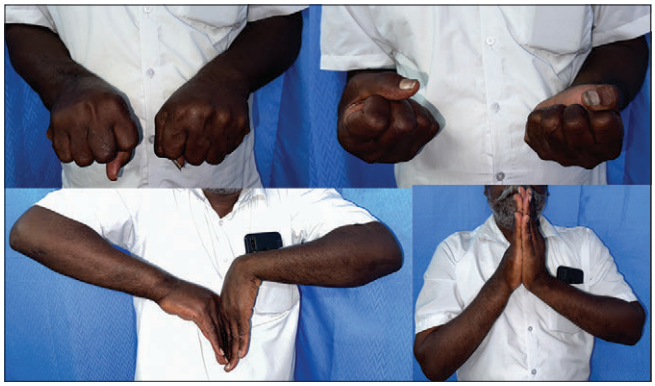

Figure 7: The follow-up wrist pictures of the patient with a range of motion. There are no movements at the wrist and good movements at the hand and elbow

In our case, surgical exploration revealed the involvement of synovium, tendon sheath, and intraosseous extension in the radius and ulna with few rice bodies. The tuberculosis wrist may sometimes have numerous rice bodies, gray caseous substances, and intra-articular involvement.[6] Since this patient was on antitubercular drugs for a year, we may not expect these findings. Notably, rice bodies are also seen in seronegative arthritis, rheumatoid arthritis, systemic lupus erythematosus, and osteoarthritis joints.[10] The histopathology (multinucleated giant cells area in the background of polygonal ovoid mononuclear stromal cells) differentiated the lesion from other pathologies. It confirmed the diffuse TSGCT in the wrist despite inconclusive clinical-radiological features of joint destruction and invasion.

Postoperatively, radiation therapy is considered for diffuse TSGCT where complete resection is impossible to reduce recurrence and is found to have no risk of malignant transformation.[11,12] Triamcinolone hexacetonide intra-articular injection is administered for children with uncertain benefits.[1,13] Recently, biological approaches targeted therapy by identifying

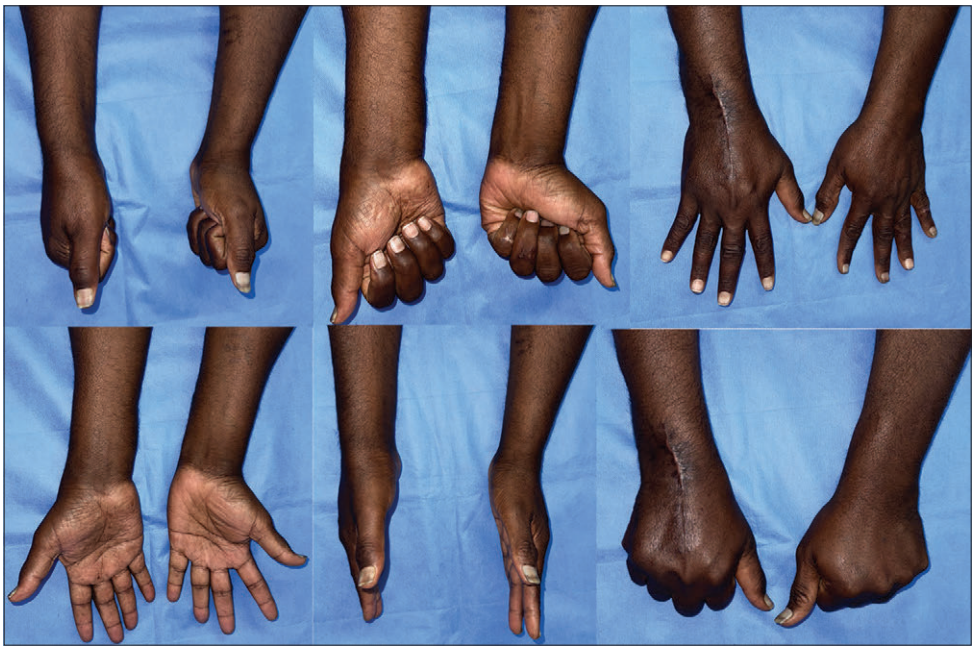

Figure 8: The follow-up pictures of the patient with a range of motion. There are no movements at the wrist and good movements at the hand and elbow

