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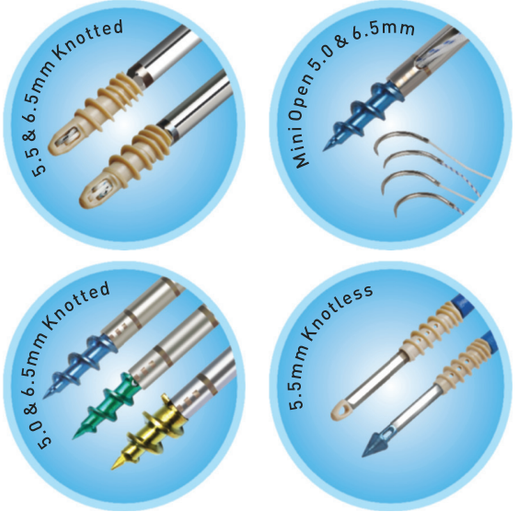

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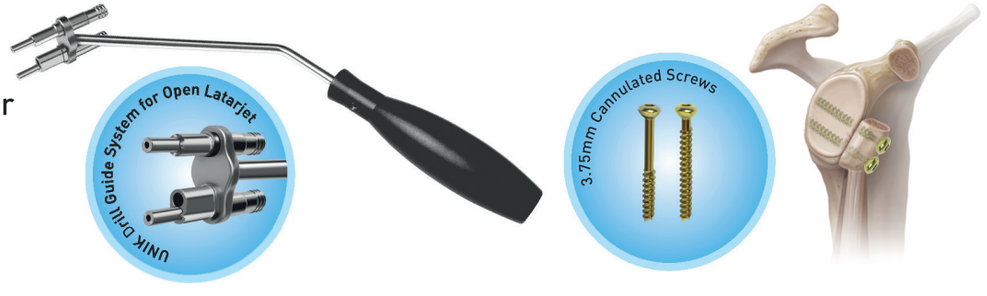

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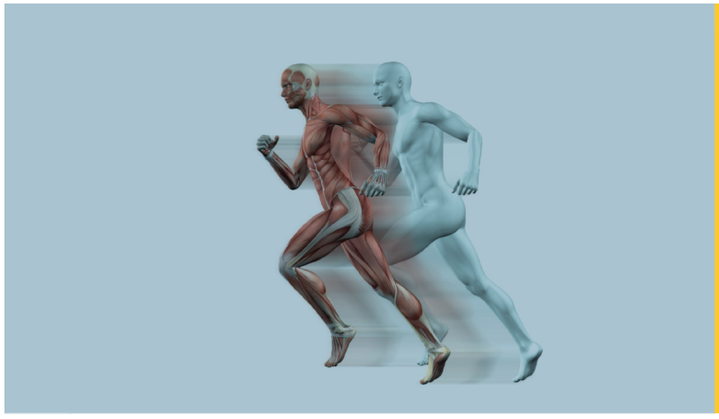

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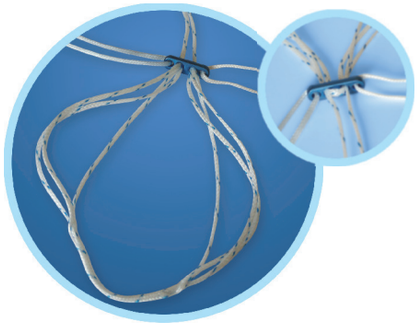

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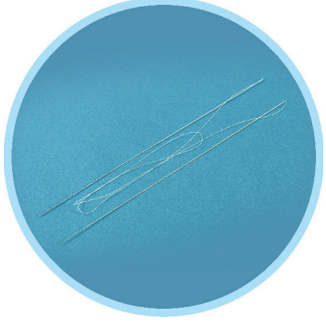

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Journal of Arthroscopy and Joint Surgery (JAJS) is committed to bring forth scientific manuscripts in the form of original research articles, current concept reviews, meta-analyses, case reports and letters to the editor. The focus of the Journal is to present wide-ranging, multi-disciplinary perspectives on the problems of the joints that are amenable with Arthroscopy and Arthroplasty. Though Arthroscopy and Arthroplasty entail surgical procedures, the Journal shall not restrict itself to these purely surgical procedures and will also encompass pharmacological, rehabilitative and physical measures that can prevent or postpone the execution of a surgical procedure. The Journal will also publish scientific research related to tissues other than joints that would ultimately have an effect on the joint function.

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Review article

Arthroscopic management of the stiff knee: A clinical outcome review

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ABSTRACT

Knee stiffness is not uncommon following knee surgeries. A stiff knee alters the normal gait of the person and is a recognized cause of social humiliation for the patient. Due to its minimal invasiveness, arthroscopic management is gaining popularity among surgeons and patients. Arthroscopy has the potential to treat the majority of the non-bony causes of knee stiffness without much hassle of open surgeries. However, arthroscopic management is not devoid of its limitations and complications. So, awareness of arthroscopic management of knee stiffness and its clinical outcomes is of paramount importance to a practising knee surgeon.

1. Introduction

The knee joint is the largest synovial joint in the body withstanding impressive loads during bipedal locomotion.[1] It is also one of the most stable joints in the human body which can allow a wide range of motion in the sagittal plane from up to −10 to 140° with limited motion in the coronal plane facilitating normal gait. Knee stiffness limits this range of motion impeding the normal function of the knee and impairs the gait and climbing ability of the patient. Since squatting and cross leg sitting are the major parts of the daily chores of the Asian population, a stiff knee causes a significant burden to the patient. Therefore, elaborate knowledge in terms of the treatment of knee stiffness is always indispensable for an Orthopaedic surgeon.

Since the knee is in the load-bearing axis of the lower extremity, its injury is the most common injury accounting for an average of 68% of musculoskeletal injuries happening during sports.[2] It also sustains a significant impact during road traffic accidents. Most of these injuries either with or without surgical intervention are associated with knee stiffness mounting morbidity for the patient.

The global burden of diseases 2010, reported that the age-adjusted standardized prevalence of knee osteoarthritis was 3.8%.[3] An international survey including 18 countries showed that the average rate of primary and revision knee replacement surgeries was 175 and 149 per 1 lac population respectively with a compound annual growth rate ranging 5.3%–17%.[4] Even though the stiff knee is an uncommon complication of total knee arthroplasty (TKA),[5] the number of replacement surgeries being performed every year draws attention to all its complications.

Apart from knee surgeries, various conditions like septic arthritis, inflammatory arthritis, and synovial chondromatosis without early treatment have also landed up with knee stiffness.

For decades, open debridement and removal of adhesions with or without quadricepsplasty have been the standard care of treatment for knee stiffness.[6] But, the discovery of keyhole surgery and its application in treating various joint pathologies has changed the perspective towards the management of knee stiffness.[7] Arthroscopic arthrolysis minimizes surgical morbidity in comparison to open surgery.[8] However, there is a scarcity of literature summarizing the clinical indications and outcomes of arthroscopic stiff knee management. Therefore, the present review aims to highlight and discuss the current application of arthroscopy in the surgical management of knee stiffness.

2. Methodology

Pub Med, Google Scholar, Embase, Web of Science, and Cochrane registry searches were performed using terms “stiff knee” “Knee arthrofibrosis” “Arthroscopic management” “Arthrolysis” “surgical management of stiff knee” and “stiff knee management” from 1960 to January 2020. Only articles relating to stiff knee or arthrofibrosis

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management including open or arthroscopic surgeries were selected. The abstracts and the full text of the matched articles were collected and reviewed in detail. References that were cited in the identified articles were also screened for inclusion. A total of 38 articles related to the present study objectives were included and reviewed extensively to consider the therapeutic potential of arthroscopy in the surgical management of stiff knee.

3. Classification of stiff knee

The crux of arthroscopic management of knee stiffness is based on identifying the cause of knee stiffness. Based on aetiology, knee stiffness can be broadly classified as.

1. Knee stiffness due to medical causes
2. Post-operative knee stiffness
3. Post-traumatic knee stiffness

Some of the medical causes of knee stiffness include but are not limited to infective arthritis, synovial chondromatosis, and inflammatory arthritis like rheumatoid arthritis, gouty arthritis, and synovitis due to various reasons. The exaggerated inflammatory cascade is the hallmark of these conditions. Prolonged inflammation along with immobilization finally leads to fibrosis causing knee stiffness.

Post-operative knee stiffness can be either due to the formation of fibrotic adhesions or improper positioning of implants impeding a normal range of motion. Knee stiffness post knee replacement is one of the major causes of postoperative knee stiffness.

Post-traumatic knee stiffness can be broadly classified as intra-articular and extra-articular causes. Intra-articular causes include intraarticular adhesions following knee effusion with or without ligament or meniscal injuries and mal-union or non-union of intraarticular fractures. Extra-articular causes include quadriceps tethering following shaft femur fractures mostly distal 1/3rd fractures and injuries affecting extensor mechanism.[9]

Identifying the cause is critical in selecting the modality of treatment for knee stiffness.

4. Examination

A thorough clinical examination to identify the aetiology of flexion or extension contracture is a must before any treatment. A goniometer can be used to measure the degree of contracture. Preoperative counselling of the patient to discuss the target range of motion required to meet the demands of the patient is mandatory. Identifying any signs of Complex Regional Pain Syndrome (CPRS) in post-traumatic patients is a must since any surgical intervention during the active phase of CRPS is contraindicated. A sequential Bone scan can be used to identify the timing of surgery in knee stiffness patients with CRPS. A successive decrease in uptake in the bone scan can signify the resolving trend of CRPS.[9]

Radiological examination is necessary to identify any bony ankylosis/obstructions due to malunion or implant mal-position. Noting patella height is a must in lateral radiograph since knee stiffness due to Patella Baja requires an open surgical procedure.[9] Radiographs can also identify loosened components in Total Knee Arthroplasty (TKA) causing obstructions in the knee range of motion.

Diagnostic confirmation of arthrofibrosis can also be done by preoperative Magnetic Resonance Imaging (MRI). It also helps in identifying any ligament or meniscal injury that can be addressed during arthroscopy.

5. Indications

Arthroscopic arthrolysis is now a standard technique for post-traumatic knee stiffness.[9] Restriction either in flexion or in extension or both due to fibrotic adhesions can be successfully treated by arthroscopy. Operative intervention done for intraarticular fractures, ligaments or meniscal injuries may lead to intraarticular adhesions, that can be addressed effectively using arthroscopic debridement after a certain duration following healing of ligaments or union of bone.

Amr El Gazzar treated 11 patients with post-traumatic knee stiffness by arthroscopic arthrolysis. Eight among 11 patients were operated on previously for intra-articular and peri-articular fractures and 3 were treated for ligament injuries.[10]

One of the early mentions of arthroscopic arthrolysis for post-operative knee stiffness was by W. Klein et al. and the majority of these patients were previously treated for Anterior Cruciate Ligament (ACL) injuries.[11]

Dhillon et al. have successfully treated quadriceps contracture due to shaft femur fracture using long arthroscopic scissors. Adhesions up to nine inches above the patella were released. They have even claimed to treat bony ankylosis between the patella and femur using arthroscopic assisted debridement with long osteotomes.[12]

Since the arthroscopic procedure is associated with minimal morbidity as compared to open procedure, its role has been extensively studied in treating complications of knee arthroplasty. In 1987, Campbell et al. could treat flexion contracture causing arthrofibrosis post TKA using arthroscopy in eight patients.[13] Klinger et al. used arthroscopy as their diagnostic tool to determine the aetiology for the painful total knee arthroplasty. Arthrofibrosis was the direct cause of painful TKA in 11 out of 27 patients who were successfully treated arthroscopically in the same setting.[14] Most of the authors have considered an aggressive, supervised physiotherapy regimen in the initial three months for the management of post-TKA knee stiffness before attempting arthroscopic arthrolysis.[13]

6. Contraindications

Infection is an absolute contraindication that requires thorough open debridement. Grade III degenerative joint disease, the active phase of CRPS, poor compliance of the patient, axis deviation of $>5^{\circ}$ are relative contraindications for arthroscopic arthrolysis.[11]

Post-traumatic stiffness due to malunited periarticular or intraarticular fractures require an open procedure to remove the bony blocks impeding joint movements. Attempting arthrolysis and mobilization before a complete union of fractures is not advisable since the uncontrolled mobilization can precipitate re-fractures. Awaiting till consolidation of reconstructed ligaments is reasonable before attempting to treat knee stiffness surgically.

Patella Infera/Baja requires an open surgical procedure to lengthen or reconstruct the patellar tendon or proximalization of the tibial tubercle.[9] Aseptic loosening or dislodgement of TKA components impeding knee motion may require revision surgery.

7. Arthroscopic technique

After a thorough pre-operative evaluation, a passive range of motion (ROM) of the affected joint should be noted under anesthesia and should be compared with the preoperative recorded ROM.

A pneumatic tourniquet when used should be applied over the proximal thigh as high as possible. It should be deflated before attempting mobilization after arthrolysis for unrestricted gliding of

Table 1
Summary and comparison of several studies evaluating the efficacy of arthroscopic arthrolysis in post-TKA knee stiffness.

STUDY	NUMBER OF PATIENTS	INDICATION	TREATMENT	RESULTS
Sprangueet al[7] 1982	1	Arthrofibrosis	Arthroscopic release	No improvement
Del Pizzo et al.[21] 1985	8	Arthrofibrosis	Arthroscopic release	No details
Campbell[13] 1987	8	Arthrofibrosis	Arthroscopic release	7/8 improved
Parisien[22] 1988	1	Arthrofibrosis	Arthroscopic release	Improved
Wasilewski and Frankl[23] 1989	13	Arthrofibrosis and infrapatellar spur	Arthroscopic arthrolysis	7/13 improved
Hirsch and Sallis[24] 1989	1	Impingement	Arthroscopic debridement	improvement
Lawrence and Kann[25] 1992	1	Arthrofibrosis	Arthroscopic arthrolysis	improvement
Jerosch and Schröder[26] 1996	29	Intraarticular fibrous plicae	Arthroscopic debridement	25/29 cases improved
Markel et al.[27] 1996	46	Peripatellar fibrosis	Arthroscopic debridement	27/46 improvement
Williams et al.[28] 1996	10	Limited ROM	Arthroscopic release of PCL	8/10 improved
Court et al.[29] 1999	4	Arthrofibrosis	Arthroscopic arthrolysis	4/4 improved
Henkel et al.[30] 1999	26	Limited ROM	Arthroscopic arthrolysis	23/26 improved
Corces et al.[31] 2000	11	Pain and Limited ROM	Arthroscopic arthrolysis	10/11 improved
Blumberg et al.[32] 2001	33	Pain and Limited ROM	Arthroscopic arthrolysis	31/33 improved
Scranton[33] 2001	10	Pain and Limited ROM	Arthroscopic arthrolysis	9/10 improved
Ternovyi and Zazirnyi[34] 2001	4	Extension Contracture	Arthroscopic arthrolysis	4/4 improved
Djian et al.[35] 2002	6	Limited ROM	Arthroscopic arthrolysis	6/6 improved
Teng et al.[36] 2002	11	Limited ROM	Arthroscopic arthrolysis	11/11 improved
Klinger et al.[14] 2005	12	Intraarticular adhesions	Arthroscopic arthrolysis	9/11 improved
Schwarzkopf et al.[37] 2013	19	Limited ROM	Arthroscopic arthrolysis	19/19 improved
Bodendorfer et al.[38] 2017	18	Limited ROM	Arthroscopic arthrolysis	17/18 improved

quadriceps muscle.

The surgical procedure requires standard arthroscopic instruments, basket clamps, mayo scissors, motorized shaver, and electrocautery probe. After tourniquet inflation, standard arthroscopic portals-anteromedial, anterolateral portals are made. Suprapatellar portals can be made if required. Inspection of the joint is done in a sequential manner starting from the suprapatellar pouch, lateral retinacular gutter, medial retinacular gutter, infrapatellar region to intercondylar notch. Adhesions noted are removed using a motorized shaver. Arthroscope and instruments interchanged between the portals as per convenience.

In cases with previous ACL reconstruction, one should look for hypertrophic tissue at the base of graft known as 'Cyclops lesion' and should be excised.[10] If there is any impingement of the reconstructed graft causing a limited extension, it might require the notch plasty.[10]

Bansal et al.[15] have described a technique where saline-soaked ribbon gauze was packed in layers between patellofemoral articulation using suprapatellar portals. The ribbon gauze piece at the patellofemoral interface lifts the patellar up, stretching the quadriceps and increases the mechanical lever arm of the extensor mechanism. An increase in the range of motion was noted after the removal of the gauze piece from the joint.

Cases with limited knee extension might have posterior adhesions and capsular contractures. To address it, the posteromedial compartment of the knee joint can be accessed by negotiating scope through the intercondylar notch along the axial axis of the medial femoral condyle. Also, it is recommended to make posterior portals at 90° knee flexion to avoid damage to posterior neurovascular structures[16]). Posterior portals are required for arthrolysis if extensive posterior adhesions are noted. The posteromedial portal is made at around 1 cm above the tibiofemoral joint line, 5 mm behind the femoral condyle through the transillumination technique.[17] The posterolateral portal is made similarly by accessing the posterolateral compartment by passing scope through the anteromedial portal along the axial axis of the lateral femoral condyle. The transseptal portal is made by passing a blunt obturator through the posterior septum just behind Posterior Cruciate Ligament (PCL) from the medial to lateral side.[18] The anterior part of the septum can be resected with the help of a shaver to convert the posteromedial and posterolateral compartment into one posterior compartment. It is recommended to pierce the distal part of the septum just behind PCL to avoid damage to vessels passing through the proximal part of the septum.[19] After releasing the posterior capsule, the origin of gastrocnemius muscles can also be released to facilitate further extension if required.

8. Results

Among 11 patients treated by Amr El Gazzar for post-traumatic knee stiffness, 8 patients showed satisfactory results.[10] W. Klein et al. treated 43 of 56 patients with postoperative knee stiffness successfully by arthroscopic arthrolysis. The majority of these patients were previously treated for ACL injuries. The average time between the two surgeries was 22.8 months and arthrolysis was done following the failure of a minimum of six months of physiotherapy.[11]

Several authors have studied the role of arthroscopy in treating post-TKA knee stiffness [Table 1]. For homogenous assessment and analysis, we have enumerated studies with only arthroscopic management of knee stiffness following TKA. Studies that were done before 2000 had shown the efficacy of arthroscopic management in 75% of patients. However, studies after 2000 have shown improvement in around 94% of the patients. This plausible difference in the outcome could be attributed to the advancement in the techniques of arthroscopy in recent years.

Fitzsimmons et al.[20] in their review article have shown the efficacy of arthroscopic arthrolysis up to one year after index surgery. And they had also emphasized that arthroscopic arthrolysis in combination with Mobilization under Anesthesia (MUA) has a superior outcome than the open procedure.

9. Complications

Since the contracted joint has limited space to manoeuvre the instruments, the chance of instruments breakage with inexperienced hands is inevitable. Post-arthrolysis infection is also a common complication. Patellar tendon avulsion, patella fracture can also occur during mobilization after arthrolysis. Due necessary precautions to avoid these complications should be taken during the procedure.

10. Conclusion

Arthroscopic arthrolysis is a better alternative to open arthrolysis for various causes of knee stiffness. It should be attempted after the failure of a minimum of 3 months of extensive physiotherapy post-primary surgery. One can achieve a good functional outcome up to 1-year post-primary surgery if combined with MUA.

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Ethical approval

Ethical approval not required as per our Institute Review Board. All procedures performed in this study involving human participants were in accordance with the ethical standard of the institutional and/international research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Author's contribution

Hemant Bansal: Conceptualization, Methodology, Writing-Reviewing and Editing. Vivek Veeresh: Data curation, Writing-Original draft preparation. Hiralal Nag: Supervision, Validation.

Declaration of competing interest

All authors declare that there is no conflict of interest to disclose.

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The management of osteochondral loss in the skeletally immature knee

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ABSTRACT

Osteochondral lesions in children and adolescents can be managed by different techniques. There is a paucity of evidence with regards to the optimal management of these particular lesions. Salvage options are mostly inferred from the adult literature, with Autologous Chondrocyte Implantation the most popular technique. The use of fresh allograft has good documented outcomes in this cohort.

1. Introduction

Osteochondral defects of the knee in the skeletally immature encompasses Osteochondritis Dissecans (termed Juvenile OCD) and traumatic osteochondral fractures (OCF). If untreated, both can lead to worsening pain and osteoarthritis. It is not uncommon to encounter neglected cases with loose fragments, or cases where both operative and non-operative treatment has failed. Where defects of the articular surface and subchondral bone are present in the paediatric cohort, techniques utilized in the adult sector often have limited evidence for use. Here we review the evidence for treatment of the paediatric cohort with osteochondral loss within the knee joint.

2. Non-operative management

Conservative management has been successfully applied for small fragment OCFs (<1.5 cm).[1,2] The decision to treat JOCD conservatively is dependent on the patient's skeletal maturity, symptoms, location and stability of the fragment. Small defects (<2 cm^2), and those located at the 'classic' area (posterolateral aspect of medial femoral condyle) are more likely to heal. Cahill proposed that 50% of these lesions heal within 12–18 months as long as the physes remain open and patients are compliant with restricted activity.[3] Other studies have shown healing rate up to 67% by 6–12 months.[4]

There is also no consensus as to the ideal method of non-operative management. Modalities range from limiting weight bearing and activity restriction to cast or brace immobilization.[1] Many children at higher levels of sporting activities struggle with compliance and may require counselling and reinforcement regarding the benefit of conservative management during this stage.

Presentation with mechanical symptoms, joint effusion, large lesions and radiological evidence of subchondral sclerosis at 6 months are all poor prognostic factors.[1,5–7] Patients with these findings and larger, displaced defects will likely suffer deleterious effects if managed conservatively. Studies in animals have shown correlation between the size of the defect and resultant surrounding chondral degeneration. Heuijerjans et al. sought to biomechanically recreate the joint and assess the effect of imparting varying forces and changes with defect sizes. They found that a small increase in defect size lead to an exponential increase in surrounding superficial collagen fibre strain. The authors proposed that filling this defect would increase the surface area able to partake in load bearing, thereby decreasing surrounding cartilage strain.[8] A cadaveric study in 8 knees also showed that in defects ≤

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8 mm there was no increased stress concentration around the defect. In this case, the menisci functioned significantly in the redistribution of this load. However, defects ≥10 mm were associated with increased stress concentration along the defect rim and within surrounding cartilage, increasing the risk of progression to osteoarthritis[9]

3. Operative management

For both OCF and JOCD, operative intervention is undertaken in patients who have failed conservative management with continued symptoms or if radiographic evidence of progression to fragment instability exists.[1,5] The aim of surgical treatment is to stabilise the cartilage, maintain joint congruity and repair the osteochondral defects, while causing minimal damage to the physes or iatrogenic injury to the joint, thereby decreasing the risk of osteoarthritis.[3] Interventions are either reparative or restorative.[10] Though multicentre studies are lacking, it is generally agreed that drilling (transarticular or retroarticular) is the best option for symptomatic stable lesions, with good outcomes demonstrated in systematic reviews.[1] Reduction and fixation of unstable but salvageable fragments is also recommended. However, difficulty exists in deciding the best options for unsalvageable lesions. Concomitant conditions such as patellar instability, Anterior cruciate ligament deficiency and limb deformity (leading to malalignment) may also need to be addressed.[11]

3.1. Debridement and fragment excision

Debridement and fragment excision has been suggested for small or irreparable OCDs. Excision of fragments <1–1.5 cm, especially if of poor quality, has been described. This may be performed as a standalone procedure or along with microfracture. Isolated excision, though beneficial in the short term, is not recommended due to long term findings of degenerative changes and poor functional scores, with the worst outcomes if performed in weightbearing areas.[1]

3.2. Osteochondral repositioning and fixation

Fixation of the osteochondral fragment can be performed for OCF or unstable JOCD and involve either in situ fixation or fragment repositioning and fixation if the fragment is viable. It is essential to remove the fibrous tissue from the base of the lesion in JOCD, though bone on the cartilage flap should be preserved.[4] Open and arthroscopic techniques are described and fixation can be performed using bioabsorbable screws and pins or metallic headless or headed compression screws. Fig. 1a and b shows the successful use of bioabsorbable pins for the fixation of an unstable OCD of the lateral femoral condyle. Metallic implants will warrant surgical removal after healing. The benefit of this is the opportunity to review stability and healing of the fragment at the time of surgery.[1] If a viable cartilage flap is present, it can be partially hinged open, its base debrided with microfracture and bone graft inserted if necessary.[10]

A French multicenter study identified 14 skeletally immature patients with OCFs of the lateral condyle and patella that underwent open or arthroscopic surgical repositioning and fixation within 20 days of injury. Over a mean follow up of 30 months, no patient needed revision of fixation.[2] Though patients in this study had surgery acutely and the recommendation is for early treatment of OCFs, case studies have documented successful surgical treatment at 2 months post injury.[12] Increase in the fragment size, cartilage degeneration and subsequent mechanical symptoms can occur if displaced fragments are not treated early.[1]

Repositioning and fixation techniques utilized for JOCDs are similar to that described for OCFs with good success rates of 91–100%. If necessary, autologous bone grafting (from the proximal tibia or iliac crest) can also be utilized.

Fixation of purely chondral lesions in children has been proposed due to greater healing potential.[2] In a retrospective multicenter study of 15 patients with isolated chondral lesions, debridement of the lesion and subchondral drilling was performed, followed by reduction and fixation of the chondral fragment with bioabsorbable screws, tacks and sutures. This was supplemented with fibrin glue in 3 patients. One patient suffered re-injury 8 weeks postoperatively and underwent fragment excision while another had surgery at 1 year to remove unrelated loose bodies. For the latter, arthroscopy showed evidence of healing of the chondral fragment. MRI was performed within a median of 12 months postoperatively and showed cartilage contour restoration in 5 patients and thinning in 2. These patients had evidence of subchondral advancement into the deep cartilage layer. Cartilage thickening occurred in 1 patient while subchondral oedema and cartilage fissuring occurred in another. All patients returned to sports and other activities post-operatively within 6 months. It was suggested that these lesions may in fact have microscopic bone attached which improved healing capability.[13] Of note, in either study, no recommendations were made as to the fragment size that was amenable to fixation. Limited studies of high caliber are available to further assess fixation of isolated chondral lesions.

4. Salvage options

Multiple methods of treatment have been described if repositioning and fixation of the fragment is not possible. Such defects have limited treatment options due to the lack of intact articular cartilage (Fig. 2). Options include bone marrow stimulation techniques (such as microfracture and autologous matrix induced chondrogenesis), autologous osteochondral or chondrocyte implantation and allograft implantation.

4.1. Microfracture

Microfracture is a minimally invasive procedure advocated for small (≤2 cm^2) OCDs not amenable to repair. Subchondral perforations are performed resulting in haematoma and subsequent fibrous clot formation. This contains mesenchymal stem cells (MSC) and growth factors. Fibrocartilage, which is less durable than hyaline cartilage, forms after MSC differentiation. This method cannot be used to address bone defects and is less effective in JOCD due to the presence of abnormal subchondral bone in some instances.[11,14]

Microfracture was used by Lee et al. for 5 patients with irreparable OCFs (average size 1.2 cm^2) secondary to patellar dislocation. Four (average size 3.2 cm^2) had fixation performed. All were postoperatively assessed with the Knee Injury and Osteoarthritis Outcome score and International Knee Documentation Committee outcome measure. Patients receiving microfracture had better outcome stores but results may be attributable to the difference in severity of injury and subsequent lesion size.[15]

Steadman et al. retrospectively reviewed 26 patients (<19 years of age) who had microfracture for full thickness cartilage defects. Twenty-two patients were followed up for a minimum of 2 years. The defect size ranged from 10 to 600 mm.[2] One patient had trochlear groove microfracture and required revision 1 year postoperatively. Patient satisfaction was excellent. Age and gender were not prognostic.[14]

Microfracture has however been shown to have poor long term outcomes compared to other restorative techniques. Gudas et al. compared this method with mosaicplasty via a prospective

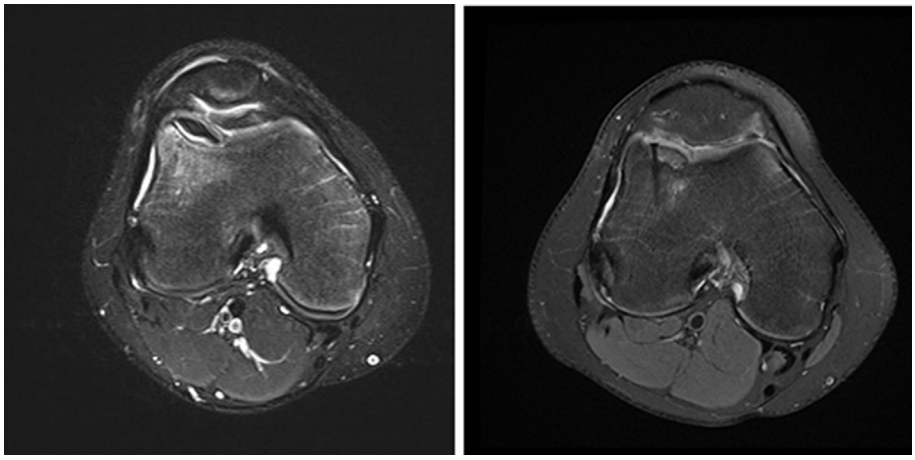

Fig. 1. a: Pre-operative axial MRI image of an unstable OCD, 23 mm diameter, of the lateral femoral condyle. b: Axial MRI image of OCD at 28weeks post fixation with one of four bioabsorbable nails demonstrated.

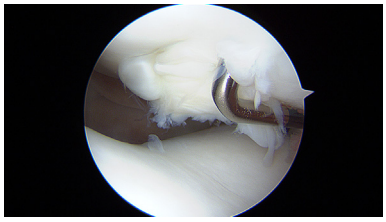

Fig. 2. An arthroscopic image of a patient with long standing unsalvageable patella OCD.

randomized controlled trial in patients less than 18 years and found that at 4.2 years only 63% of patients maintained good to excellent outcomes compared to 83% in the OAT cohort despite comparable results at 1year after surgery. Microfracture was still recommended as there was improvement of the preoperative clinical status.[16]

Due to its shortcomings, 'PLUS microfracture' was developed. This included the use of a membrane (synthetic or periosteum) after microfracture. The principle is to contain and concentrate MSCs at the defect site instead of continued intraarticular expulsion. This procedure has further evolved into autologous matrix induced chondrogenesis (AMIC) which consisted of applying a collagen membrane or matrix after microfracture. Sutures and biological glue are then applied to maintain a stable matrix.[17,18]

4.2. Osteochondral autograft transplantation system (OATS) and mosaicplasty

This is single stage surgery, open or arthroscopic, taking a cylindrical osteochondral graft from a healthy non weight bearing area of the patient's knee and implanting it into the defect. In the mosaic type, multiple small cylinders may be taken from the donor site to fill the defect. Fibrous cartilage is therefore interposed between hyaline cartilage of the osteochondral graft. The success depends on the size and site of defect and matching the radius of curvature on the donor and recipient site. Outcomes are best for defects <2 cm,[2] but it can be used to treat defects up to 4 cm^2 [17]. Valtanen et al. have shown OATS to be useful in lesions up to 3 cm^2 with good to excellent clinical outcomes.[14]

As the graft is from the same patient, there are no risks of disease transmission or graft rejection issues, though donor site morbidity limits the size of the graft harvested. Osteochondral bone plugs have also been used for in situ fixation or splinting of stable fragments.[10] Larger defects can be filled with a 'MEGA-OATS' technique, in which larger grafts can be taken from the dorsal or posterior femoral condyle and inserted via the press-fit method.[17]

Hybrid methods of OATS with stabilisation with bioabsorbable or metal implants have been advocated in adults, but there is no literature evidence available for skeletally immature.[4]

4.3. Osteochondral allograft transplantation

Osteochondral allograft transplantation (OCA) is advantageous in the management of large (>2 cm^2) defects that are unsalvageable. A fresh, fresh-frozen or stored allograft, matched for size and contour is transplanted into the defect after it is prepared. An example of this is shown in Fig. 3a–e.

Ninety-eight percent of chondrocytes remain viable at 7 days in fresh allografts and decreases to 70% after 1 month.[14,19] OCA replaces abnormal subchondral bone with normal bone and allows for early structural stability. With time, creeping substitution occurs and the donor bone is replaced.[20] OCA is expensive and microbiological and immunological investigations must be performed during its preparation to decrease the risk of disease transmission and associated morbidity.[19] Some studies address OCA use specifically for OCD in the paediatric age group. At 10-years post OCA in children with a mean age of 16.4 years treated for cartilage defects secondary to JOCD, avascular necrosis and trauma, graft survivorship was 90% with 89% of patients satisfied with their clinical outcome. OCA is also performed as a salvage procedure after failure of other modalities.[20] Availability and cost, often with logistical difficulties due to the shelf life make use of fresh allograft a challenge.

4.3.1. Autologous chondrocyte implantation

The two-stage procedure, autologous chondrocyte implantation (ACI), was initially described for defects >2 cm^2 and involved an initial biopsy of non-articulating cartilage (such as the superomedial or superolateral trochlear edge and the intercondylar notch) with associated subchondral bone.[21] After in vitro multiplication, the chondrocytes are placed within the defect and covered with periosteum harvested from the tibia. If the depth of the subchondral defect is significant (>6–8 mm), autologous grafting is recommended in conjunction with ACI. The graft may be soaked in autologous bone marrow aspirate obtained from iliac crest prior to insertion. Chondrocyte maturation results in hyaline cartilage formation but with a known risk of graft hypertrophy and

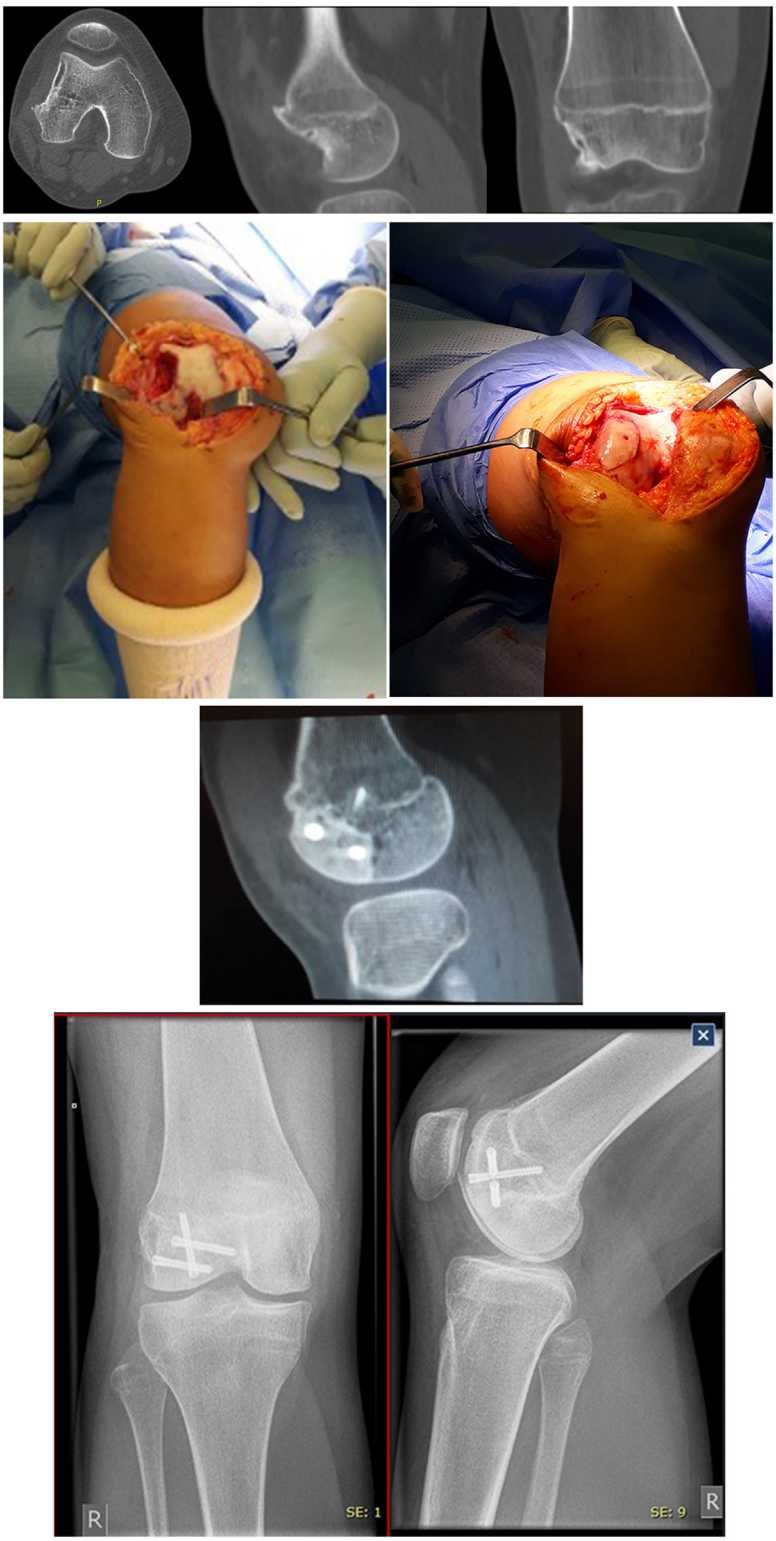

Fig. 3. a. Axial, sagittal and coronal CT images of a large osteochondral defect in the lateral femoral condyle.b. Intra-operative image after the bed of the osteochondral defect has been debrided to bleeding bone.c. The intra-operative appearance after allograft fixation in the same patient. d. A post-operative sagittal CT image of the patient after fixation with metallic variable pitch head-less screws at 6 weeks. e. Plain radiographs 24 months after the initial surgery. There is good bone incorporation of the allograft.

arthrofibrosis.[17,21,22] Long term results were poor when implemented for the treatment of kissing lesions. Hence it is not recommended.[17]

This first-generation procedure has been refined to include artificial membranes instead of periosteum and can be classified as synthetic, proteic and polysaccharid. Hyaluronic acid is commonly used as it aids inhibition of chondrocyte apoptosis and regulates the membrane. Further evolution of the Matrix induced ACI (MACI)

involved porcine derived collagen I and III being used as the scaffold for chondrocyte implantation, resulting in less morbidity and even chondrocyte distribution. High-density ACI, in which the chondrocyte density is increased over MACI fivefold, has been described but no comparative studies are available to assess its benefit.[22] The ACI 'sandwich technique' describes the use of 2 collagen membranes. The membranes are placed over the impacted bone graft and secured with fibrin glue and sutures. The chondrocyte matrix is then placed between the 2 membranes. Though recommended in the paediatric age group for large defects, there is a paucity of literature regarding its use.[11,23,24]

MSC can also be implanted into the defect with the aid of scaffolds including platelet-rich fibrin. The cells are usually derived from bone marrow and can be implanted within a single procedure. The added benefit is that these cells are multipotent and therefore regeneration of both subchondral bone and cartilage is possible 25. Further advancement has led to Autograft Cartilage Transfer (ACT) involving the combination of autologous bone marrow aspiration and concentration, autologous cartilage harvested from the non-articular femoral condyle and a scaffold of allograft cartilage extracellular matrix. These procedures eliminate the need for multiple surgeries but do carry an increased risk of donor site morbidity. They are recommended for young patients with unsalvageable lesions. Likely as a result of its novelty, no studies were identified in the English literature to assess their efficacy in the skeletally immature.[26]

Further benefits of tissue engineering are currently being investigated. The expression of chondrogenic genes can be increased by the in vitro addition of specific growth factors and bone morphogenetic protein 2 (BMP2) to MSC. Tensile strength can be improved by increasing collagen concentration and cross linking with glycosaminoglycan-depleting enzymes and cross linking agents respectively. Non-articular chondrocytes are also being engineered into viable cells, thereby expanding the availability of autologous donor sites.[27]

4.4. *Particulate juvenile articular cartilage allograft transplantation (PJAC)*

PJAC is an emerging single stage procedure involving harvesting cartilage from young donors (0–13 years) and mincing them into small 1 mm^3 fragments. These chondrocyte rich particles are then implanted into the defect and covered with fibrin glue. Its benefit is in its ability to be used for chondral defects with multiplanar contours such as within the patella. Studies involving both adults and children have shown good short-term outcomes.[28]

4.5. *Acellular scaffolds*

Recently, the use of acellular scaffolds has been advocated for JOCD, highlighting the benefit of a single stage procedure over ACI with no need for in vitro chondrocyte manipulation and the costs associated with it. A study in 20 children described implantation of a biphasic acellular scaffold consisting of collagen type 1 and hydroxyapatite at varying concentration ratios to mimic the osteochondral unit as best possible. A press-fit technique was ensured and fibrin glue applied. Assessment of regeneration was via MRI performed at multiple intervals post-operatively with 11 patients undergoing all scans. At a mean follow up of 6 years, clinical outcome measures showed improvement from baseline pre-operative levels for all despite non-reassuring findings on final MRI. Though two-thirds had intact articular cartilage, the majority had abnormalities within the subchondral bone.[25,29]

Multiple systematic reviews encompassing the different techniques and their outcomes have been performed. Methods of OCD description varied. Abouassaly et al. in the review of 25 level 4 studies found that both stable and unstable defects were addressed with drilling, bone pegs and bioabsorbable screws while metallic screws and fixation were employed for only unstable lesions. A systematic review identified drilling for stable OCDs and bioabsorbable pin fixation for unstable OCDs as the most common techniques employed. No specific documentation was made of OATS or OCA usage.[30] Two other systematic reviews, each analyzing 11 studies and including only one level 1 study, noted that ACI was the most common treatment method in the paediatric population. OCA had the highest revision rate.[14,31] Across all studies, some general observations were made. Regardless of the modality of treatment, majority of defects healed and resulted in clinical improvement. Limitations were noted in the strength of studies, sample size, documentation of additional surgical procedures performed, assessment of outcomes and duration of follow-up.[14,30,31]

5. Conclusion

Osteochondral loss in the young patient is associated with the development of pain and osteoarthritis. Fixation of loose defects should be the focus of management. For cases where this is not possible, microfracture of the defect can be carried out, although this facilitates symptomatic benefit only in the short term. Other restorative procedures can be considered but evidence in this age group is lacking at present. There are emerging techniques, however these are mostly documented in adult case studies with small sample populations. Furthermore, the majority of larger powered studies are performed in a heterogenous population of adults and children with varying aetiologies for osteochondral loss. Though it is well documented that most defects will heal, further investigation is warranted as to the best methods of treatment in the young, especially for unsalvageable lesions.