the molecular mechanisms underlying TSGCT. Imatinib, a tyrosine kinase inhibitor (nonspecific anti-inflammatory treatment by anti-TNF alpha), and monoclonal antibody inhibiting CSF1 receptors with emactuzumab has reported encouraging results for the treatment of locally advanced and/or metastatic TSGCT/pigmented villonodular synovitis.[1,13,14] However, there is yet to be consensus on when to use this biological approach and whether to combine it with surgery exclusively as adjuvant or neoadjuvant. Since we had complete resection of the pathology, the wrist being amenable to resect dorsal and volar extension of lesion, nonspecific anti-inflammatory treatment (anti-TNF alpha), or CSF-CSF1 receptor/1R inhibitors was not given to our case.

Kim *et al*.[14] reported a case of huge TSGCT in the volar aspect of the wrist involving the capsule and flexor tendons without joint involvement. The authors removed the mass and performed a synovectomy. The patient reported good functional outcomes and no recurrence at 1 year of follow-up. Zhao and Lu[15] reported a slow-growing giant cell tumor of the tendon sheath involving the extensor indicis proprius (EIP) tendon, which was excised. EIP was reconstructed by direct repair, and the patient remained recurrence-free at 2 years of follow-up.

Our case is unique and rare, with extensive wrist joint destruction and invasion. This has yet to be reported. With difficulty differentiating from tuberculosis, extensive surgical debridement, excision of the eroded distal ulna, and wrist fusion with LCP plates and screws achieved a good functional outcome and no recurrence at 2 years of follow-up. The histopathological study confirmed the diffuse TSGCT in our case. We did not give postoperative radiation therapy or a biological approach for our patient because of extensive surgical resection of all pathological lesions in a small joint wrist amenable for 360° debridement. Furthermore, the decision was made on clinical improvement, pain-free wrist, objective responses, and radiological fusion. However, this patient is on radiological and clinical surveillance.

We recommend having a suspicion in patients with painful swelling and joint restriction and should have TSGCT wrist as one of the differential diagnoses. This single case is a limiting factor and may not play a traditional role or a protocol for all wrist joint destruction and invasion. Histopathology remains the gold standard for diagnosis in such cases. Immunohistochemical examination and CD 68 (+) and Ki-67 (+) confirm the TSGCT and differentiate it from other conditions. Not performing the immunohistochemical study is an additional limiting factor of this report.

Conclusions

Diffuse TSGCT is rare in the wrist, with intra-articular destruction and invasion that may mimic tuberculous arthritis. Histopathological evaluation and radical resection of the synovium, tendon sheath, bursae, distal radius, ulna, and wrist fusion can achieve a good functional and radiological outcome. Still, case–case discussion and complete surgical excision of intra-articular TSGCT wrist are mandatory to treat effectively and prevent a recurrence. Extended follow-up and surveillance are vital.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Megaprosthesis Elbow Replacement in Chronic Nonunion of Distal Humeral Fracture

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Abstract

Megaprosthesis replacement of the joints is mainly indicated to manage the bone defects caused by the excision of malignant tumors. Megaprosthesis replacement of the elbow is comparatively less done as compared to the knee joint. In posttraumatic sequelae of elbow injuries like chronic nonunion of distal humeral fracture with bone defects, the megaprosthesis replacement of the elbow can be a viable option to restore the function and stability of the elbow. We present here a case of chronic nonunion of the distal humerus managed successfully by megaprosthesis replacement of the elbow.