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Isolated posterior cruciate ligament injuries

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ABSTRACT

Isolated posterior cruciate ligament (PCL) injuries are rare but PCL injuries commonly occur as part of multiligament knee injuries. PCL is the largest ligament in the knee and has two main bundles: anterolateral and posteromedial. These two bundles are thought to work in a co-dominant relationship to provide restraint/stability to posterior tibial translation. The PCL also has good capacity to heal following an injury. Majority of isolated PCL injuries can be treated non-operatively with rehabilitation focusing on prevention of posterior tibial sag, progressive weight bearing, prone range of movement exercises and quadriceps strengthening. PCL reconstructions are undertaken in chronic injury with persistent symptoms, failure of non-operative treatment and combined multiligament knee injuries. Common PCL reconstruction techniques include single bundle vs. double bundle and transtibial vs. tibial inlay. There is controversy on which reconstructive method is best.

1. Introduction

The Posterior cruciate ligament (PCL) is an important stabiliser of the knee. PCL injuries are rare in isolation but can occur as part of multiligament knee injuries.[1] PCL injuries are complex but recent literature has improved our understanding of these injuries and therefore their treatment. In this article, we aim to discuss the anatomy of the PCL, its biomechanics and function, diagnosis and management of PCL injuries with specific emphasis on the isolated injury.

2. Anatomy

The PCL is the largest ligament in the knee (Fig. 1). The average diameter at its mid-portion is 11 mm with an average length of 38 mm.[2,3] The PCL is attached from the lateral wall of the medial femoral condyle to the posterior intercondyloid fossa, on the posterior tibia just inferior to the joint line.[4] The PCL is unique as it is an intraarticular structure but it is also extrasynovial. The PCL is covered in a layer of synovial sheath within knee, protecting it from the harsh intraarticular environment. This is the main reason why PCL injuries has an intrinsic capacity to heal.[5]

The PCL consists of two main bundles: the anterolateral bundle (ALB) and the posteromedial bundle (PMB).[6] (Fig. 1).

The cross-sectional area of the anterolateral bundle is twice the size of the posteromedial bundle. Important arthroscopic landmarks have been described to identify the centre of the femoral and tibial footprints to aid accurate tunnel placement during surgical reconstruction.[6]

The centre of the ALB femoral insertion is on average 7.4 ± 1.2 mm from the trochlear point and 11.0 ± 2.4 mm from the medial arch point. The centre of the PMB femoral attachment is a mean of 11.1 ± 1.9 mm from the medial arch point and 10.8 ± 2.0 mm from the posterior point. The distance between the centre of ALB and PMB footprint is 12.1 mm.[6]

The tibial footprint of the PCL is much smaller than the femoral footprint Fig. 2. The ALB and PMB tibial footprint are separated by the 'bundle ridge'. The 'champagne glass drop off' marks the distal extent of the PMB bundle and the 'shiny white fibres' are located anteromedial to the anterolateral bundle. On average, the centre of the PCL tibial footprint 7.8 ± 1.4 mm from the shiny white fibre point, 9.8 ± 1.6 mm from the lateral cartilage point, 5.0 ± 0.9 mm from the medial groove, and 1.3 ± 0.5 mm proximal to the bundle ridge. The distance between the centre of the ALB and PMB tibial footprint is only 8.9 mm.[6]

There are two meniscofemoral ligaments which travel from the medial femoral condyle to the posterior horn of the lateral meniscus. They are named after its relationship to the PCL. The

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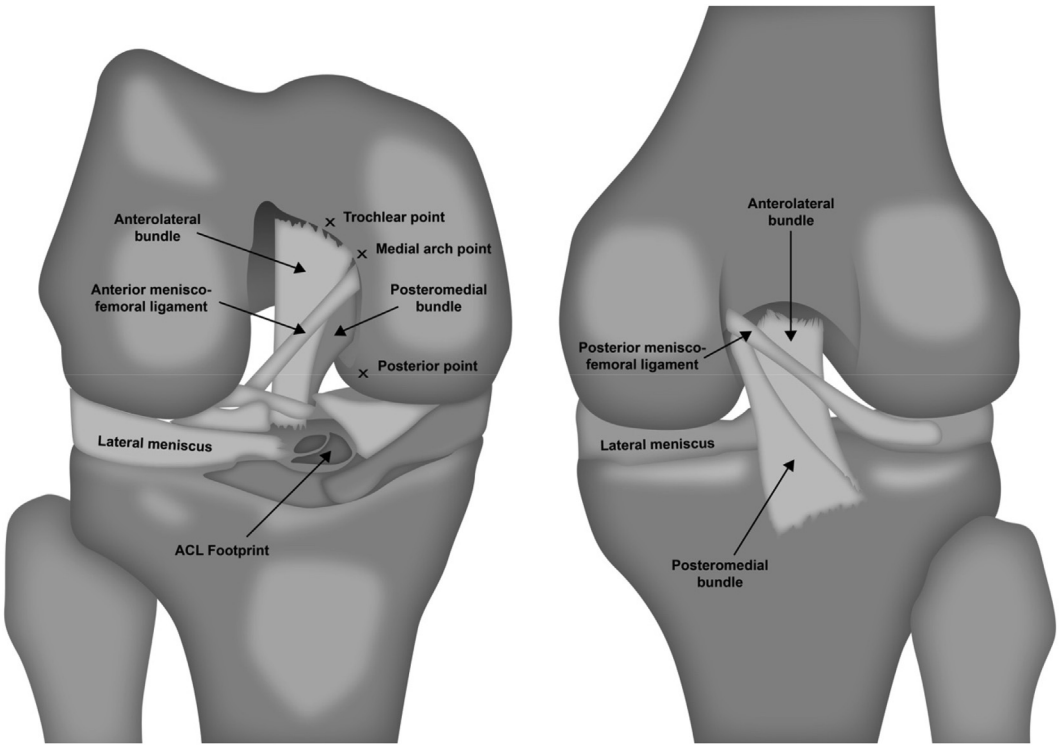
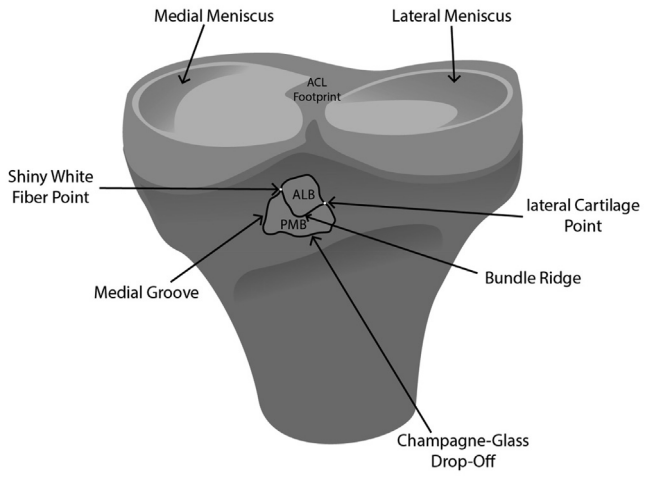


Fig. 1. Anatomy of PCL



ALB: Anterolateral bundle
PMB: Posteromedial bundle

Fig. 2. PCL tibial attachment.

anterior meniscofemoral ligament (Ligament of Humphreys) travels anterior to the PCL and the posterior meniscofemoral ligament (Ligament of Wrisberg) travels behind the PCL. The meniscofemoral ligaments are thought to be secondary stabilisers to posterior tibial translation.[7]

The medial and lateral meniscal roots are in close relationship to the tibial PCL insertion and care must be taken not to injure the meniscal roots. The shiny white fibres of the posterior horn of the medial meniscus are visible during arthroscopic PCL reconstruction and acts as an important landmark as described above.

The popliteal neurovascular structures travel in the posterior aspect of the knee and is within 5 mm of the knee joint in full extension. This distance is increased to 10 mm when the knee is flexed to 90°.[8]

3. Biomechanics and function

The PCL is the primary restraint to posterior tibial translation.[4] Although some biomechanical studies[9–11] have demonstrated its effect throughout the range of motion, it is likely that the effect of the PCL on resisting posterior tibial translation is greater at higher degree of knee flexion (60–120°).[12–14]

The individual function of the ALB and PMB of the PCL to resist posterior tibial translation has been studied. Early literature demonstrated that the ALB is tight in flexion whereas the PMB is tight in extension.[3] However, more recent literature has suggested that both bundles work synergistically and have a codominant relationship.[15–19]

The PCL has also been shown to provide secondary restraint to rotation and valgus stress, particularly in high knee flexion angle[13,17,20] However, in isolated PCL deficiency, the increase in rotation and valgus stress is small and may not be clinically relevant.[17]

In addition, the PCL plays a role in proprioception. Studies have shown decrease in proprioceptive function using the threshold to detect passive motion (TTDPM) and the ability to reproduce passive positioning (RPP) in PCL deficient and PCL reconstructed knees, when compared to normal, contralateral knees.[4,21,22]

The PCL deficient knee can also lead to secondary degeneration of the medial compartment and patellofemoral joint due to increased contact pressure and joint reaction force.[4,23,24]

4. Diagnosis

PCL injuries commonly occur as part of multiligament knee

injuries. Common mechanisms for isolated injury include dashboard injury and sports injury (fall on flexed knee with plantarflexed ankle).[1] Isolated injuries are uncommon with an estimated annual incidence of 2 per 100 000[25] and therefore high level of suspicion is required to diagnose other associated injuries.

A focused and thorough history taking is required to determine the mechanism of injury, history of spontaneous reduction of a dislocated knee, neurological deficit, patient's level of activity, expectations, and whether this is an acute or chronic injury.

A thorough assessment of all suspected PCL injuries must include assessment of neurovascular status (in particular vascular status and common peroneal nerve) and stability of the knee.[26]

4.1. Assessing PCL stability

4.1.1. Posterior tibial sag and posterior drawer test

The patient is positioned supine on the examination couch with both knees flexed to 90°, hips flexed to 45° and both feet positioned together. It is important for the examiner to palpate for the medial tibial plateau on the normal knee and compare it to the affected knee. In the normal knee, the medial tibial plateau should lie approximately 10 mm anterior to the medial femoral condyle (MFC). If there is PCL injury, the medial tibial plateau will sag posteriorly. The amount of posterior sag can then be used to grade the severity of PCL injury.[27–29] (See Table 1).

After assessing the tibial position at rest, the examiner pulls the tibia anteriorly to its reduced position. From the reduced position, a posteriorly directed force is used assess the amount of posterior laxity. This is termed as the posterior drawer test.[28]

4.2. Quadriceps active test

With the patient positioned in the same manner as assessment of posterior tibial sag, the examiner stabilises the patient's foot using a hand and asks the patient to actively extend the affected knee. The proximal tibia is seen to move anteriorly with contraction of the quadriceps muscle, signifying the presence of PCL injury.[28,30]

Kopkow et al. have demonstrated good specificity and sensitivity of the posterior tibial sag, posterior drawer and quadriceps active test.[27]

4.3. Reverse pivot shift

The reverse pivot shift test is a dynamic test to assess for posterior laxity. It is similar to the pivot shift test for the anterior cruciate ligament (ACL) and relies on an intact medial collateral ligament and iliotibial band (ITB). To perform this test, the knee is flexed to 80–90°. In this position, the tibia is subluxed posteriorly in the presence of posterior laxity. The examiner then gradually extends the knee whilst applying valgus and external rotation force to the knee. As the knee is extended, the ITB moves from being a flexor of the knee to an extender, pulling the tibia forward and reduces the knee. As the knee reduces, there will be a visible slide/clunk and may also be audible.[31] An 'explosive' reverse pivot shift is thought to represent combined PCL and posterolateral corner injury, rather than isolated PCL injury.[32]

Table 1
Grade of PCL injury.

Grade of PCL injury	Position of medial tibial plateau in relation to MFC
Normal	10 mm anterior to MFC
Grade 1	5 mm anterior to MFC (reduced compare to other side)
Grade 2	Flush to MFC
Grade 3	Posterior to MFC but less than 10 mm
Grade 4	More than 10 mm posterior to MFC

4.4. Reverse Lachman's

This test is performed by applying a posterior force to the tibia with the knee flexed to 20–30°. The tibia will move posteriorly in the presence of a PCL injury.[33]

4.5. External rotation dial test

External rotation dial test is performed with the patient in the prone position. It is important to eliminate any hip movement by placing both the knees together. The examiner holds both of the patient's ankles and applies an external rotation force. This test is performed with the knee in 30° and 90° flexion. Isolated posterolateral corner injury will produce increased external rotation at 30° flexion only. Combined PCL and posterolateral corner injury will produce increased external rotation at 30° and 90° flexion.[27,28,29]

5. Investigations

Further investigations are required to determine and/or confirm the grade of PCL injury, exclude other associated injuries and for surgical planning. The choice of investigation(s) will depend on whether the injury is acute or chronic.

5.1. Magnetic resonance imaging (MRI)

MRI is commonly performed in any suspected soft tissue injury of the knee. MRI is particularly useful to determine the grade of the PCL injury in the acute setting but may not be as useful to assess chronic PCL injury as the PCL can heal in an elongated position. However, MRI is still useful to exclude other associated injuries such as ligament, meniscal or chondral injuries.[19,31]

Kneeling stress radiograph (knee flexed to 90°).

In the setting of chronic PCL injury, kneeling stress radiograph provides much more useful information with regards of posterior laxity of the knee. This is performed with the patient kneeling with the knee flexed to 90°. The contralateral knee is also imaged to determine the side-to-side difference. The amount of posterior displacement of the tibia determines the severity of posterior instability.[19,34,35] (See Table 2).

5.2. Full length tibia plain radiograph

Reduced or flat tibial slope has been shown to place excessive force on PCL reconstruction graft, leading to failure. It is therefore important to assess the tibial slope using a full length tibia plain radiograph as an osteotomy may be required prior to, or concurrent with, PCL reconstruction.[36,37]

5.3. Management

5.3.1. Non-operative treatment

Due to the intrinsic capacity of the PCL to heal, good outcomes from non-operative treatment of isolated PCL injuries have been

Table 2
Side-to-side difference on kneeling stress radiograph. [19,34,35]

Side-to-side difference	Injury
<8 mm	Partial PCL injury
8–12 mm	Complete isolated PCL injury
>12 mm	PCL + PLC/PMC injury

reported.[38–40] However, the PCL can heal in an elongated and attenuated position, causing posterior laxity. Therefore, prevention of posterior tibial translation is required so that the PCL can heal in its physiological length.[19,41]

Several studies have shown excellent medium to long term outcomes with high rate of return to sports.[38–40,42–44] Shelbourne et al. reported excellent long term outcome scores (mean follow up of 17.6 years) using International Knee Documentation Committee and modified Cincinnati Knee Rating System in 68 patients treated non-operatively. Only 11% (5 patients) had radiographic evidence of osteoarthritis.[38] Agolley et al. reported non-operative treatment with bracing in athletes with isolated grade II (n = 25) and III (n = 21) PCL injuries in athletes. 91% of the athletes were playing at the same or higher level of sports 2 years after injury, with a mean Tegner score of 9.[39]

Jacobi et al. reported excellent functional outcomes with significant reduction in posterior tibial sag following treatment of acute isolated PCL injuries in a dynamic PCL brace.[41]

Ahn et al. treated 49 patients with acute isolated PCL injury with cast immobilisations and PCL braces. They reported good functional outcomes and better objective stability. They also found that PCL continuity with low signal on post-treatment MRI is predictive of better outcome and stability.[43]

Despite the literature on successful non-operative treatment, there is some evidence to suggest that surgical reconstructions more reliably reproduce posterior stability of the knee than non-operative treatment.[45] However, the difference is small and surgical risks have to be considered.

As discussed previously, untreated PCL injuries lead to medial compartment and patellofemoral joint degeneration due to increased joint contact pressure secondary to posterior tibial sag. A long term cohort study by Wang et al. showed that patients with PCL tears which are treated non-operatively have a higher incidence of meniscal tears, osteoarthritis and subsequent total knee replacement compared to PCL reconstructed patients. However, the risk of symptomatic osteoarthritis is increased in patient with PCL tears whether or not PCL reconstruction was performed.[25,46,47] These had led to debate on the optimal treatment for acute isolated PCL injuries.

Non-operative treatment of an acute, isolated PCL injury typically involves the use of a dynamic PCL brace or extension splint with posterior tibial support to prevent posterior tibial sag.[19,48] Some clinicians advocate the use of knee extension splint for 2 weeks prior to transitioning to the dynamic PCL brace. Flexion of the knee is usually limited in the first 4 weeks of injury as excessive flexion (>60°) can lead to increased shear force on the damaged PCL. Range of motion exercises are performed in the prone position and the dynamic PCL brace must be worn at all times for 12–16 weeks. Other parts of the rehabilitation include progressive weight bearing in the first few weeks and quadriceps strengthening. Isolated hamstring exercises are avoided until at least 12 weeks post injury. Athletes are allowed to return to sports once they have regained 90% of quadriceps strength and a firm end point on clinical examination.[19,48]

5.4. Indications for operative treatment

Despite the ability of the PCL to heal with non-operative treatment, there are several indications for operative treatment of a PCL injury. Some authors recommend operative treatment for isolated acute complete PCL tears (stress radiograph ≥8 mm), but this remains controversial.[5,19]

In the chronic setting, it is generally accepted that persistent functional limitation with posterior tibial sag is an indication for PCL reconstruction.[5,19]

5.5. Operative treatment

5.5.1. PCL avulsion fracture

PCL avulsion fracture from its tibial attachment has excellent outcome when treated operatively. Operative fixation allows anatomical reduction and preservation of native PCL fibres and its function. Studies have demonstrated restoration of near normal knee function and a high rate of return to pre-injury activity with operative fixation of PCL avulsion fracture.[49] Multiple techniques have been described in the literature, including open reduction internal fixation using screw, plate, suture or wire (posterior approach or posteromedial approach) or arthroscopic fixation using suture fixation. No significant differences have been demonstrated between open and arthroscopic approach.[49,50]

5.6. Single bundle PCL reconstruction

Historically, single bundle PCL reconstruction was based on non-anatomic 'isometric' reconstruction. However, this technique has been shown to lead joint overconstraint initially and increased laxity over time.[51,52] Recent literature has reported on the anatomic single bundle PCL reconstruction. The anatomic single bundle reconstruction aims to reconstruct the ALB of the PCL. As discussed previously, the ALB is two thirds the size of the PCL and is thought to be the main bundle for PCL function.[19,53,54]

There are two main variations for tibial fixation: transtibial and tibial inlay (Figs. 3 and 4).[53,55,56] Transtibial technique involves making a tibial tunnel and passing the PCL graft through the tibial tunnel. The disadvantage with transtibial technique is the 'killer turn', which is the sharp angle formed by the tibial tunnel and posterior tibia as the graft exits the tunnel and takes a sharp turn proximally and anteriorly into the intercondylar notch.[19] In addition to the technical challenge caused by the 'killer turn', there are biomechanical studies which demonstrate abrasion, attenuation and increased failure of patellar tendon PCL graft during cyclic loading.[19,57] However, this phenomenon has not proven to be true in other types of graft or in a biological environment where remodelling occurs.

In order to overcome the technical and biomechanical issue of the transtibial technique, the tibial inlay technique has been developed with good outcomes being reported by several studies.[55,58–60] The tibial inlay technique involves creating a trough on the posterior tibia where the graft with bone block is fixed into the trough using a screw. This is originally described using an open posteromedial approach of the tibia but has since been modified to be performed arthroscopically. The typical graft used for this technique includes bone-patella tendon-bone (BPTB) autograft or Achilles tendon allograft.[5,19]

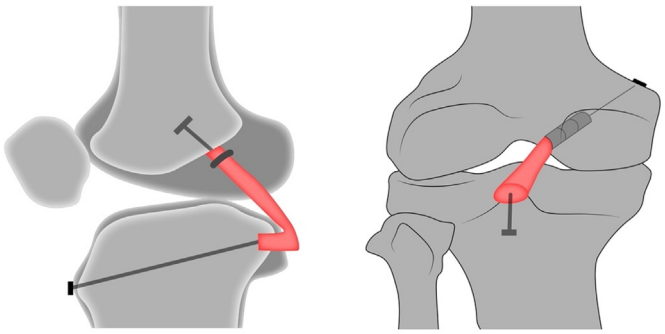


Fig. 3. Single bundle transtibial PCL reconstruction.

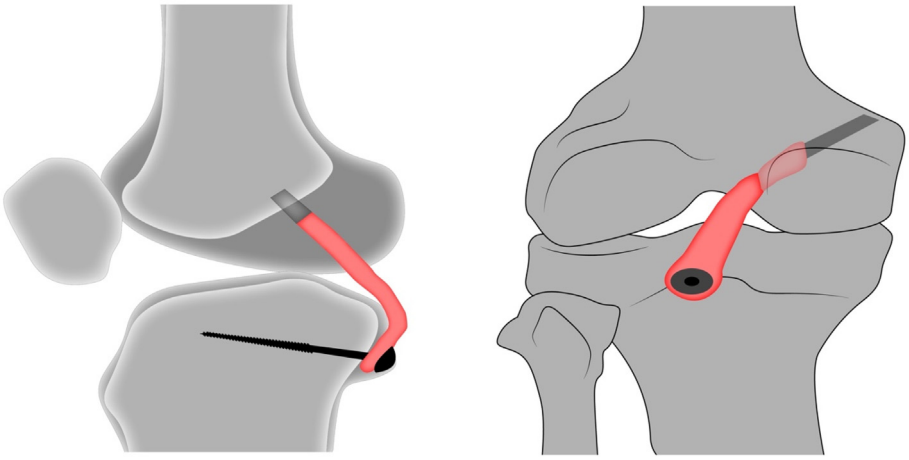


Fig. 4. Tibial inlay single bundle PCL reconstruction.