Keywords: Chronic nonunion, distal humeral fracture, elbow replacement, mayo elbow score, megaprosthesis elbow replacement, nononcological, range of motion

Introduction

Since the 1940s, reports of using megaprosthesis replacement of the joints have primarily centered around managing bone defects caused by the excision of malignant tumors.[1] Megaprosthesis refers to an extensively engineered, modular, and customizable implant specifically designed to replace large portions of a joint. Megaprosthesis replacement of the elbow is comparatively less done as compared to the knee joint.[2] In severe posttraumatic sequelae of elbow injuries such as malunited, ununited, or nonunited fractures with bone defects and implant failure, the surgery is difficult due to the biomechanical complexity of the elbow joint and the closer proximity of vital structures including blood vessels and nerves.[3] The megaprosthesis replacement of the elbow in such a scenario may be the optimal choice to restore the function and stability of the elbow.[4]

We report a rare case of 68 years female, who underwent megaprosthesis replacement of the elbow for a chronic nonunion of the distal humerus with implant failure and severe osteoporosis.

Case Report

A 68-year-old female presented to us with a history of injury to the left elbow 2 years prior. This led to a comminuted fracture of the left distal humerus with intra-articular extension. Open reduction internal fixation (ORIF) with a distal humeral locking plate and screws was done followed by an above elbow slab application for 3 weeks. Active as well as passive range of motion was initiated after the removal of the slab. However, this distal humeral fracture did not heal and progressed to nonunion with stiffness and deformity of the elbow. There was no neurological involvement.

Her presenting complaints were pain and reduced range of motion (ROM) of the elbow. Local examination revealed a surgical scar on the posterior midline of the distal arm and elbow and deformity [Figure 1]. There was no local rise of temperature around the left elbow. Preoperative erythrocyte sedimentation rate, C-reactive protein, and blood counts were normal, ruling out infection. The elbow flexion was possible up to 90° but there was 40° of extension deficit. Assessment of muscle power using the Medical Research Council grading

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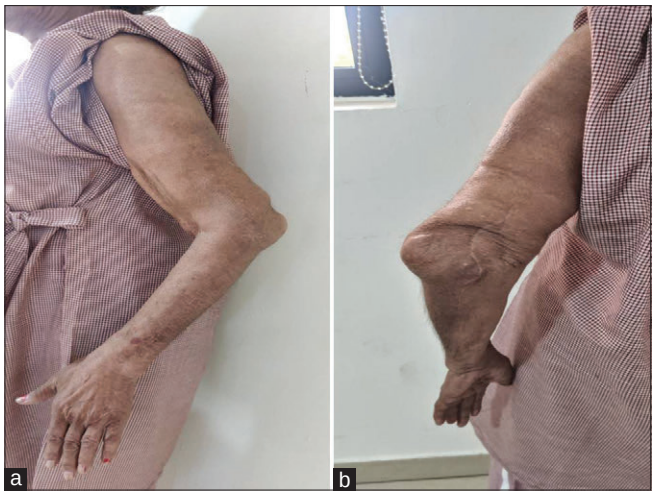

Figure 1: Preoperative clinical photograph showing elbow deformity. (a) Side view; (b) Posterior view

scale indicated that the power of her finger flexors, wrist, and elbow flexors was 4/5. The motor power of the left fingers, wrist, and elbow extensors was 4/5.

Plain radiographs revealed a nonunited distal humeral fracture with plates and screws *in situ* and bone gap at the fracture site and osteoporosis around screw and metal implants. In addition, there was a deformity of the distal humerus [Figure 2].

Given the pronounced distortion in the anatomy of the distal humerus with the presence of insufficient bone stock and a noticeable gap at the site of the nonunited fracture, alongside the severe deformity and stiffness evident in the elbow joint, the decision was made to proceed with a megaprosthesis replacement of elbow. Under general anesthesia, the elbow and distal humerus were approached posteriorly. The ulnar nerve was first isolated and carefully dissected. A nerve tape was passed around the ulnar nerve for preservation and easy identification of the nerve. We avoided the use of cautery, sharp dissection, and vigorous retraction around the ulnar nerve, during the surgery. The metal implant plates and all the screws were removed. Bone gap, fibrosis, and osteopenia were encountered between the fractured ends of the bone. It was observed that the distal humeral condylar fragments exhibited malpositioning, signs of osteoporosis, and destruction. Hence, osteosynthesis or conventional total elbow replacement (TER) was deemed unfeasible. Hence, the distal humeral bone fragments were excised, and the residual bone gap was reconstructed using cemented titanium elbow megaprosthesis (xl-Advance modular elbow systems™-XLO, India). A good correction of the elbow deformity was achieved intraoperatively, with a ROM of 10°–130°, and a stable elbow joint. Postoperative X-ray showed good placement of the prosthesis with adequate cementation [Figure 3]. The limb was kept in an above-elbow slab for 3 weeks, followed by physiotherapy and rehabilitation exercises. At 6-month follow-up, the Mayo Elbow score exhibited marked improvement rising from an initial score of 50 to a new score