5.7. Double bundle PCL reconstruction

The double bundle PCL reconstruction was developed to more closely reproduce native knee kinematics and reduce posterior tibial sag following PCL reconstruction.[61–63] Biomechanical studies have found that the ALB and PMB work in a codominant relationship and are both important in restoring stability of the knee.[61,62] This technique aims to reconstruct both the ALB and PMB of PCL using two femoral tunnels but only one tibial tunnel.[63] As discussed previously, the small tibial footprint does not allow two tunnels to be made on the tibia. The ALB bundle is tensioned with the knee in 90° flexion and the PMB is tensioned with the knee in full extension.[61]

Similar to single bundle PCL reconstruction, tibial fixation can be achieved with transtibial and tibial inlay techniques.[19]

5.8. Single bundle vs. double bundle

Recent biomechanical studies have demonstrated the benefits of double bundle PCL reconstruction over single bundle reconstruction. These benefits include improved knee kinematics and improved resistance to posterior tibial translation.[51,61,64–66] However, it is unclear whether the biomechanical advantage of double bundle PCL reconstruction translates to improved clinical outcomes.[67–69] A recent systematic review demonstrated better objective posterior tibial stability and objective International Knee Documentation Committee (IKDC) score, but no difference in other outcome scores such as Lysholm and Tegner score.[64]

5.9. Transtibial vs. tibial inlay

Both transtibial and tibial inlay are described techniques for single bundle and double bundle reconstruction. As described above, the tibial inlay technique avoids the problems associated with the 'killer turn' but has the risk of non-union of the bone plug and causing adhesion which complicates revision surgery. Studies have not shown any clinical or biomechanical differences between transtibial and tibial inlay techniques.[60,70,71]

5.10. Remnant preservation

Remnant preserving PCL reconstruction has the theoretical advantage of preserving proprioception and enhance healing of the PCL graft. However, no clinical differences have been shown in the literature.[69,72,73] It is important that remnant preservation does not compromise the accuracy of tunnel placement.

5.11. Rehabilitation

The rehabilitation of PCL reconstruction is vital in ensuring its success. The main components of rehabilitation include progressive weight bearing, prevention of posterior tibial translation and quadriceps strengthening. Patients are typically placed in an extension knee brace with posterior tibial support post-operatively before transitioning into a dynamic PCL brace. Whilst in the dynamic PCL brace, some authors advocate limiting flexion (0–60°) to reduce the shear force on the PCL graft. The patient is typically kept non weight bearing for 6 weeks as its postulated that PCL graft takes longer to heal.[74] The dynamic PCL brace must be worn at all times to maintain the tibiofemoral position for at least 4 months. All range of motion exercises must be performed in the prone position initially and return to sports typically takes 9–12 months.[19,48]

5.12. Posterior tibial slope

A flattened or reduced posterior tibial slope can place significant stress on a reconstructed PCL graft.[36,37] It is therefore crucial to assess this using a lateral tibial radiograph in chronic PCL injuries and failed PCL reconstruction.[36,37] An anterior opening wedge osteotomy of the proximal tibia can be performed to improve posterior stability in patients with flattened posterior tibial slope and PCL deficient knee. Some patients do not require subsequent PCL reconstruction following correction of the posterior tibial slope.[75,76]

5.13. Special considerations of PCL injury in children

A PCL injury in children is rare with little published in the literature. Initial non-operative treatment is recommended with operative treatment reserved for those who have persistent posterior laxity and in multiligament injuries.[77] There are several factors which need to be considered in children undergoing PCL reconstruction, such as the patient's age and remaining growth. Standard drilling techniques with femoral and tibial tunnels can cause damage to the open physes and lead to growth disturbance. Steep tunnel drilling has been recommended as a technique to reduce the cross-sectional area of tunnel across the physes, therefore reducing the risk of growth disturbance.[78] To avoid the risk of growth disturbances, all-epiphyseal reconstruction techniques can be performed with satisfactory outcome Fig. 5.[79,80] However, due to

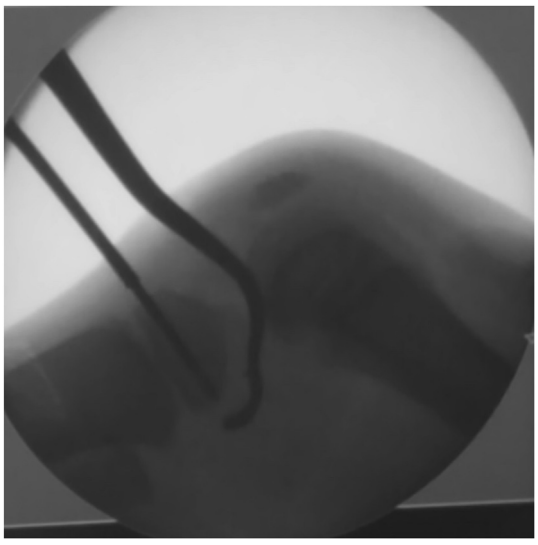


Fig. 5. Intraoperative fluoroscopy showing drilling of all epiphyseal tibial tunnel for paediatric PCL reconstruction.

the small number of publications on this topic, it is unclear what the best reconstructive technique would be.

6. Conclusion

Clear understanding of the anatomy and biomechanics of PCL injuries are vital in management of these injuries. Although the majority of isolated PCL injuries can be treated non-operatively, failure of non-operative treatment and chronic injury with persistent symptoms are indications for operative treatment. Although double bundle reconstruction has biomechanical advantages over single bundle reconstruction, no significant difference in clinical outcomes have been demonstrated.

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Research paper

Effect of 1.5 mm biter-width meniscectomy on cadaveric knee pressure, peak pressure, force, and contact area

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ABSTRACT

This study investigated the immediate biomechanical effects of a biter-width partial medial meniscectomy. Small tears on the free edge of the meniscus are occasionally discovered during arthroscopic knee procedures. Removal of these tears often requires no more width than that of a biter from the edge. While past cadaveric partial meniscectomy studies have reported on the effects of meniscectomies from resection of one-third to three-quarters of meniscal width, the biomechanical sequelae of substantially smaller meniscectomies remain unknown. This study was performed to determine how single-biter-width meniscectomies affect the pressure distribution and peak pressure on the tibial plateau, as these parameters are correlated with increased likelihood of development of osteoarthritis. Eight cadaveric knees were instrumented with a thin-film pressure sensor underneath the menisci while retaining the major ligaments and most of the capsule. Knees were loaded to 1000 N at angles of flexion of 0, 15, 30, and 45 in normal tibio-femoral angles and in 7° of varus. Pressure, peak pressure, force and contact area were recorded. Afterwards, biter-width meniscectomies were performed, and measures repeated. There were significant changes in contact area at most flexion and tibio-femoral angles. There were no changes in the amount of force that was transmitted through the medial compartment. The overall pressure on the tibial plateau did not change in most knee conditions and peak pressure did not change significantly in any condition. The changes in contact area were consistent with our expectations. Similarly, the lack of change in force was also expected. However, the lack of significant changes in pressure and peak pressure represent findings indicating that a biter sized meniscectomy may have clinically insignificant effects on biomechanics.

1. Introduction

The meniscus is a fibrocartilaginous structure located between the femur and tibia in the synovial space. Slightly varying in size and shape, the lateral and medial sides are responsible for the low friction of the knee, as well as even weight distribution from the femur onto the tibial plateau.[1,2] It is estimated that approximately 8 in every 1000 people experience meniscal injury on a yearly basis.[3] The meniscus is a frequently repaired structure, with approximately 1 million meniscal operations performed yearly in the US alone.[4] In both men and women, knee injuries are among the most common sports injuries.[5] Football, basketball, wrestling, skiing, and baseball have the highest likelihood of injury.[6] Among active populations, the medial meniscus is more likely to be injured than the lateral, 81%–19%.[5] Of note, acute anterior cruciate ligament injury is associated with meniscal injury in 41–54% of patients, with an increased incidence of lateral meniscus injury compared to meniscus injury without associated ACL injury.[7] Additionally, meniscal aging also contributes to the likelihood of meniscus injury through disruption of meniscal cellular, collagen, and proteoglycan components.[8,9]

Meniscal damage results in debilitation of normal knee function and often warrants a dedicated procedure, particularly in the setting of mechanical symptoms such as locking and clicking. Damage can be locatized to the outer, vascularized red zone, the

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middle red—white zone, the inner, avascular white zone; or any combination of those. Tears can follow many different patterns or shapes including, vertical, oblique, buckethandle, horizontal, or complex tears. Root injuries occur when the attachment of the meniscus to the tibial plateau is disrupted. Non-operative management of meniscus injury includes non-steroidal anti-inflammatory drugs, muscle relaxants, analgesics, and physical therapy.[10,11] In certain cases, surgical intervention is warranted. The method of surgical management is dictated by tear type and location. Specific procedures, are available for radial, horizontal cleavage, bucket handle, flap, and complex tears.[12–17] Procedures include various suturing techniques, meniscectomies, and use of surgical staples.[12,13,18–27] The standard methods for assessing meniscus function are the analysis of contact area, force, pressure, and peak pressure before and after injury and repair.[12,25,26] After meniscal damage or removal, increased contact forces, pain upon flexion and extension, and decreased range of motion are some of the short-term sequelae.[28] Long-term sequelae include articular cartilage degeneration that can ultimately result in debilitating osteoarthritis. In this context, osteoarthritis occurs as a result of increased contact forces and pressures due to compromised meniscal pressure and force redistribution and subsequent high peak pressures.[29,30] Much of the existing orthopaedic literature argues for preserving as much of the meniscus as possible so as to avoid these sequelae.[31–35] However, a dedicated repair or reconstruction is not always feasible or warranted. Often times a small meniscal tear on the inner rim or free edge is discovered during knee arthroscopy. There is currently an ongoing debate as to whether it is best to repair, resect, or ignore these tears.

A small meniscal tear can appear as a partial thickness tear at the meniscal edge, which is normally smooth and well-defined.[14] While not generally warranting a separate arthroscopic procedure if discovered on MRI, small tears are often removed if the patient is undergoing knee arthroscopy for another indication.[36] To remove this tissue, an arthroscopic biter or punch is used to resect the torn portion of the meniscus. Smaller sized tears can often be resected using a single biter-width with subsequent tapering towards the anterior and posterior horns as to prevent further tearing. While this is a common procedure, it is not yet known how this procedure affects contact forces and pressures between the femur and tibia. Past studies evaluating partial meniscectomies have only addressed meniscal resection of one-third to three-quarters of the entire free edge, equating to at least 5 mm, and in some cases, performed the studies after sacrificing some if not all major ligaments of the knee.[26,37] It is thus unknown if there are significant effects of tapered biter-width partial meniscectomy on femorotibial contact areas, forces, and pressures. In this study, our objective was to identify any significant changes in these parameters after performing medial biter-width partial meniscectomies on cadaveric knees with mechanical loading in 0, 15, 30, and 45° of flexion, at normal tibio-femoral angles and 7° of varus.

2. Methods

2.1. Knee preparation

Eight fresh frozen cadaveric knees were obtained (Anatomy Gifts Registry, Hanover, MD; and United Tissue Network, Norman, OK). Inclusion criteria for the knees were male sex, at least 180 cm tall with no disease or injury. Donors meeting these criteria provided the largest knees, which were crucial to fit the sensors with minimal compromise of the synovial capsule and ligaments and sensors themselves. Knees were stripped of all soft tissues up to the superior border of the patella and the tibial tuberosity, as deep as the synovial capsule. Care was taken not to damage the capsule and ligaments in order to preserve native biomechanics. The femur, tibia, and fibula were cut to leave 5.5 inches of bone from the mechanical rotational axis of the knee. Subsequently, a 1.6 mm Kirschner wire (K-wire) was driven though the tibia, parallel to the tibial plateau, in the midline of the medial-lateral axis, 1.5 cm below the plateau under fluoroscopic guidance. A rigid frame was used to suspend the knee with the K-wire horizontal. Plastic boxes were used as molds to pot the knees in construction mortar (CTS Cement, Atlanta GA) with steel bolts placed for attachment of the flexion/tibio-femoral angle apparatus (described below) (Supplementary Figure 1). After setting, the knees were flipped upside down and the other sides were potted in a similar fashion.

2.2. Mechanical testing

An apparatus was designed to allow us to alter knee flexion and tibio-femoral angles while the knee was fixed in a hydraulic press with a load cell (MTS mini bionix 858, MTS Systems, Eden Prairie MN) (Fig. 1). It consisted of a plate that could be moved in any dimension by adjusting the nuts secured to a flag-pole bracket (Valley Forge Flag, Wyomissing PA) that could induce knee flexion in increments of 15°. Thin-film sensors (4011, Tekscan, South Boston, MA) were placed underneath the menisci of both medial and lateral compartments. The sensors were calibrated to 200, 750, 1000, and 1500 N with a device that was constructed to load most of the sensor with the contact surface from rubber stopper to mimic femoral cartilage before use of the sensor (Supplementary Figure 2). The knees were then loaded to 1000 N over of 1 s in the hydraulic press. Pressure data were captured and analyzed by the Tekscan I-Scan software with values recorded after 1 s of target load. Each test was repeated 3 times at each angle combination and the most stable trial was selected to be to the representative trial. Trial stability was determined by the least sensor movement during loading. Contact area, force, pressure, and peak pressure in a 1 mm × 1 mm square was then measured in the medial and lateral compartments of the knees in 0, 15, 30, and 45° of flexion. At each flexion angle, normal tibio-femoral angle, and 7° of varus were also induced and tested. The contact area was measured between the femur and tibia through the medial meniscus. Force data were recorded and reported as the total force through the medial compartment. Pressure was calculated based on force through the medial compartment over the contact area detected by the sensor. Peak pressure was calculated as the highest pressure in any 1 mm × 1 mm square in the medial compartment. After collecting data for the intact knees, a biter-width meniscectomy was performed on the medial meniscus using a standard two-portal arthroscopic approach. Briefly, antero-lateral and antero-medial portals were created for visualization and meniscectomy. The meniscectomies were performed with an arthroscopic biter (Acufex 012,013). One full biter-width resection was performed in the inner rim of the postero-medial corner of the meniscus. The resection was subsequently tapered towards the anterior and posterior horns to mimic the common surgical practice (Fig. 2). Maximum resection width was 4 mm and average width was 1.5 mm. The mechanical testing was then repeated under the conditions described above.

2.3. Statistics

Sample size was determined by an online power analysis performed on preliminary area and pressure data from 4 samples using an alpha of 0.05 and a power of 80% to detect differences in peak pressure.[38] The analysis assumed a non-parametric data set would be compared using Wilcoxon rank sum tests and found that 8 samples would be required. Data are reported as group mean±-standard deviation. The means of the data collected from the eight

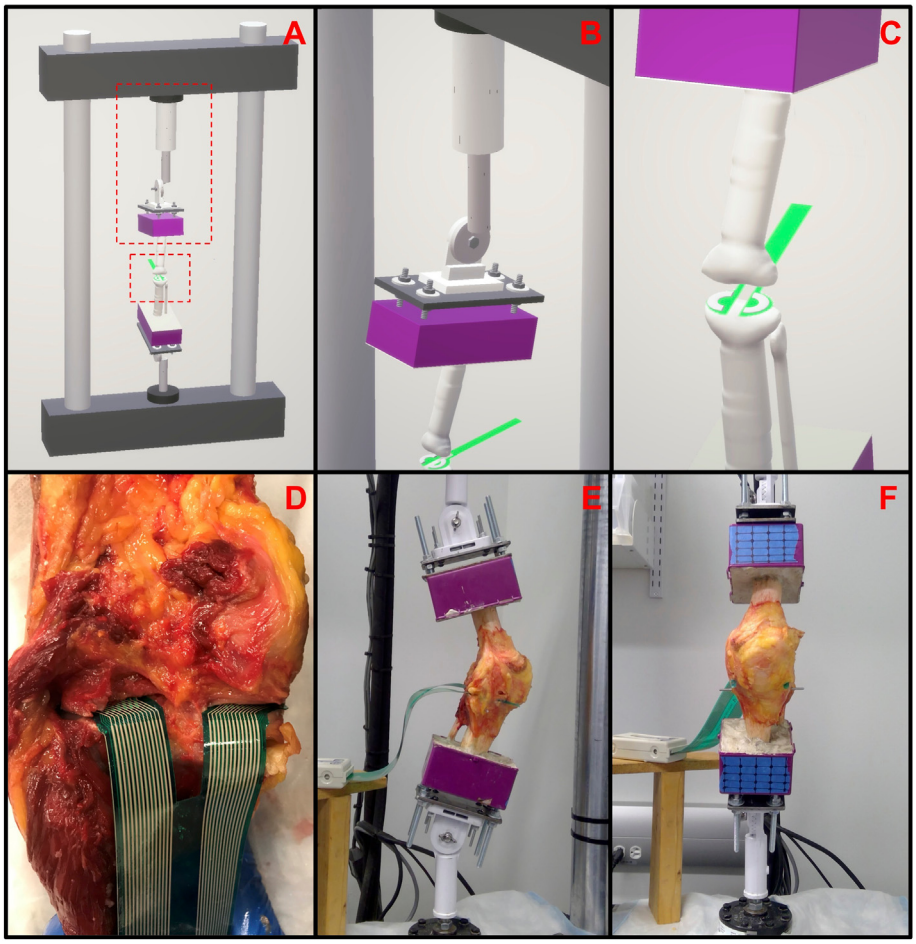

Fig. 1. Model and photograph of a knee in the hydraulic press. A) shows a model of the whole apparatus. B and C) show magnification and rotation of the upper and lower boxed areas, respectively. C and D) show sensor (green) placement in the knee, underneath the menisci with the capsule intact. E and F) are photographic representations of A. The knee is in 30° of flexion and at normal tibia-femoral angle.

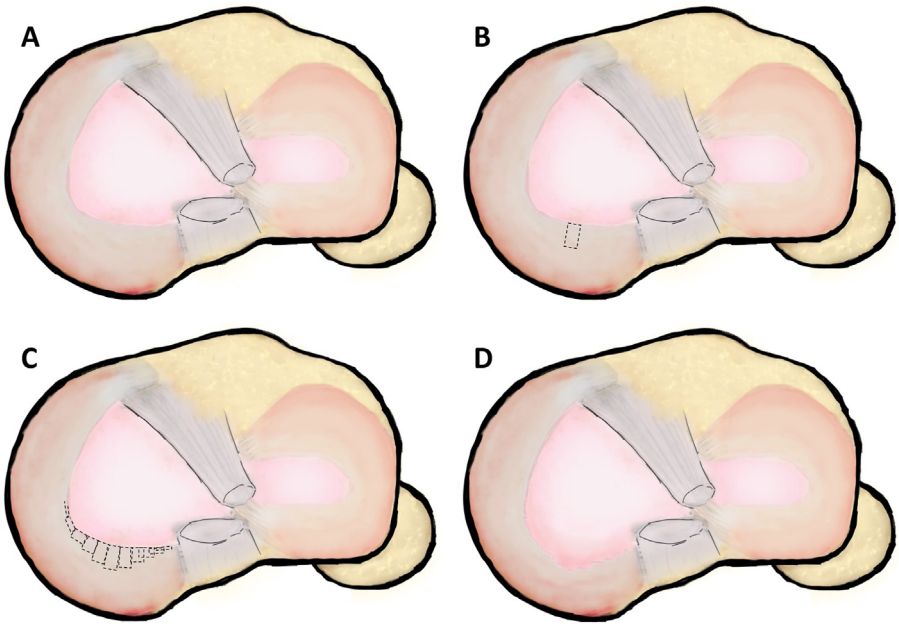

Fig. 2. Methodology used to perform biter-sized meniscectomy. A. The medial meniscus prior to meniscectomy. B. Placement of the first biter in the posterior-medial corner of the meniscus. C. Subsequent biters were taken in order to taper the meniscectomy to the original inner rim. D. The medial meniscus as it appeared after meniscectomy.

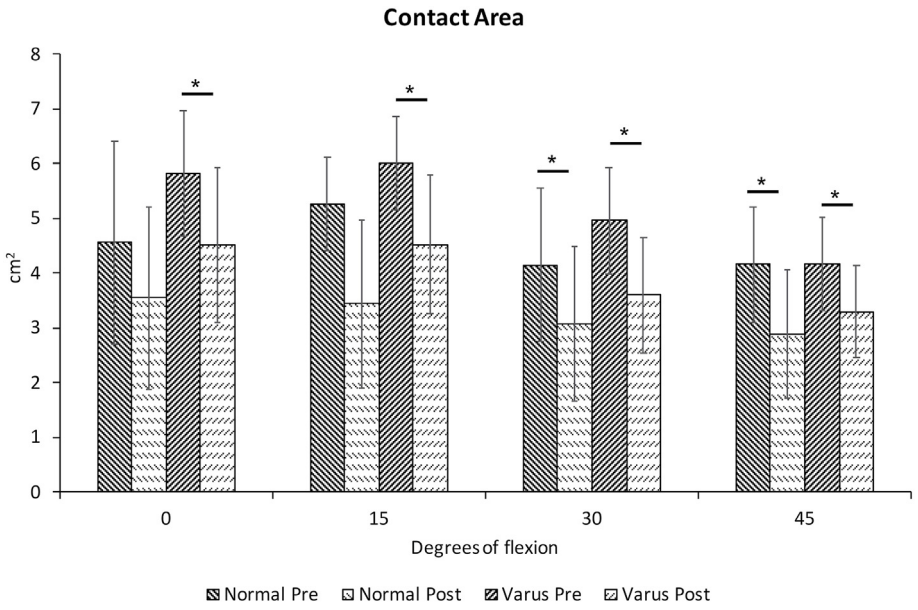

Fig. 3. Contact area between the femur and tibia in the medial compartment before and after meniscectomy. Area is reported as cm^2 as a function of degrees of flexion and tibio-femoral angle. Error bars are standard deviations. Comparisons were made between before and after meniscectomy, with * indicating significance between the groups under the solid line, $p < 0.05$.

knees for each test before and after the meniscectomy were compared for each flexion and tibio-femoral angle. Wilcoxon ranked sum tests were used as the data were non-normally distributed related samples. Significance was determined for $p \leq 0.05$. Analyses were performed using SPSS Ver. 22 (SAS institute, Cary, NC).

3. Results

The area of the femoral medial condyle and medial meniscus in contact with the sensor over the tibial plateau decreased significantly in all angle combinations after biter-sized meniscectomy except for 0 and 15° of flexion at normal tibio-femoral angle (Fig. 3). At 30° of flexion and normal tibio-femoral angle, the contact area decreased from 4.153 to 3.069 to cm^2 ($p = 0.05$). At 45° of flexion and normal tibio-femoral angle, the contact area decreased from 4.162 to 2.889 cm^2 ($p = 0.025$). In 7° of varus at 0, 15, 30, and 45° of flexion, the contact area decreased from 5.821 to 4.519 ($p = 0.028$), 6.015 to 4.530 ($p = 0.012$), 4.961 to 3.599 ($p = 0.017$), and 4.169 to 3.299 ($p = 0.012$), respectively. There were no significant changes in force transmitted through the medial compartment of the knee before vs. after meniscectomy (Fig. 4). Significant changes in pressure from before to after meniscectomy were observed at 0 and 15° of flexion in normal tibio-femoral angle, and at 45° of flexion in 7° of varus (Fig. 5). Under those conditions, the pressure increased from 25.6188 to 36.2255 N/cm^2($p = 0.05$), 28.7218–39.8330 N/cm^2

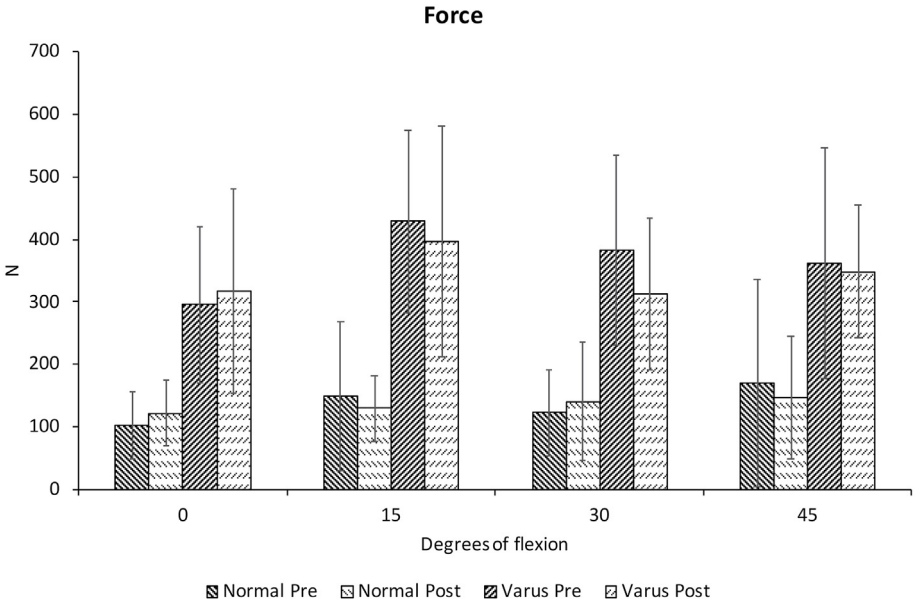

Fig. 4. Force through the medial compartment before and after meniscectomy. Values are given as a function of flexion and tibio-femoral angles. Error bars are standard deviations. Comparisons were made between before and after meniscectomy, with * indicating significance between the groups under the solid line, $p < 0.05$.

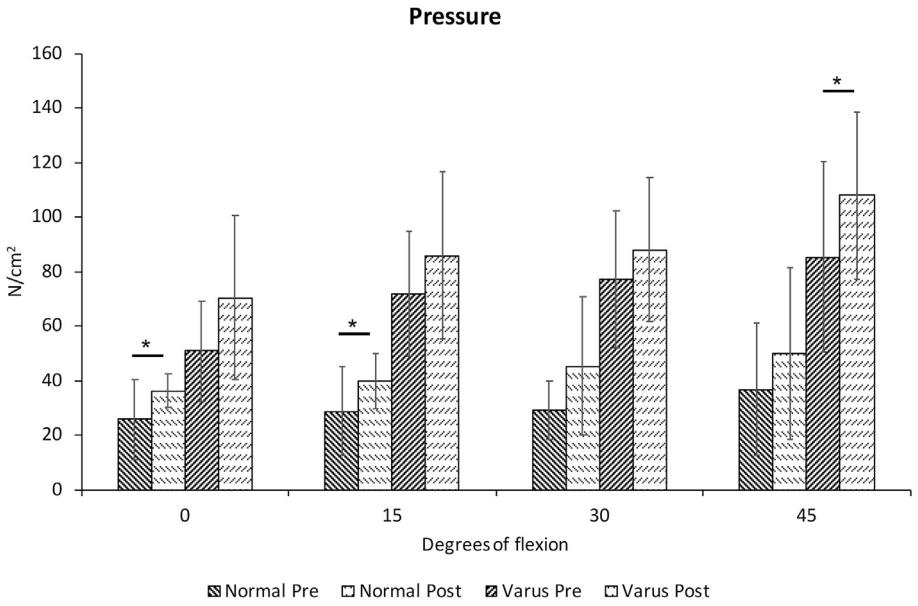

Fig. 5. Pressure in the medial compartment of the knee before and after meniscectomy. Values are given as a function of flexion and tibio-femoral angles. Error bars are standard deviations. Comparisons were made between before and after meniscectomy, with * indicating significance between the groups under the solid line, $p < 0.05$.

($p = 0.036$) and 85.1503–1077.7645 N/cm^2 ($p = 0.012$), respectively. There were no significant changes in peak pressures in the medial compartment after meniscectomy at any flexion or tibio-femoral angle. (Fig. 6). Increases in force and pressure through the medial compartment were expected between normal and varus tibio-femoral angles. Thus, no statistical comparisons were made between those groups.

4. Discussion

4.1. Discussion

The objective of this study was to determine if the common practice of removing a small tear in a meniscus with a biter during an arthroscopic procedure affects pressure on the medial tibial plateau. To this end, we prepared eight knees for mechanical loading and determination of these parameters at various degrees of flexion and tibio-femoral angle. Our findings show a significant decrease in contact area after meniscectomy, except at zero degrees flexion and normal tibio-femoral angle. The only other significant changes were in pressure at zero degrees flexion and normal tibio-femoral angle, 15° of flexion and normal tibio-femoral angle, and 45° of flexion and 7° of varus.

The changes in contact area after meniscectomy were expected since removing part of the meniscus should decrease its footprint on the sensor and thus, the tibial plateau. We also observed few significant changes in the amount of force transmitted through the medial compartment of the knee after partial meniscectomy. This

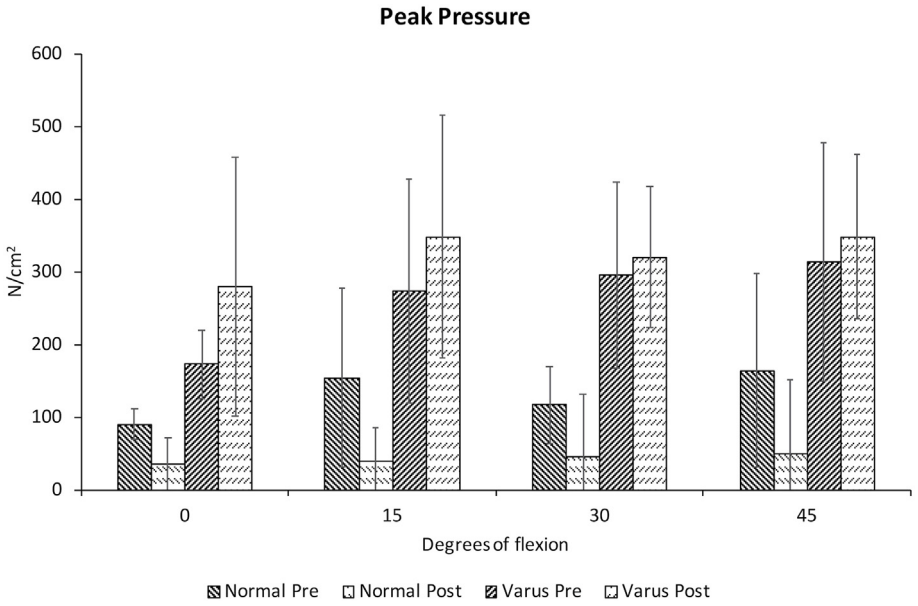

Fig. 6. Peak pressure in the highest 1 mm × 1 mm region within the medial compartment of the knee before and after meniscectomy. Values are given as a function of flexion and tibio-femoral angles. Error bars are standard deviations. Comparisons were made between before and after meniscectomy, with * indicating significance between the groups under the solid line, $p < 0.05$.

was also expected because changing the geometry of the meniscus would only be expected to change how the force is distributed within the medial compartment, not how much is transmitted, which is more likely to be affected by changes in loading conditions or overall knee geometry. Pressure in the medial compartment showed few changes from after meniscectomy and peak pressure did not significantly change in any flexion and tibio-femoral angle combination. As significant increases in pressure and, more importantly, in peak pressure are widely accepted as strong risk-factors for the development of osteoarthritis,[30] our demonstration of few changes in these parameters after a tapered, biter-width partial meniscectomy suggests that the practice of removing small tears at the free edge of a meniscus with one-biter depth will not increase the risk of osteoarthritis. Moreover, by eliminating small meniscal tears, smooth knee function may be able to be established, thereby reducing the chances of a future tears or tear propagation.

4.2. Limitations

The limitations of this study are the relatively high variability of our cadaveric data, making smaller differences between groups difficult to discern. Additionally, any cadaveric study does not consider the effects of living and functional tissue. Living tissue may behave differently and active muscle groups may add forces to the knee that are impossible to recreate with this model. However, despite these general limitations, cadaveric models are often used to estimate functional orthopaedic outcomes.[39–42] Furthermore, further investigation determining at what resection width significant peak pressures begin to be detected is important. A surgeon may wish to resect a tear that is more than on biter-with and an awareness of the depth at which significant increases in peak pressure could be expected would be useful.

4.3. Conclusions

Overall, our results show that a partial meniscectomy does not greatly affect pressure and peak pressure when restricted to the width of one biter. The implications of these results are that this procedure may not increase the likelihood of development of osteoarthritis and may be worthwhile if shown to improve knee motion and patient satisfaction or reduce risk of tear propagation. These results have clinical importance when a surgeon considers removing small tears in the meniscus with up to one biter-depth of meniscal resection. In addition to addressing limitations, future studies that aim to determine at which resection size is there a significant effect on knee pressures are important as well. We believe a clinical study of patient reported and objective outcomes is warranted to establish meaningful clinical guidance.

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Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jajs.2021.10.003.

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Review article

Surface Electromyographic Analysis of Soleus muscle activity in different shod conditions in Healthy Individuals – Systematic review

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ABSTRACT

Objective: Soleus is an effective plantar flexor that has distinct functional roles and behaves differently during different biomechanical actions. Different footwear types may give rise to adjusted muscular effort and biomechanics of Soleus muscle action. Consequent altered ground reaction forces created at the foot may give rise to injuries/fatigue during different activities. Relatively little is known about in vivo behavior of the Soleus muscle during walking and running. Surface Electromyography (SEMG) is commonly analyzed by researchers to understand lower limb muscle activity. The Objective of this study was to systematically review available research literature investigating Soleus SEMG activity in healthy subjects under different footwear conditions during different tasks.

Methods: electronic databases PUBMED, EBSCOHOST (Academic Elite) and SCIENCEDIRECT were searched on 30.11.2020 for the combination of keywords "Surface Electromyography" AND "Shoe" AND "Soleus". Inclusion and exclusion criteria were specified in advance. The methodological quality of each relevant study was independently evaluated for "Risk of bias" on Modified Downs and Black checklist. Studies with quality score >50% were considered reasonable to be included in this review.

Results: Total 435 research publications were generated in search; 247 articles were excluded on the basis of initial title screening (including duplicates), 155 articles were excluded after Abstract and (or) full text screening, 33 studies were included for quality assessment. 15 studies were considered of reasonable quality (>50% score) to be selected for this review. Information was extracted from each selected study on: PICOT terms and Outcome Measures (SEMG activity) reported in each study.

Discussion: Results of the reviewed studies generally reported that, "Shoe conditions lead to different soleus activation patterns", however there is weak to moderate evidence on difference in soleus muscle activity on SEMG under different footwear conditions. All studies involved highly variable features on PICO (terms) characteristics.

Conclusion: The clear effect of shoe on Soleus muscle activity is not fully understood; further research work especially investigating effect of footwear in non locomotor actions of soleus muscle in real life setting is recommended.

1. Introduction

Soleus is a monoarticular (Class 1) muscle with a very high proportion (88%) of slow-twitch muscle fiber.[1] Together, gastrocnemius (GM) and soleus (SOL) muscle are known as the Triceps Surae. Soleus arises from the posterior surface of the head and proximal part of upper end of the fibula and also from Tibia, where it finds greater attachment i.e. soleal line and the middle third of the medial border of the Tibia and also from a fibrous band (arching over the popliteal vessels and tibial nerve) between the tibia and fibula. Oblique and bipennate fibers of soleus converge as central intramuscular tendon and merges distally with the principal

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Table 1
Eligibility criteria.

Inclusion criteria	Exclusion criteria
(1) PEOPLE – healthy individuals of any age	(1) PEOPLE –
(2) INTERVENTION – Studies investigating soleus muscle activity in at least one shod conditions.	a. With any diagnosed disease (or injury) especially musculoskeletal and neurological at the time of study
(3) COMPARISON	b. Studies not performed on humans
Independent variables - footwear conditions shod and barefoot including Specific variation in design, material, heel height, wedges, insole, midsole etc.	c. Studies on cadavers
(4) OUTCOME – Studies that reported at least one Surface Electromyographic parameters as a direct measure of soleus muscle activity.	(2) INTERVENTION – studies involving special treatment like orthosis, Kinesio-taping, injection or topical application of drug etc.
(5) STUDY DESIGN	(3) STUDY DESIGN
a. Cross-sectional or Longitudinal study design	a. Studies with high risk of bias (methodological quality below 50%)
b. Randomized or non-randomized controlled trials	b. Studies on Validity, reliability or standardization
c. Case-control study, controlled clinical trial, pre-post trial	c. Studies with low level of evidence - Letters/Opinion articles/Editorials
d. Studies with number of participants >1	(4) PUBLICATION
(6) PUBLICATION	a. Unpublished studies
a. Peer-reviewed journal articles	b. Published studies without peer review process
b. Original Studies	c. Reviews or systematic Reviews
c. Studies published in English	d. Studies with Inadequate information – Only Abstracts available
d. Studies available in Full text	e. Non-English articles

tendon which joins the tendon of gastrocnemius to form the calcaneal (Achilles) tendon. This tendon thereafter is attached to posterior surface of the calcaneus separated by retrocalcaneal bursa.

The synergistic action of Triceps Surae muscle is plantar flexor of the foot. When the knee is flexed, the effect of the GM is reduced, and soleus is an effective plantar flexor. GM and soleus though combined in one Achilles tendon, have distinct functional roles and behave differently during different biomechanical actions.[2] Functionally Soleus is a very significant muscle, its role ranges from; Synergistic to Gastrocnemii action in plantar flexor of the foot,[2] Antagonistic to Gastrocnemii action in leg withdrawal reflex[2] and intrinsic stiffness generator across ankle joint in Standing. Soleus is reported to be the primary source of force generation and mechanical work during human walking and running[3]; being one of the major contributors to energy storage and return during running[4] as per concept of "Simple Spring-Mass Model" of running.

One of the extrinsic sources of variability in efficiency of Spring-Mass Model is impact of Ground Reaction Force (GRF). Impact of GRF can be affected by changes in a variety of extrinsic factors including shoes, surfaces, weather, anthropometric measures, fitness level, and others.[5] Difference in interface (Shoe) types gives rise to adjusted muscular effort and biomechanics of plantar flexion action. Altered (high) ground reaction forces created as the foot strikes the ground may give rise to injuries during running. Interestingly both hard and soft interfaces may adversely affect biomechanics around ankle during running; running on hard surfaces results in high impact force that may put increased mechanical loads past the biological limits of joints and tendons[6]; alternatively, running on soft surfaces may rapidly fatigue the muscles and lead to injury.[7] Therefore it is evident that cushioning and frictional properties of a surface (interface) are claimed to influence injuries.[8] Incidence for running injuries is very high, 70–80% of running injuries occur in the lower extremities.[9] As a consequence Achilles Tendon Disorder (ATD) is a common manifestation of high GRF impact. Achilles tendon ruptures are common, especially in middle-aged individuals, and the incidence in both men and women is rising.[10,11]

The rising incidence[12,13] and associated high economic cost[14] of Achilles tendon disorders necessitates accurate and detailed clinical assessment of the Triceps Surae muscle-tendon unit and in order to reduce such injuries, more knowledge about the sources of altered GRF is imperative.[15] The present knowledge suggests that "in depth individual biomechanical assessment is required for the identification of desirable shoe-surface (interface) combinations"[15] previously it has been commented that "Electromyographic analysis is required to confirm or disprove the contribution of muscle activation to running adjustments due to changing surfaces".[3] It is also found that "Tibial musculature attenuates ground reaction forces, deficits in its strength might contribute to stress fractures". However data that can be used to characterize the Tibial musculature is scarce[3] thus more quantitative assessment is needed.[16] Further, several researchers have found that in contrast to the Gastrocnemii, relatively little is known about in vivo behavior of the Soleus muscle during walking and running.[17–19] In a study titled[2] "Different activations of the Soleus and Gastrocnemii muscles in response to various types of stance perturbation in man" authors found that "though the Soleus and medial & lateral Gastrocnemii behave differently during various movements, but no attempt has been made to disclose any distinct activation of these muscles during perturbations of upright stance". There is a certain dearth of research evidence differentiating the soleus from gastrocnemius in

Table 2
Criteria for quality assessment.

No. Study	Reporting							
	1. Hypothesis/aim/ objective clearly described?	2. Outcomes measures clearly described	3. Participant characteristics clearly described	4. Interventions clearly described	5. Confounding variables clearly described	6. Main findings clearly described	7. Estimates of the random variability reported	8. Actual probability values reported
SCORES Research Article	**0/1**	**0/1**	**0/1**	**0/1**	**0/1/2**	**0/1**	**0/1**	**0/1**

weight-bearing situations. Such information is vital for podiatrists, physiotherapists, arthroscopic surgeons and orthopaedicians to device their interventional/rehabilitative strategies. A preliminary search revealed that, the literature currently lacks a systematical overview that provides clinician's insight in normal Soleus muscle activity and its adjustments in different tasks and footwear conditions. Surface Electromyography (SEMG) is commonly analyzed by researchers & clinicians to understand muscle activity.[20,21] SEMG studies frequently analyze signal amplitude, fatigability and frequencies/patterns[22] to understand individual muscle activity. The Objective of this study was to systematically review available research literature investigating Soleus muscle activity on Surface Electromyography (SEMG) features, in healthy subjects under different footwear conditions during different task.

2. Methods

2.1. Search strategy

The Items included in this systematic review are as per recommendations of "PRISMA - Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols".[23] The title of this systematic Review was converted into keywords based upon its PICO terms. The combination of keywords applied to the search were "Surface Electromyography AND Shoe AND Soleus" to electronic databases PUBMED, EBSCOHOST (Academic Elite) and SCIENCEDIRECT on 30.11.2020. There was no cut-off year of publication set, to restrict the search for potentially relevant articles. Search results were initially screened on the title; relevant articles were further screened on abstract and full text based on predetermined eligibility criteria (Table 1). These criteria were derived from the PICOS methodology and publication feature.

2.2. Quality assessment

The methodological quality of each included study was evaluated for "Risk of bias". Two independent "appraisers" separately (Author 2 & 3) evaluated each "included research article" on Modified Downs and Black[24] checklist consisting of a total of 16 quality parameters (Table 2). An agreement meeting was later arranged between the 2 "appraisers" to confirm that their evaluation is in accordance with the quality assessment criteria. Further to resolve disagreements between two "appraisers" and validation of their evaluation a moderation meeting was arranged between the two "appraisers" under the chair "arbitrator". The final decision of selection of "research articles" for review was made in the moderation committee by the "arbitrator" (Author 4).