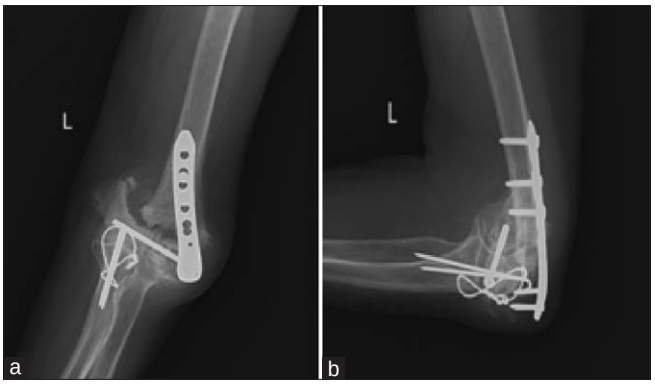

Figure 2: Preoperative plain radiograph showing nonunited distal humeral fracture with implants *in situ*. (a) Anteroposterior view; (b) Lateral view

of 80. The range of motion (ROM) of the elbow was 10° to 110° with good stability [Figure 4]. At 9-month follow-up, the Mayo Elbow score further improved and the new score now is 85. She has a stable elbow joint with a ROM from 10° to 120°. We have emphasized the need for a regular and long-term follow-up to the patient, to check on the progress of the elbow megaprosthesis.

Discussion

Megaprosthesis has been traditionally used for neoplastic conditions of the elbow. The nonneoplastic elbow conditions that may require megaprosthesis include sequelae of severe trauma, where there is extensive damage to the joint after injury, for example, multiple fractures, resistant nonunion, etc., Traditional treatment modalities, in such scenarios, such as open ORIF or primary elbow arthroplasty may not be feasible or may result in inadequate outcomes. Megaprosthesis offers a viable option as a salvage/reconstructive option in these complex situations, as it addresses both the structural integrity and functional requirements of the joint.

The use of megaprosthesis dates back to the 1940s.[2] The term megaprosthesis was introduced during the International Conference on Design and Application of Artificial Materials in Tumor Pathology, which took place at the Mayo Clinic in 1981.[5] Indications for the use of megaprosthesis joints are debatable, even today. Most authors recommend its use in cases such as: after wide excision of malignant bone tumor (for limb salvage), extensive bone loss or very poor bone quality, and posttraumatic sequelae with bone defect or nonunion after surgery.[6,7]

There are cases reported on TER, to manage complex elbow trauma,[8,9] but the use of an elbow megaprosthesis for nonneoplastic indications has only been reported once by Vaishya *et al*.[2] In a study by Figgie *et al*.,[8] a group of 14 patients who underwent total elbow arthroplasty (TEA) were assessed. On an average follow-up of 5 years, Mayo's elbow score improved from 17 to 84 points. However, three patients experienced failure attributed secondary to dislocation, deep infection, and loosening of the humeral component.

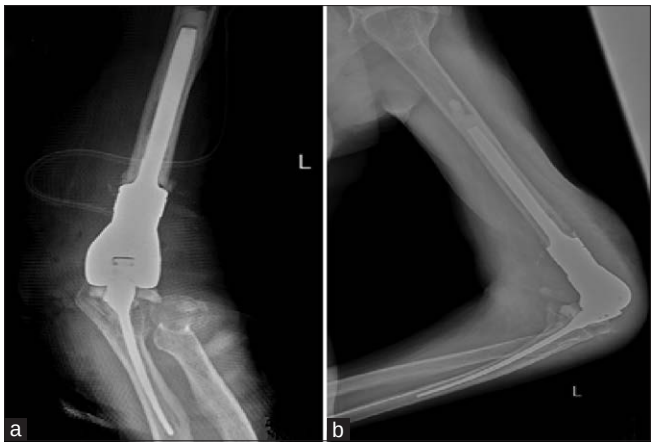

Figure 3: Postoperative plain radiograph showing elbow megaprosthesis. (a) Anteroposterior view; (b) Lateral view