2.3. Data extraction

Information was included from each selected study on: Sample characteristics; Task; Footwear (Intervention) Comparison; SEMG activity reported/analyzed of Muscles; SEMG, Kinematic, Kinetic Outcome Measures Reported/Analyzed and Quality Assessment Score of each study. The information on data extracted is summarized in Table 3.

2.4. Guarantor of the review

Author 1 accepts the complete accountability for the reliability of this review and should be identified as such.

3. Results

3.1. Study selection

Searches of electronic databases generated 176 results from PUBMED, 27 results from EBSCOHOST and 232 results from SCIENCEDIRECT; a total of 435 search publications. Duplicate publications were omitted and 247 articles were excluded on the basis of initial title screening. Remaining 188 relevant articles were further applied to both inclusion and exclusion criteria. 33 studies were finally selected for quality assessment. All articles investigated SEMG activity of Soleus Muscle under one or more footwear conditions. All studies were original research articles published in English.

3.2. Search summary (Fig. 1)

Total Results – 435.

- EBSCOHOST (includes - Green FILE, Library Information Science & Technology Abstracts, Teacher Reference Center and Academic Search Elite)
  - o Keywords - "surface electromyography + soleus muscle + shoes or footwear"
  - o Results - 27
- SCIENCEDIRECT ELSEVIER
  - o Keywords – "Surface Electromyography AND soleus AND shoe - Advanced search
  - o Results - 232
- PUBMED
  - o Keywords – "Surface Electromyography AND soleus AND shoe"
  - o Results - 176

3.3. Quality (risk of bias) assessment

All 33 articles were assessed for quality on modified Downs and Black[24] checklist; with a maximum total score of 17 points, all articles scored between 13 and 04 points. 15 articles scored more than 50% of the maximum score. On individual quality parameters; all

External validity		Internal validity				Selection Bias	Power	Maximum Total Score	Percentage of Maximum Total Score
9. Participants representative of entire population	10. Intervention(s) representative of those in clinical practice	11. Attempt to blind participants to intervention	12. Attempt to blind those measuring outcomes of intervention	13. Appropriateness of statistical tests	14. Accuracy of main outcome measures	15. Participants randomized to intervention group	16.Adequately justified sample size		
0/1	**0/1**	**0/1**	**0/1**	**0/1**	**0/1**	**0/1**	**0/1**	**17**	**100**

Table 3
PICO Information of the studies included in the Review.

Sl. No.	Reference Study with year of Publication	Sample size & characteristics	Task	Comparison/ Intervention	SEMG activity reported/ analyzed of Muscles	Outcome Measures Reported/Analyzed				Quality Assessment Score
						SEMG		Kinematic	Kinetic	
						Side	RMS ONSET iEMG	Foot-strike pattern/ Gait timing/Stride/ JROM/economy	GRF COP Moment Loading Rate	
1	**Branthwaite et al (2013)**[26]	20 volunteers (12 male + 8 female); mean: age 26 years; height 170 cm; weight 69.8 kg Foot Posture Index range +2 and + 12	walking along a 10-m walkway at a self-selected pace.	own training shoe and MBT shoe	SOL, MG, LG, TA, PL, RF, BF, GMed	randomly assigned	Mean, Maximum and % value of EMG (mV)	average steps taken timing of heel strike, heel off and toe off	NA	12 (71%)
2	**Ervilha et al (2016)**[27]	10 healthy male (22.1 ± 2 years, 1.81 ± 6 m, 79.8 ± 6 kg) habitually shod runners with used rear foot footfall pattern. Completed min 15 km/week at min running speed 3.5 m/s	Running straight line along 20-m runway striking the force plate using right lower limb	(1) barefoot forefoot footfall pattern (BFF); (2) shod using forefoot pattern (SFF); (3) shod with rear foot pattern (SRF).	VL, BF, TA, GM and SO	Right	Mean (±SD) iEMG, Muscle latency, Co-activation index	NA	integrated vertical GRF, and vertical GRF peak	10 (59%)
3	**Friesenbichler et al (2015)**[28]	20 healthy 12 men & 8 women volunteers; mean age 32 ± 7 years, height 174 ± 7 cm, weight 71 ± 11 kg)	stand (heels 10 cm apart) as motionless as possible for 5 min with conventional or unstable shoes with 2 sets per condition	unstable shoes Fora (women) & Kimondo (men)	SOL, LG	Right	bEMG H_{max} M_{max}	NA	NA	9 (53%)
4	**Harry et al (2015)**[29]	15 men (179.8 cm; 84.5 kg; & 23.8 years) recreationally active basketball, soccer, resistance training, and running for at least 6 months & experienced jump training	3 Vertical Jump (VJ) and standing long jump (SLJ) at self-selected depth & arm swing	barefoot, minimal shoes (Vibram KSO), and Cross-training shoes (MX623)	BF, MG, PL, SM,/ ST, SOL, TA, VL, VM	dominant	peak RMS	Jump displacement Propulsive phase Countermovement phase duration	GRF Propulsive impulse Countermovement impulse	9 (53%)
5	**Kermani et al (2018)**[30]	40 young women of 18–40 years; accustomed to wearing HHS/LHS Shoes 8 h per day; averagely 5 h standing/ walking & 3 h sitting each day	walked on a 6-m walking way with and without their routine shoes on	HHS- women wearing HHS, AND no shoes, LHS -women wearing LHS, AND no shoes.	TA, MG, SOL, PL, BF and RF	dominant	RMS% onset/offset time	NA	NA	9 (53%)
6	**Koyama, and Yamauchi (2018)**[31]	18 healthy men (age, 20.9; height, 1.71 m; weight, 64.0 kg)	Drop jump - stepped off a box 45-cm high and landed on force plate then quickly jumped to land again on force plate	barefoot (BARE) and shod (SHOD) conditions - shoe had carbon rubber outsoles 4.0-cm thick EVA midsole	RF, VL, VM, BF,TA, MG, SOL	Right	mEMG	Jump Height, angles of the knee & ankle joints, foot strike & time of landing, Contact time	1stGRF &TGRF, vertical impulse, loading rate, rebound jump index RJI	9 (53%)
7	**Landry et al (2010)**[32]	28 healthy subjects (19 females, 9 males) able to wear unstable shoe for a min. 30 h/week while walking or standing at work	standing erect & steady on a force plate with hands by their side and feet spaced 15 cm apart	barefoot, stable control shoe and unstable MBT shoe condition.	SOL, FDL, TA, EHL, EDL, PB, PL	Left	Integrated Wavelet Intensity	NA	COP	10 (59%)
8	**Lesinski et al (2018)**[33]	28 healthy (male 14, female 14) active sports science students age 19–26 yrs; with DJ height (>30 cm) and ground contact time (>200 ms)	3 drop jumps; for each condition on stable (force plate) and unstable surfaces (balance pad on force plate)	hard-cushioning sole shoe, soft-cushioning sole shoe & barefoot	TA, GM, SOL, VM, VL & BF	dominant	iEMG	DJ height, time of braking and the push-off phases	DJ performance index	11 (65%)
9	**Morio et al (2016)**[34]	8 healthy male recreational runners (26 ± 2 years; 74 ± 11 kg; 1.78 ± 0.06 m)	Submax. Treadmill run & max. drop jump PRE & POST exhaustive intermittent SSC exercise ergometer	Barefoot and shod treadmill running tests	SOL, GAM, GAL, PL, TA, VM, VL & STSM	Right	aEMG	striking pattern, striking angle, Peak-to-peak amplitude (PPA) acceleration, stride frequency	NA	9 (53%)
10	**Morio and Herbaut (2018)**[35]	16 healthy active females (26.7 ± 7.3 years, 168 ± 3 cm, 64.1 ± 9.0 kg); regularly involved in gym, between 1 and 3 h/week. Shoe size of 39 EU (foot	completed a specific forward stop and go backward walking	2 different indoor gym shoes one ethyl-vinyl-acetate outsole (EVA)	SOL, GAM GAL, TA, VM	Right	Normalized iEMG	Stance, braking and push off duration	Static and Dynamic CoF	9 (53%)

		length 24.5 ± 0.6 cm and foot width 9.4 ± 0.5 cm)	movement called "change of direction"	and one rubber outsole (RB)	VL, RF and BF					
11	**Noé et al (2020)**[36]	10 young active participants (6 females, 4 males; age 19.8 ± 1.5 years, height 171.8 ± 8.6 cm, weight 63.0 ± 9.1 kg) not used to wearing ski-boots	2 bipedal dynamic postural tasks while maintaining the seesaw horizontal with ML AP instability with eyes open looking in front	Barefoot, soft ski-boots and rigid ski-boots	SOL, GM, TA, VM, BF, GLU, ES & RA	left	Normalized EMG RMS	peak-to-peak amplitude of angular movement and the joint angle	COP	11 (65%)
12	**Nurse et al (2005)**[37]	15 subjects, 12 males, 3 females, mean ± SD age:24.7 ± 2.9 yrs; height: 177 ± 9 cm; weight: 74 ± 12 kg	walk at speed of 1.5 m/s along a 30-m indoor pathway	2 shoe insert conditions.; control and textured	SOL, MG, TA, VM., RF, and BF	right	Wavelet analysis	Rear foot eversion and Tibial Rotation	VGRF, impact peak	9 (53%)
13	**Sobhani et al (2013)**[25]	16 heel-toe runners (8 females and 8 males); 29 ± 9 years, height:177.1 ± 9.3 cm, weight: 69.8 ± 11 kg, BMI: 22.1 ± 2 kg/m^2; shoe size: 41 ± 2	run slowly and walk over ground in the 10-m long Gait lab.	standard shoe & Rocker Shoe	TA, LG, MG, SOL	both	EMG peak amplitude, and time to peak (% of GC)	speed, step length, cadence and stance phase, ankle peak angles in late stance and range of motion (RoM)	ankle, knee and hip net joint moments and ankle joint power, ankle PFM "impulse"	13 (76%)
14	**Wang et al (2020)**[38]	20 collegiate male physical education students; 21.8 years (SD = 1.2), 1.72 m (SD = 0.03) and 68.00 kg (SD = 4.32)	Run on 10 m runway, with two force plates to capture right and left foot impact.	Shoe with mass 175, 255, 335 & 415 gms each	VM, VL, RF, TA, GAS lat, GAS med, SOL	right	IEMG	NA	Strike Index SI, VGRF, Peak moment of ankle plantarflexion	9 (53%)
15	**Yick et al (2018)**[39]	5 healthy women from higher education institution age 21.80 ± 4.09 yrs; height, 1.58 ± 0.53 m; weight, 50.20 ± 4.15 kg; size, 34 to 38 (EU); high-heeled shoe wore for, 5.20 ± 4.09 years	shuttle walk on 10 m long and 1 m wide seamless plastic floor walkway for 15 times at consistent self-paced speed	control and multiple-hardness midsole (MHM) and three heel heights	MG, LG, SOL, PER and TA	dominant	Muscle Activation Ratios, Co-contraction Index	NA	NA	9 (53%)

Muscle Abbreviated in Column 6 Table 3 - Tibialis Anterior (TA), Medial Gastrocnemius (MG, GAM, GAS med), Gastrocnemius Lateral (GAL, GAS lat), Soleus (SOL), Peroneus Longus (PL, PER) Biceps Femoris (BF) Rectus Femoris (RF)) and Vastus Medialis (VM) Vastus Lateralis (VL), Semitendinosus (ST) Semimembranosus (SM), Gluteus Medius (GLU), Erector Spinae (ES), Rectus Abdominis (RA).

articles scored point on "Main findings clearly described" and "Accuracy of main outcome measures" and none of the articled scored on parameters "Confounding variables clearly described", "Attempt to blind participants to intervention" and "Attempt to blind those measuring outcomes of intervention". The study by Sobhani et al. (2013)[25] scored maximum 76% and 2 studies scored minimum 24% points on quality assessment. 15 studies were considered of reasonable quality (>50% score) to be included in this review.

3.4. Sample characteristics

There were a total of 269 participants in 15 studies with individual samples ranging from 5[39] to 40[30] participants; all studies included asymptomatic (healthy) participants. The average sample size being 17.9; 05 studies included only male participants,[27,29,31,34,38] 04 studies included only female participants[30,35,39] and 06 included both male and female participants.[25,26,28,32,33,36,37] The age of the participants included in all studies ranged between 18 - 40 yrs. All participants were free from any injury, musculoskeletal/neurological symptoms at the time of study. Sample activity profile was highly variable within studies ranging from recreational/runner,[25,27,34] footballer,[27] Gym,[35] and students.[33,38,39]

3.5. Task characteristics

All studies investigated outcome measures in one or more footwear conditions under a specifically prescribed protocol/task. The subjects performed the respective task actively. The types and procedure of task prescribed were highly variable. Subjects were studied in running,[25,27,38] walking[30,35,37,39] Jumping[29,31,33,34] and standing (postural task)[28,32,36] under different footwear conditions. The characteristics determinants of these prescribed tasks were also found to be highly variable and largely not supported by literature/reference.

3.6. Footwear comparison (intervention) characteristics

07 studies compared the task in barefoot conditions. 09 studies compared task outcome in more than one footwear conditions (including barefoot). 01 study analyzed effect of skiboot, 02 studies investigated rocker shoe and 02 studies analyzed MBT shoes. One study considered foot strike pattern in running under different footwear condition.

3.7. Soleus SEMG reporting

Upon application of clear eligibility criteria and quality assessment parameters 15 articles were considered for review however, several methodological differences in SEMG data acquisition, data analysis and reporting were found that need to be mentioned. The information on SEMG activity of soleus investigated was found to be highly variable in reporting. 05 studies adequately described, 02 inadequately described and 08 studies did not describe at all; the electrode type and technique of placement. Only 11 studies described the procedure of skin preparation and electrode placement/location. 12 studies described the process of signal processing; whereas only 09 studies described the normalization method applied to the data. It is pertinent to mention here that remarkably, 12 studies reported significant difference in Soleus Muscle activity, though the outcome measures (SEMG features) reported were highly non-aligned namely: Mean activity Increased,[26] decreased Co-contraction Index (CCI) and latency,[27] earlier contraction and

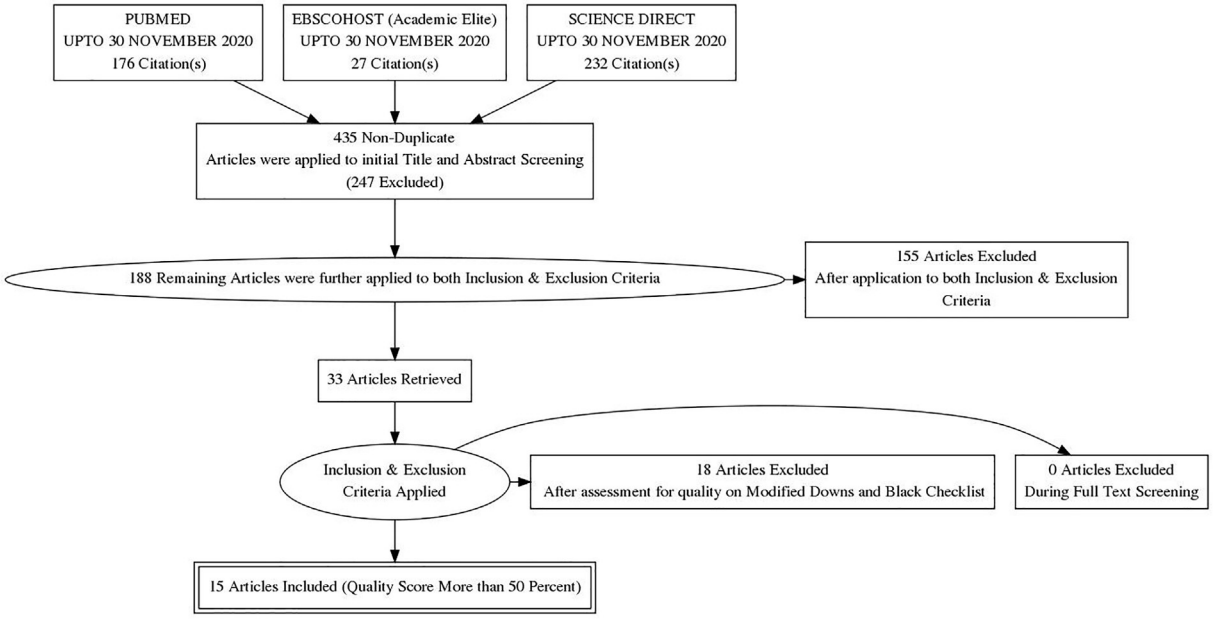

Fig. 1. Summary of manuscript search and selection process.

more muscle activity (RMS),[30] significant footwear-surface interactions in pre-activation phase,[33] decreased activity,[34,35] reduction in total energy,[37] delayed peak activation[25] and increase in CCI.[39] On the contrary two studies[28,31] found no significant differences in Soleus Muscly activity SEMG parameters. One study[36] though collected, but did not analyzed Soleus muscle SEMG data.

4. Discussion

This systematic review aimed to extract evidence regarding soleus muscle activity and timing on SEMG parameters under different shod conditions in healthy subjects. Results suggest that shoe conditions lead to different soleus activation/time patterns on SEMG feature analysis, however there is weak to moderate evidence about individual differences reported in such studies on soleus muscle activity on SEMG under different footwear conditions. All studies involved highly variable features on PICO terms making their individual results potentially weak evidences. The choice of footwear (feature) comparison was somewhat arbitrary in all studies. The feature of the footwear considered for comparison was found highly variable; features studied ranged from type (stability), material (sole), stability, heel size and weight. Though majority of studies investigated the SEMG parameters during locomotion (walk/run), the prescribed task was found to be highly variable. It is important to mention that soleus is an important muscle to many actions that are very different to that performed during walk/run/gait; actions like isolated plantar flexion (pedaling action) and heel rise especially in knee flexion remain largely uninvestigated. None of the study carried further finding/suggestion of the previous studies. All studies were performed in different laboratory setting and no mention/reference was considered to real life situation and contexts. This further makes direct application of their results in clinical (regular) context, unreasonable. Also the variability in muscle SEMG is not clearly related/explained with respect to any shoe feature. This is mainly due to scattered focus on features and dearth of strong evidence on any particular feature. The subjects were given exposure to shoe condition in a variable manner; the effect of habituation following a change in footwear was not considered in general. Further the inconsistent findings between studies can be due to variability in task tested in different footwear conditions. Additionally, considering high degree of variability in commonly available shoe types the generalization of effect of such standalone studies remain elusive.

5. Conclusion

The clear effect of shoe on Soleus muscle activity is not fully understood. Definite evidence is not available about change in SEMG activity of Soleus muscle in different shoe conditions. Consultants aiming to use shoes as a modality in their training protocols need more consistent information on soleus muscle activation to better understand the mechanism of its altered biomechanics in different shod conditions. Further research work especially investigating effect of footwear in non-locomotion actions of soleus muscle in real life setting is recommended.

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Conflict of interest and authorship conformation

With respect to article submission titled “Surface Electromyographic Analysis of Soleus Muscle Activity in Different Shod Conditions in Healthy Individuals - Systematic Review”, I declare herein as under:

- The authors report no potential conflicts of interest in the development and publication of this article.
- All authors have participated in drafting the article or revising it critically for important intellectual content; and approval of the final version.
- This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript

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Recent advances in wrist arthroscopy: A literature review

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ABSTRACT

Wrist arthroscopy is a common procedure done by hand surgeons which have undergone many modifications and improvements since it was first described. The advent of new portals (both dorsal and volar) means that the wrist joint can be viewed from virtually any perspective ("box concept"). Indications for wrist arthroscopy include diagnostic and reparative procedures and, more recently, reconstructive, soft-tissue, and bony procedures.

With an expanding list of indications and procedures that can be performed with this technique, it with an essential diagnostic and therapeutic tool for orthopedic hand surgeons.

Arthroscopic assessment of traumatic conditions such as distal radius fractures, scaphoid fractures, and their associated non-unions, soft tissue, and chondral injuries are thought to be superior to fluoroscopy. Management of non-traumatic conditions such as triangular fibrocartilage complex injury (TFCC), instability, excision of ganglions, kienbocks disease are also possible. Complications of wrist arthroscopy are relatively uncommon.

1. Introduction

Wrist arthroscopy has come a long way since been introduced by Chen[1] in 1979. It is one of the commonly performed procedures by hand surgeons and in the last five years, the wrist has become the third most common joint to undergo arthroscopy, after the knee and shoulder.[2] From being just a diagnostic tool, in the last decade or so it has firmly established itself as a therapeutic procedure in the vast majority of wrist pathologies.[3]

Arthroscopic examination of the wrist includes the radiocarpal and midcarpal joints. Traditionally, the 3–4, 4–5, 6R, and midcarpal portals have been used as diagnostic and working portals.[4] With the advent of new volar portals, it is now possible to have viewing and working portals that encircle the wrist.

The new NanoScope™ (Arthrex, USA) along with wide-awake, local anesthetic, no tourniquet techniques (WALANT), means that we can dynamically assess and treat wrist pathology without the associated risk of general or regional anesthesia. Wrist surgery is evolving, and arthroscopy is right at the forefront. Wrist arthroscopy now has a wide range of indications for both diagnostic and therapeutic purposes.[2–4] The purpose of this article is to outline recent developments and current indications in the field of wrist arthroscopy by looking at recent literature.

2. Methodology

2.1. Search strategy

A literature search was conducted through databases including PubMed (MEDLINE), Embase, ScienceDirect, and Google Scholar. In recent articles published from 2019 to 2020, a total of one hundred and thirty-two articles were included and the search was limited to articles available in the English language only (Fig. 1). The articles were reviewed by subdividing them into respective wrist pathologies. The quality of the studies found were mixed levels of evidence. A trend towards focussing concerning wrist pathology was also looked at for the last five years. Literature review proves 65% of publications were from Asian countries. Metanalysis could not be performed due to heterogeneity of studies.

2.2. Search terminologies

The National Library of Medicine's (NLM) Medical Subject Headings (MeSH) terms were selected and used along with text words. MeSH terms provided a consistent way to retrieve

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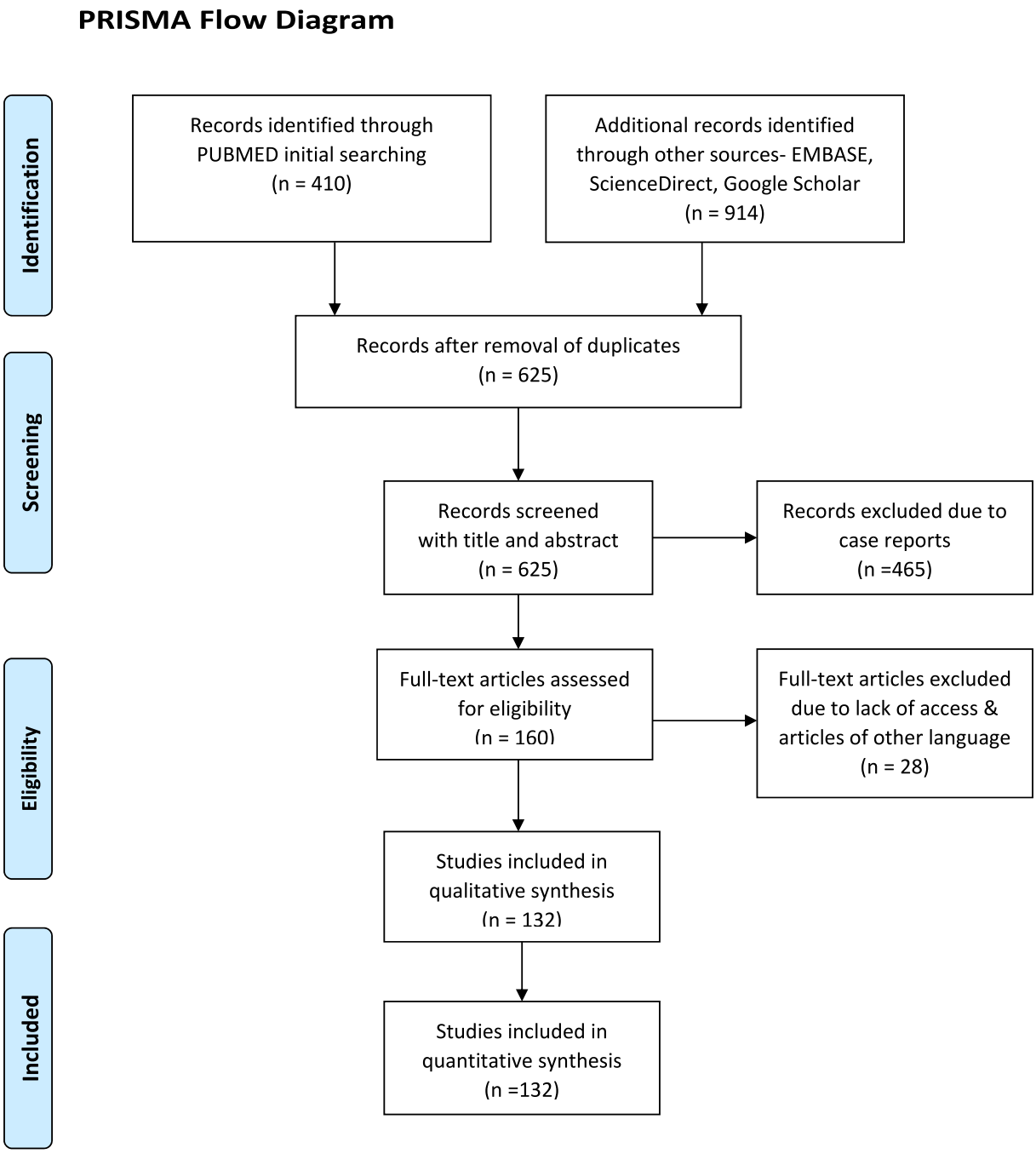

Fig. 1. Flow diagram of search methodology.

information where different terms had been used by authors for the same concept. The terminologies used included 'Wrist arthroscopy'.

2.3. Wrist pathologies

2.3.1. Distal radius fractures

One-third of distal radius fractures are associated with injuries to the scapholunate (SL) and lunotriquetral (LT) interosseous ligaments. Diagnosis of these injuries is challenging on plain radiographs and wrist arthroscopy is considered an adjuvant tool. Because the natural history of these injuries is unclear, the necessity of diagnosing and treating these SL and LT interosseous ligament defects remains speculative.[5] Patients treated with arthroscopically assisted reduction appear to have a greater range of motion (ROM). However, there is still no consensus on the benefit of arthroscopically assisted treatment of intra-articular distal radius fractures.[6]

Failure to reduce intra-articular distal radius fractures (DRF) can lead to persistent pain, restricted joint motion, or post-traumatic arthritis. Arthroscopy has several advantages including a less invasive approach and superior view of the intraarticular surface as compared to an open arthrotomy.[6]

Although there is a temptation to think that intraarticular visualization would lead to better fracture reduction, a multicentre randomized trial found no clinically relevant functional outcomes in patients with or without arthroscopically assisted distal radius

fracture fixation.[7] Krustins et al.[8] in a prospective cohort study found that the method of fixation does not affect the clinical outcome in arthroscopically assisted distal radius fracture fixation.

TFCC injuries are an important associated injury affecting the outcome of distal radial fractures.[9] Carpal arthroscope-assisted treatment of intra-articular fractures of distal radius can achieve good reduction and postoperative function. Ya-Bo Cheng[10] showed that wrist arthroscopy assisted open reduction and bone graft through bone window internal fixation in treating distal radius die-punch fractures has advantages of good recovery of wrist function, reduction in pain, and satisfactory clinical outcomes.

As per the authors, wrist arthroscopy has a role in significantly comminuted distal radius fracture management. Not only does it help in the accurate reduction of the articular surface, but it also allows finding concomitant injuries.[11] Failure to reduce intra-articular fractures caused by a distal radius fracture (DRF) can lead to persistent pain, restricted joint motion, or post-traumatic arthritis.

In our practice indications for arthroscopy in DRFs are intra-articular fractures with comminution and/or die-punch fragments, associated carpal bone fractures or obvious intrinsic ligament injuries, an obvious widening of the distal radioulnar joint (DRUJ) suspecting a triangular fibrocartilage complex (TFCC) lesion, and radial styloid fractures because of a potential incomplete greater arch lesion with an SL ligament tear.

2.3.2. Scaphoid fracture

Arthroscopic realignment and osteosynthesis for the treatment of unstable scaphoid non-union with ipsilateral radius bone graft, even with humpback deformity, can achieve a high union rate, good radiological correction, and functional recovery.[12]

Scaphoid non-unions less than 1 year after trauma and no carpal malalignment can be treated with percutaneous screw fixation under fluoroscopic and/or arthroscopic guidance.[13] Wrist arthroscopy also provides a minimally invasive means of assessing scaphoid pathology and direct assessment of fracture stability without causing significant surgical trauma to the ligamentous architecture and vascularity for stable scaphoid non-unions over percutaneous fixation alone.[14]

Arthroscopic bone grafting (ABG) in difficult scaphoid delayed union and non-union allows thorough assessment and comprehensive management for scaphoid fracture and its sequelae. It provides a favorable biological environment for bony healing and produces minimal trauma to the soft tissues, aiding in rehabilitation. Despite a long learning curve, with adequate training and experience, high union rates and satisfactory clinical outcomes can be achieved.[15] Karthik et al. showed that in 18% of patients the initial management plan changed after arthroscopy.[16]

Arthroscopic distal scaphoid resection alone can reduce pain and improve functional outcomes for early to mid-stage isolated STT osteoarthritis in patients without dorsal intercalated segment instability deformity. Resection of greater than 3 mm of the distal scaphoid may result in carpal malalignment.[17]

For proximal scaphoid non-union, arthroscopic-assisted reduction, bone grafting, and screw fixation across the SL joint could be an alternative treatment.[18] With healing rates comparable to open methods, arthroscopic management has the advantages of providing a thorough wrist assessment, a comprehensive approach to address coexisting intraarticular pathologies, and minimal surgical trauma to the structure and vascularity, which is favorable for fracture healing.[19]

2.3.3. De Quervain's disease

Both one portal and two portal endoscopic 1st extensor compartment release have been discussed in the literature recently. Karkaplan et al.[20] retrospectively reviewed patients who underwent single portal endooscopic 1st extensor compartment of the wrist release following failed non-operative management. They found excellent results in these patients and conclude that a single portal extensor compartment is a safe and effective procedure.

There is still a debate on the benefits of endooscopic versus open procedure for the management of De Quervain's tenosynovitis and in the author's view, a prospective well-powered RCT will be a solution to this answer.

2.4. Triangular fibrocartilage complex (TFCC)

TFCC continues to be an evolving as well as a challenging topic in wrist arthroscopy. The vagueness of symptoms has prompted an investigation of the best possible diagnostic method for TFCC tear. Recent evidence suggests that non-invasive diagnostic methods are as good as arthroscopy in diagnosing TFCC tear.

Park et al.[21] have tried to compare indirectly the finding of MR arthrogram of the wrist with a TFCC tear. They compared 131 MR arthrograms and concluded that the proximal ligamentous component (PLC) with a distal prolapse pattern and large height-to-length ratio (HLR) are associated with TFCC foveal tears. The HLR of the PLC measured on coronal MR images can therefore be used as an additional predictor of tears of the foveal attachment of the TFCC.

Petsatodis et al.[22] have compared the diagnostic accuracy of Magnetic Resonance Imaging (MRI) and MR Arthrogram (MRA) with wrist arthroscopy. Of the forty cases diagnosed by wrist arthroscopy, the pick-up rate with MRI was 26 and MRA was 38. They concluded that there was no difference in the diagnostic accuracy between wrist arthroscopy and MRA.

Zhan et al.[23] retrospectively looked into the traumatic injury of the triangular fibrocartilage complex (TFCC) by using high-resolution 3-T magnetic resonance imaging (MRI) and found that more detailed injury patterns including capsular injuries, horizontal tear of the articular disk, and the bucket-handle tear could be diagnosed with this modality.

Tomori et al.[24] divided the ulnar styloid fracture into two-part - tip and middle part (up to 5 mm from the tip) and the base and compared the incidence of TFCC tears in patients with distal radius fracture. They found that there was a statistical difference in TFCC tears in patients with base of ulnar styloid fracture having a greater incidence of a TFCC injury. They also found that traumatic TFCC injury can occur in adults with Distal Radius Fractures, regardless of the presence of Ulnar Styloid Fracture.

There have been new surgical techniques described as well as established surgical techniques compared with patient-reported outcomes. Johnson et al.[25] in a cadaveric study compared arthroscopic transosseous ulnar tunnel repair with the arthroscopic peripheral capsular repair. Trans osseous ulnar tunnel repair effectively restored DRUJ stability whereas the stiffness and maximal displacement of those specimens undergoing peripheral capsular repair remained different from the intact state.

In chronic irreparable injuries of TFCC where there is no chondral loss of the DRUJ. Baixauli et al.[26] have shown that a completely arthroscopic reconstruction technique of the triangular fibrocartilage complex using tendon graft provides stability to the DRUJ.

Sarkissian[27] has published his results of 22 patients who had failed non-operative treatment of Palmer Type 1B TFCC tear and underwent all-arthroscopic technique using a pre-tied suture device. At seven-year follow up the study shows that patients regained near full grip strength and more importantly the improvement in outcome continues well after the first year following the surgery.

Foveal attachment of TFCC continues to give good mid to long

term outcome either done as Arthroscopically assisted[28] or all inside knotless repair[29] Early surgery or surgery at 12 months from actual injury doesn't seem to have much effect on the outcome for foveal detachment of TFCC.[30]

With improving, diagnostic methods more paediatric and adolescent TFCC tears are being diagnosed. Most of these tears are posttraumatic and peripheral. Nearly half of them are associated with other pathology and about a quarter of these need Ulnar shortening osteotomies.[31,32] However, the functional outcome in the majority of these patients post-operatively is excellent.

Multiple factors have been looked into which predict the group of patients who would benefit from surgical intervention for TFCC tear. For acute, traumatic, ulnar-sided tears in young patients, arthroscopic repair remains an effective treatment option regardless of ulnar variance.[33] In patients who undergo complex arthroscopic transosseous triangular fibrocartilage complex (TFCC) foveal repair, lower Pronator Quadratus muscle cross-section area on magnetic resonance imaging was found to be the most independent prognostic factor negatively affecting clinical outcomes.[34]

2.4.1. Ganglion

Arthroscopic versus open excision of ganglion continues to be a topic of debate. A systematic review conducted by Crawford et al.[35] found comparable outcome profiles in both modalities of treatment. However, because of the quality of evidence available, they considered it to be a level II study.

There have been quite a few case series published on arthroscopic excision of wrist ganglion with a common theme of lower recurrence rate and better wrist function compared to open method of excision of wrist ganglion. Fernandes et al.[36] looked retrospectively into a case series of 34 dorsal wrist ganglion which underwent arthroscopic excision. Their follow-up at four years showed a good outcome with no serious postoperative complication. There was only one recurrence out of 34 cases during their follow-up. In another case series on arthroscopic excision of volar wrist ganglion, Oliveira et al.[37] reported 21 patients who underwent the procedure for four years. During their follow-up for a minimum of six months, they found no recurrence of the cyst. Open volar wrist ganglion is notoriously associated with a higher risk of complications due to the proximity to the palmar superficial branch of the radial artery, flexor tendons, superficial terminal branches of the median nerve, and cutaneous palmar branch of the median nerve all being very close to the surgical incision.[35] In their case series, only one patient had mild neuropraxia which settled in six weeks.

In another retrospective case-control study, Yen et al.[38] have reviewed the cost-effectiveness of Wide-Awake Local Anesthesia No Tourniquet (WALANT) arthroscopic gangliectomy versus arthroscopic excision of wrist ganglion under general anesthesia. They found that WALANT arthroscopic wrist gangliectomy to be much more cost-effective than the general anesthetic gangliectomy. The complication rate and recurrence rate were also comparable.

Although the current literature suggests that there may be is slight benefit in arthroscopic excision of ganglion, we need a good prospective randomized control trial that is adequately powered to answer as to whether arthroscopic wrist ganglion excision has any patient-specific benefit compared to the open excision of wrist ganglion.

2.4.2. Instability

A scapholunate ligament tear can lead to chronic instability and post-traumatic arthritis. Arthroscopy remains the gold standard for diagnosing acute SL injury. Non-invasive investigations include X-ray, MRA, and Flat-panel Cone-beam CT Arthrography. Dornberger et al.[39] compared the sensitivity and specificity of multislice CT arthrography and cone-beam CT arthrography with arthroscopy and found that the sensitivity and specificity of these modalities were quite high in comparison with arthroscopic findings. The radiation dose was lowest with CBCT arthrography. Hence CBCT can be a non-invasive diagnostic tool in places where MRA is unavailable.

Management of scapholunate ligament injury by open repair or reconstruction very often leads to a stiff joint.[40] Carratalá et al.[41] presented a prospective study of 19 patients with acute SLL injury which was managed by arthroscopic reinsertion and dorsal capsular reinforcement of the SLL. Their outcome was very good and they concluded that arthroscopic anatomical repair can be done similar to that obtained with open surgery without the complications and stiffness secondary to aggressive interventions on the soft tissues that are inherent to the open dorsal approach.

Arthroscopic thermal annealing can be used in the management of chronic ligament laxity. Halsper[42] clinical outcomes of patients treated for chronic distal radioulnar joint instability with arthroscopic thermal annealing of the superficial radioulnar ligaments, ulnar palmar wrist ligaments, and dorsoulnar wrist capsule using a radiofrequency probe. At a mean follow-up of 10 years very high proportion of their patients were satisfied with the outcome. Thermal shrinkage was also used by Crespo Romero et al.[43] in the management of partial tear of SL ligament. In a prospective study, they found out that electrothermal shrinkage effectively provided pain relief and grip strength increase for most of the patients.

2.4.3. Chronic wrist pain

Chronic wrist pain more often than not needs further evaluation in the form of clinical examination as well as invasive and non-invasive investigations. Studies have compared the best possible way of diagnosing and localizing any structural pathology in chronic wrist pain. Omar et al.[44] and Mehta et al.[45] compared non-invasive modalities of MRI and MRA and found out that apart from Ligamentous lesion and TFCC injury, MRI is equivalent to MRA in picking other pathologies of wrist pain. However, in this study, MRA was inferior in picking ligamentous injuries in comparison to wrist arthroscopy in chronic wrist pain. The authors believe that for ulnar side wrist pain a careful physical examination can narrow the differential diagnosis, and adjunctive imaging with X-ray and MRA can pick up most of the pathologies, especially TFCC. However, for radial side wrist pain diagnostic arthroscopy preferably dry scope is still the gold standard.[46] Negative results of MR arthrography in patients with clinical suspicion of TFCC tear should be interpreted with caution and followed up with arthroscopy[47]

2.4.4. Further indications

The potential benefit of arthroscopic assisted wrist fusion includes an aesthetically acceptable scar on the skin as well as less scar formation and subsequent less extensor tendon adhesion giving good hand function. Nazerani et al.[48] have prospectively used arthroscopy for total wrist fusion with an excellent outcome in four very selected groups of young patients - three of which had brachial plexus injury and the fourth had cerebral palsy with a three month follow up. We need to wait and see how these procedures do in a general group of patients and also their long-term outcome.

Although arthroscopic washout of septic arthritis in large joints is an established treatment, in the wrist there is still a dearth of literature on arthroscopic washout of the septic wrist. Chow et al.[49] retrospectively reviewed patients who presented with septic arthritis of the wrist and who underwent arthroscopic washout of the wrist with an average follow-up of ten months. Out of fifteen wrists, thirteen responded to one washout however two patients

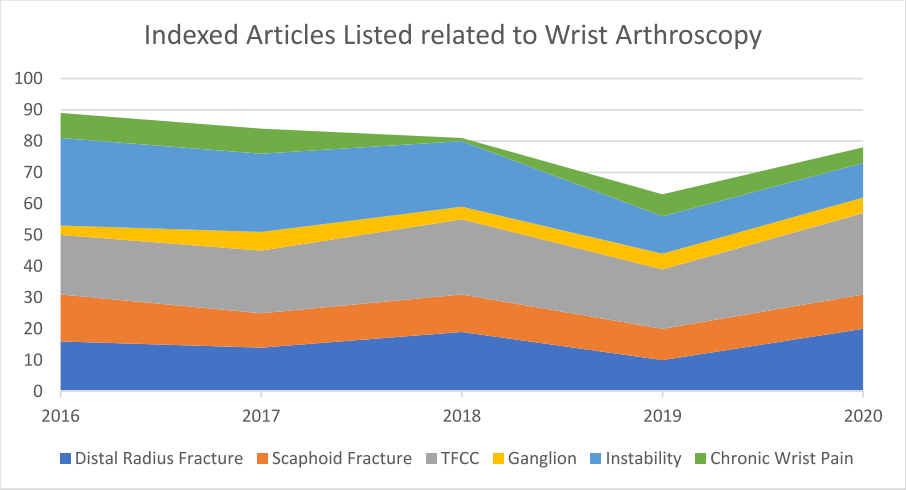

Fig. 2. Indexed Articles listed related to Wrist arthroscopy from 2016 to 2020.

needed further surgery due to concomitant tenosynovitis. They conclude that arthroscopic wrist washout for septic arthritis is a safe and optimum treatment.

Both professional and amateur athletes can present with acute traumatic and overtraining or repeated injury-related pathologies. Arthroscopy has the potential of quicker rehabilitation and in turn quick return to sports.[50]

2.4.5. The trend of indexed articles in the last five years

On searching indexed articles, a total of 377 articles are listed from 2016 to 2020. Articles published in Distal Radius fractures were 70, Scaphoid fractures-51, TFCC - 94, Ganglion –21, Instability –86, Chronic wrist pain –25, remaining were miscellaneous conditions (Fig. 2).

3. Conclusion

Wrist arthroscopy has a steep learning curve, but the potential advantage over open procedures has led to an increase in the number of surgeons turning towards arthroscopic techniques. Wrist arthroscopy is a relatively safe procedure that has undergone many advances since it was first described. It is now regarded as the gold standard in the diagnosis and treatment of a variety of conditions. Its clinical applications continue to expand, with more complex reparative, reconstructive, and salvage procedures now being performed. Further advances are likely to occur from adapting open reconstructive procedures into an arthroscopic model. For most indications the level of evidence is still low, but as there is increasing interest in arthroscopic techniques larger RCTs are required.