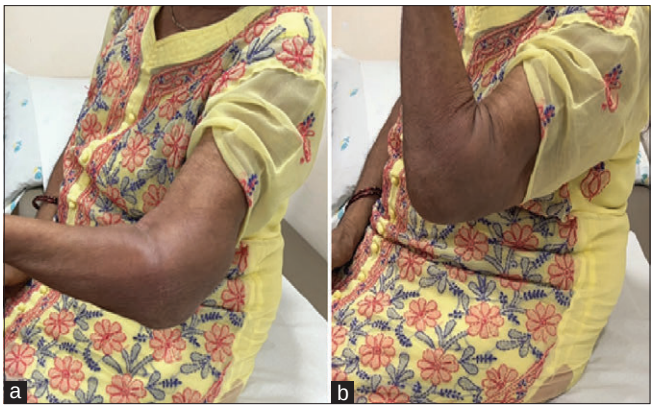

Figure 4: Postoperative photograph showing a range of motion of the elbow at 6-month follow-up. (a) Elbow extension; (b) Elbow flexion

Morrey and Adams[9] conducted a review of 36 middle-aged patients who had undergone TEA. Their study with a mean follow-up of 4 years revealed satisfactory outcomes in 86% of the cases.

Vaishya *et al*.[2] reported their experience of using an elbow megaprosthesis that was used for chronic, resistant nonunion of the distal humerus in a 49-year-old male. This patient had a neglected comminuted fracture of the distal humerus for 5 years, with grossly distorted anatomy and bone loss. Postoperative pain-free ROM of 30°–100° was achieved and the Mayo Elbow score improved from 50 to 80. Our present case too has similar results in terms of pain relief and functional outcome.

The indications of the use of megaprosthesis have now extended from neoplastic to nonneoplastic conditions, like posttraumatic, especially around the knee for distal femoral nonunion.[10] We believe that the use of megaprosthesis in severe and challenging traumatic situations provides a definitive solution.

The planning for a megaprosthesis surgery requires a detailed clinical examination of the elbow joint, a thorough neurovascular examination, and previous operative scars. A new incision should be planned after a detailed examination of the previous scar. The posterior approach is useful to adequately expose the elbow joint. Ulnar nerve isolation and exploration must be done before starting bone preparation. Loose fractured fragments must be excised taking special care to preserve the surrounding neurovascular structures. The bone must also be preserved, to use them as bone grafts later. The humeral and ulnar reaming is to be done with care, especially in old osteoporotic patients. It is essential to evaluate a trial implant to ascertain the absence of impingement caused by osteophytes and also to assess the ROM. In our case, the extension of the elbow was not possible beyond 100°. For this, we had to extend the humeral cut further proximally. The use of antibiotic-loaded cement and a good cementation technique is necessary to achieve a good cement bone interface which in turn prevents future implant loosening and implant failure. However, achieving optimal outcomes also necessitates implementing an effective rehabilitation protocol and patient compliance. The enhancement in quality of life resulting from improved elbow function in these patients supersedes the potential risk associated with this procedure. We acknowledge the limitations of this case report in being a solitary case and with a limited follow-up of 9 months. Nevertheless, it is important to acknowledge that studies incorporating larger case series with long-term follow-up will provide a comprehensive understanding of the efficacy of the procedure, safety, and impact on patient outcomes. Through this case report, we wish to sensitize the readers about this method of treatment, as a reconstructive procedure, for challenging cases like this one.

Conclusion

The advent of elbow megaprosthesis offers a viable treatment option for patients with complex joint nonneoplastic pathologies. These implants hold promise in restoring function, alleviating pain, and improving the overall quality of life in elderly individuals with chronic nonunion of the distal humerus with bone defect and osteoporosis.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given her consent for her images and other clinical information to be reported in the journal. The patient understands that her name and initials will not be published and due efforts will be made to conceal her identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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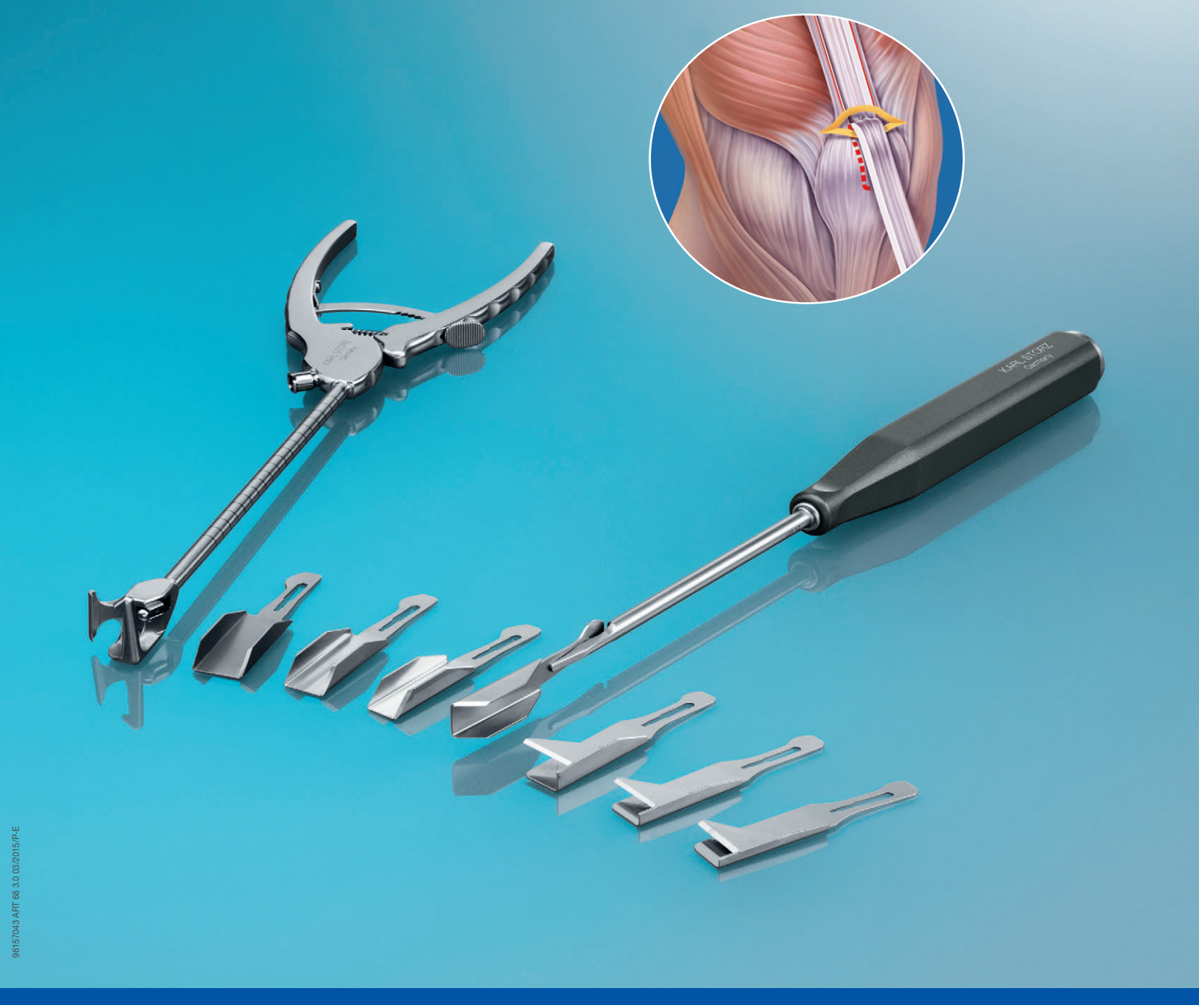

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