Recent advances of NanoScope™, WALANT and dry arthroscopy, arthroscopic reduction and internal fixation, and arthroscopic fusion procedures have changed the face of minimally invasive wrist surgery.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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Research paper

Efficacy of topical versus intravenous tranexamic acid in bilateral total knee arthroplasty

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ABSTRACT

Introduction: Multiple strategies, used either in isolation or combination, are available to reduce the need for post-operative blood transfusion in joint replacements. Amongst them, the use of tranexamic acid (TXA) has been rising and this study was conducted to compare the efficacy of topical and intravenous TXA in bilateral total knee replacement patients.

Materials and methods: Randomised prospective study with 120 patients (male: female: 25:95) undergoing bilateral TKA. Patients were divided into two groups A and B after computer randomization, who received intravenous or topical (intra-articular) TXA respectively.

Results: The average haemoglobin loss in intravenous group was 90.2379 g/L as compared to 39.137 g/L in topical group ($p < 0.005$).Moreover, there was reduction in blood loss in topical (330.1602 ml) as compared to intravenous group (764.9622 ml). The blood transfusion rate was more for the intravenous group (average 1.73 units) than for the topical group (average 0.75, unit). WOMAC score at 6 weeks in the intravenous group was 12.50, and in the topical group was 7.23 (p value < 0.001).

Conclusion: Topical TXA is better than intravenous TXA for reduction of blood loss, which also reduces the need for blood transfusion in bilateral TKA patients.

1. Introduction

With an increase in the aging population, the number of knee joint replacements is expected to increase fivefold by 2030.[1] Since the longevity of the implants has been fairly accepted, current research is aimed at refining the design to improve patient function, reducing the post-operative morbidity and improving the patient satisfaction.

Blood management strategy is an essential component of good patient care in such surgeries.[2] Literature reported that approximately 20–70% of patients undergoing knee arthroplasty require blood transfusion.[2–4] The transfusion rates following unilateral TKA range from 4 to 46%, whereas single stage bilateral TKA results in transfusion rates ranging from 31 to 72%.[5,6]

Multiple strategies are available to reduce the need for blood transfusion which can be used alone or in combination in patients undergoing joint replacement.[7–9] Recently the use of pharmacological agents is popularised to reduce blood loss.[2,3] Tranexamic acid (aminomethylcyclohexane-carboxylic acid) is such anti-fibrinolytic agent, commonly used either preoperatively, intra-operative or post-operative to reduce blood loss in TKR.[3–5]

Few studies have been published showing promising results of TXA used as topical/intraarticlar agent.[10,13,18] The advantages reported were achieving maximum concentration at bleeding site, easy administration and minimal systemic side effects as compared to intravenous administration. As the use of tourniquet has led to decrease in blood loss during such surgeries.[2,5] However, studies suggested most of blood loss occurs in the post-operative period, where topical TXA could help in reducing blood loss.[1,10] The efficacy of intra articular and intravenous use of TXA is still debatable. Our study aimed to compare topical and intravenous use of TXA in blood loss reduction in bilateral TKR. The secondary objective was to calculate the need for blood transfusion and functional outcome WOMAC score in both groups.

2. Materials and methods

This prospective randomised study was conducted from May 2016 to Oct 2016 in tertiary hospital of National capital region

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(NCR). Patients between age group (55–80 years) undergoing bilateral TKR who were medically fit were included in this study. Patient with history of cerebrovascular attack (CVA), myocardial infarction (MI), deep venous thrombosis (DVT), pulmonary thromboembolism (PE), acquired coagulopathies, treatment with antiplatelets or warfarin or plasma creatinine greater than 115 mmoL/litre in men and 100 mmoL/L in women were excluded.

The final patient cohort comprised of 120 patients (male: female: 25:95) undergoing bilateral TKR. The patients were randomized through computer generated randomization and divided into two groups of 60 patients each. All surgeries were performed by single surgeon through standard medial parapatellar approach using tourniquet. Patients in group A received intravenous TXA and in group B received intra-articular TXA through the suction drain. The observer was blinded to reduce bias in the study. The demographics of both groups are depicted in Table 1.

2.1. Mode of administration

Group A (Intravenous group): In this group, 10 mg/kg body weight of tranexamic acid was given by slow intravenous infusion 10 min before inflation of tourniquet. A suction drain was applied, and the tourniquet was released after applying compressive dressing. Second dose was given 8 h post-operative in a dose of 10 mg/kg body weight.

Group B (Intra-articular group): In this group, 20 mg/kg body weight tranexamic acid was dissolved in 100 ml normal saline and 50 ml of each was given through drain into each knee after closer of the surgical wound and before tourniquet deflation.

In both groups, the drain was opened after 3 h post-operative period in the ward. In the immediate post-operative period blood loss, general condition and vitals were assessed. Our cut off limit for blood transfusion was 8.5 mg/dl. Adductor canal block was given to all patients before shifting them from theatres. Postoperative pain relief was given according WHO pain ladder. We used mechanical pumps as well as chemical thromboprophylaxis (Enoxaparin) to prevent DVT in both groups. The suction drains were removed after 24 h post-surgery. The total stay for bilateral total knee replacement in our hospital was 6 days. During this period, majority 98% of our patients were safe to be discharged to home under the care of physiotherapist. Before discharge, on 5th post-operative day hemoglobin was measured in both groups. The amount of blood loss was calculated using Good et al. equation.[11]

$$\text{Hb loss} = \text{BV} \times (\text{Hbi} - \text{Hbe}) \times 0.001 + \text{Hbt}$$

Note: Hbi – Hb concentration before surgery; Hbe – Hb concentration on the fifth day after surgery; Hbt – total amount of allogenic Hb transfused; BV – blood volume taken as 7% of total body weight of the patient. A unit of banked blood was considered to contain 52 g Hb.

The blood loss (ml) was related to the patient's preoperative Hb value (g/L)

$$(\text{Blood loss} = 1000 \times \text{Hb loss} / \text{Hbi})$$

Table 1
Demographic characteristic in two groups.

	Group A (intravenous) N = 60	Group B (Topical) N = 60
Sex (M/F)	13/47	12/48
Age (years)	63.24	64.11
BMI	25.34	25.11
ASA class (I/II)	11/49	13/47

We calculated short term functional assessment of our patients using WOMAC scoring pre operatively, 2 weeks at suture removal and 6 weeks post-operatively. The other variables like blood volume, pre and post-operative hemoglobin levels and number of units of blood transfusion were recorded along with WOMAC score in each case and comparisons were made between the two groups.

2.2. Statistical methods

The analysis of data was done using student's *t*-test which compared average blood loss in the intravenous (group A) and topical (intra-articular) group B. All other averages such as for decrease in hemoglobin, average total blood loss, average drain output at 24 h was compared by student 't' test in the hope that these follow a Gaussian distribution. The level of significance of these entire tests was the usual of 5% and SPSS-20 was used for calculation.

3. Results

The average haemoglobin loss was 90.2379 g/L (0.09–156.45 g/L) in the intravenous group and 39.137 g/L (0.01–156.23 g/L) in intra-articular group ($p < 0.001$) [Fig. 1]. The reduction in blood loss in intraarticular group averaged 330.1602 ml (0.09–1514.89 ml) as compared to 764.9622 ml (0.79–1405.87 ml) in intra venous group ($p < 0.001$)[Fig. 2]. Blood transfusion rates were more for the intravenous group (average 1.73 unit) as compared to topical group (average 0.75 unit) and it was statistically significant. ($p < 0.001$) Post-operatively the functional outcome was assessed by WOMAC score and no significant difference was found at 2 weeks between two groups.(p value > 0.05) However, at 6 weeks post operatively the average score in the intravenous group was 12.50, and topical group average was 7.23 which was found to be statistically significant (p value < 0.001).[Fig. 3].

4. Discussion

Bilateral single staged total knee replacement, uncommon in Western countries, is prevalent in our country as majority of our patients wanted to return to work after one surgery and its puts less financial burden on them along with anaesthetic side effects. TXA has been introduced with an aim to reduce blood loss and thereby eliminate the need for allogenic blood transfusion.[12–15] However, intravenous TXA has been associated with thromboembolic events in some patients (stroke, coronary artery disease, history of VTE).[16–18] This has shifted the focus to topical application of TXA and the results were encouraging.[16–21]

Our results were comparable to a double-blind, placebo-

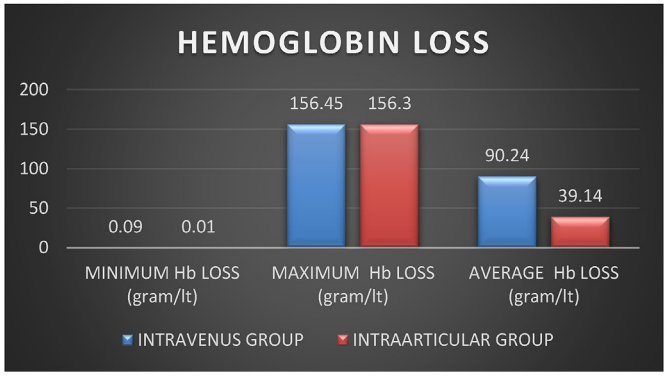

Fig. 1. Showing differences in haemoglobin loss (g/L).

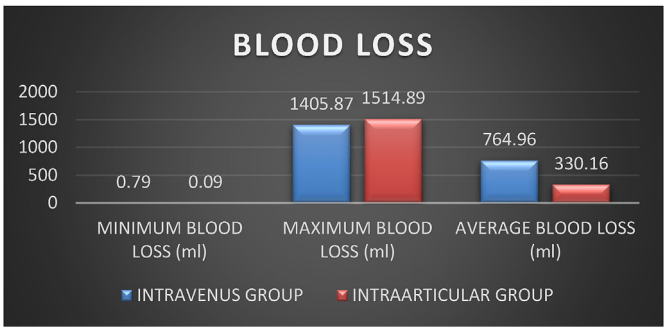

Fig. 2. Showing differences in blood loss (ml).

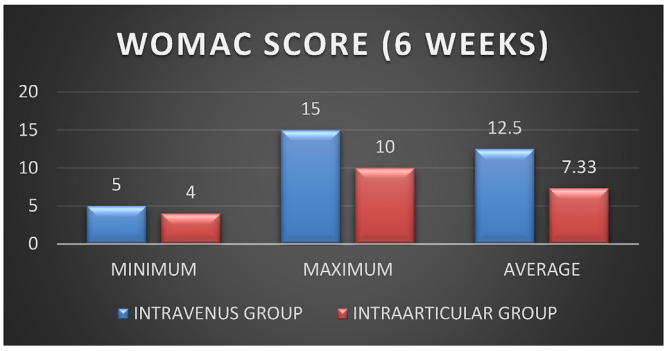

Fig. 3. Showing differences in WOMAC score (6 weeks).

controlled trial conducted by Wong and colleagues.[22] They reported postoperative blood loss was reduced to 1200 ml in tranexamic acid group in comparison with the placebo group of 1610 ml whereas we reported blood loss reduction of 330.16 ml in topical group and 764.96 ml in intra venous group. However, we had a few differences in methodology and results in our study. Firstly, we compared intra-articular with intravenous administration and not placebos. Secondly, we administered drug through drain and then deflated the tourniquet. The suction drain was opened after 3 h, providing sufficient time for topical action. The same practice has been advocated by others like Sa-Ngasoongsong and co-authors.[23] We used a dose for intra-articular injection 20 mg/kg body weight dissolved in 100 ml normal saline and delivered 50 ml through drain in each knee as compared to their intra-articular administration (1.5 g). Since both studies calculated blood loss using difference in pre- and postoperative haemoglobin the timing of tourniquet would not be a confounding factor. We obtained slightly better results with this technique than Wong et al., regarding total blood loss with intra-articular administration of 1.5 g TXA (330.16 ml as compared to 1295 ml).[22]

Another study compared the use of five regimens of TXA (four intravenous, one local; 40 patients each) with a control group (no tranexamic acid).[24] The four intravenous (10-mg/kg dose) regimens comprising of intraoperative dose given before tourniquet deflation, another preoperative dose, postoperative dose and all three doses. The fifth dose was a single local application (LA). The authors concluded, local application of TXA had good results as compared to single dose and intra-operative doses of TXA.[24]

Our study reported significant reduction in decrease in haemoglobin, blood transfusion rates and drain outputs. However, our results varied with literature for intravenous use of TXA. The total blood loss for the intra-articular administration group in our study was less than most trials (330.16 ml) compared to 1,301 ml for Alvarez et al. and 1,225 ml for Molloy et al.[2,25] Even the drain output was less than most published studies [187.50 ml in our study as compared to 385 ml of Good et al. and 478 ml for Zhang et al.[11,26] On the other hand, our results of blood loss and drain output for the intravenous TXA were equivocal with other studies.[25]

The blood transfusion rate in our study for topical group was comparable to other studies but slightly higher for the intravenous group.[25,27] This might be because we chose a lower value of hemoglobin (8.5gm/dl) as the lower limit for blood transfusion criteria in our study. As compared to intravenous, intra-articular TXA seems to be more effective regarding reducing hemoglobin loss, blood loss and frequency of blood transfusion. The results of our study were similar to the study done by Seo JG et al. in which they compared TXA in intravenous, topical, and placebo using fixed dose of TXA in both group (1.5gm mixed in 100 ml NS).[28] Our study supported the fact that the intra-articular route of TXA was superior to intravenous in all aspects.[28,29]

The functional outcome was assessed using WOMAC score. We did not find any significant difference at 2 weeks post-operative in both groups, but at 6 weeks the topical group had significantly better results than intravenous group and the difference was statically significant.($p < 0.001$) Ishida and colleagues reported that intra-articular administration of TXA not only decrease blood loss but also decrease joint swelling after TKA because the TXA has anti-inflammatory property.[30] We did not report any infection or hematoma in any group in our cohort and all patients were discharged after 6 days from hospital and progressed to normal suture removal at 2 weeks and regular physiotherapy for 3 months (initial 4 weeks supervised by physiotherapist and then on their own for 8 weeks). Strict inclusion criteria, antibiotic prophylaxis (preoperatively before incision and post operatively for three days) and good surgical dissection with adequate hemostasis intraoperative and use of drains might be a reason postulated for absence of infection or hematoma.

Moreover, our study did not report any increase of thromboembolic phenomenon with topical TXA like most other studies.[25,28,30] Although our study showed similar results for both groups, it seems practical that if any increased risk of thromboembolism did exist, it would certainly be lesser with intra-articular administration.[22] More research might be needed to establish link between topical TXA and venous thromboembolism in total knee replacement.

5. Conclusion

Our study showed topical TXA was better than intravenous route for reduction of haemoglobin fall and blood loss along with need for allogeneic blood transfusion especially in bilateral total knee replacements. We believed that because of the low systemic toxicity and better efficacy intra-articular TXA can be used for high-risk patients alone or as adjunct to intravenous route to reduce the dose related complications.

Consent

Written Consents Taken.

Ethics committee

Approval Taken For The Study.

Disclosur

Nothing to disclose.

Credit author statement

Gur Aziz Singh Sidhu, Conception and design of study, Acquisation of data, Analysis and/or interpretation of data, Revising manuscript, critically for important intellectual content. SKS Marya, Conception and design of study, Revising manuscript, critically for important intellectual content. Chandeep Singh, Analysis and/or interpretation of data. Shitij Kacker, Revising manuscript, critically for important intellectual content. Sushil Singh, Acquisation of data.

Declaration of competing interest

No conflict of interest.

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Research paper

Comparison of effects of medial parapatellar and subvastus bilateral simultaneous approaches in total knee arthroplasty

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ABSTRACT

Background: Total knee arthroplasty is the prevalent surgical intervention being used to treat knee osteoarthritis. Although the medial parapatellar approach is the prominent surgical approach, the parapatellar incision has concerning theoretical risks. The subvastus approach is a less invasive, but less commonly used alternative. The aim of this study is to compare the post-operative outcomes of these two surgical approaches with respect to retropatellar knee pain, knee range of motion, and quadriceps muscle strength at 6 and 12 months post-operation.

Methods: In this randomized controlled trial, 50 patients who suffered from advanced osteoarthritis in both knees underwent simultaneous bilateral total knee arthroplasty, one using the medial parapatellar approach and the other using the subvastus approach. Retropatellar knee pain, quadriceps muscle strength and knee range of motion were assessed pre-operation, as well as at 6 and 12 months post-operation.

Results: This study found no statistically significant differences in retropatellar knee pain, quadriceps muscle strength, or knee range of motion between the medial parapatellar and subvastus approaches at 6 and 12 months post-operation.

Conclusion: The results of this study provide further evidence that the subvastus approach is a comparable alternative to the medial parapatellar approach, but do not indicate any advantages to one over the other. More research is necessary in order to determine if there is an added benefit to the subvastus approach in the short term (<3 months).

1. Introduction

Osteoarthritis (OA) is an age-related articular condition that is one of the leading causes of disability worldwide.[1] According to the World Health Organization, 9.6% of men and 18% of women over the age of 60 suffer from symptomatic OA, while 13% of women and 10% of men over 60 are affected by OA of the knee (KOA).[2] The increased average age of the population, along with other risk factors such as obesity, ethnicity, and joint trauma, has resulted in a rise in the occurrence of KOA.[1,3–5] The pain, decreased mobility, and daily living impairment caused by KOA affect both physical and psychological aspects of a patient's life. This is especially important considering more than half of KOA patients in the United States are under 65.[6] Thus, it is essential that orthopaedists provide patients with an effective treatment for this condition.

Although pharmacological treatment plays an important role in management of KOA, surgical therapy is still the prominent approach to treat this condition.[7] Total knee arthroplasty (TKA) is the prevalent intervention being used to treat the pain and

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disability caused by KOA.[3,8] The medial parapatellar (MP) approach is the most common surgical therapy,[8] however there are concerns that the parapatellar incision in this approach damages the vascularity of the patella.[9–11] The resulting partial avascularity may lead to patellar fracture, button loosening and anterior knee pain.[12,13]

The subvastus (SV) approach is an alternative to the medial parapatellar approach. This approach is less invasive, preserves patellar vascularity, does not affect the extensor mechanism, and provides an easy evaluation of patellar tracking intraoperatively.[14] Despite its theoretic advantages, the SV approach is not as commonly used as the MP approach.

Comparing the post-operative effects of these surgical approaches has illustrated that patients treated with the SV approach rehabilitated faster and had shorter hospitalizations than those who underwent the MP approach.[15–17] However, to our knowledge, no study has conclusively determined the superiority of either procedure.[18,19] The aim of this study was to compare the short-term effect of the MP and SV approaches on patients by evaluating postoperative retropatellar knee pain, knee range of motion, and quadriceps muscle strength.

2. Methods

This study reports the findings of a randomized controlled trial that looked to elucidate a significant difference in the outcomes of patients with KOA treated with the MP approach versus the SV approach. All participants were formally informed and signed consent prior to enrolment, and the study was approved by the Ethics Committee and Institutional Review Board of Shahid Beheshti University of Medicine and Science.

Recruitment of patients occurred at Akhtar Orthopaedic Educational Hospital, affiliated by Shahid Beheshti University of Medicine and Science. In order to be included in this study, participants were required to be 18 years of age or older, have advanced osteoarthritis in both knees which required TKA, and have adequate mentation to give informed consent. Osteoarthritis was diagnosed by an orthopaedic surgeon based on clinical history, physical examination, and plain radiography of both knees in the standing position. Patients with any of the following were excluded: inflammatory joint diseases, previous knee surgery, arthritis due to any cause other than primary osteoarthritis, joint ligament injuries, and body mass index higher than 30. In total, 52 patients were chosen as participants, with two eventually being excluded – one patient expired 5 months post-operation, and the other suffered a ruptured patellar tendon.

Prior to surgery, each participant attended 10 physiotherapy sessions. They subsequently underwent bilateral TKA, both on the same day, one with the SV approach, and the other with MP approach. All procedures were carried out by an orthopaedic surgeon who is familiar with both approaches and was not involved in the study. The surgical approach used on each knee and the order in which the operations were conducted were chosen randomly in order to prevent selection bias. Consequently, homogenization was unnecessary as all participants received both procedures. However, participant demographic data including age, gender, cause of surgery, pre-operative clinical state and type of implanted knee system were still recorded prior to surgery.

Physiotherapy treatment with isotonic exercise was initiated from the first day post-operation. All participants were examined for retropatellar knee pain, knee range of motion, and quadriceps muscle strength before surgery, then again at 6 and 12 months post-surgery. Retropatellar knee pain was measured using the visual analogue scale, range of motion was evaluated by physical examination, and quadriceps strength was measured using hand-held dynamometry. Since the type of surgical approach used on each knee was evident by the scar, an orthopaedist who was unaware of the subject of the study carried out the evaluation.

2.1. Statistical analysis

Data analyses were done using the SPSS 21.0 software package. All data are expressed as mean (standard deviation). After testing for normality of pairwise differences with Shapiro-Wilk normality test, the difference in the effect of the SV or MP approaches on retropatellar pain, range of motion, and quadriceps muscle strength were compared using one-way ANOVA. Demographic data are presented in a descriptive manner. A value of $P < 0.05$ was considered statistically significant.

Intra-group range of motion and the quadriceps muscle strength parameters, which were measured pre-operation, 6 months post-operation, and 12 months post-operation, were analyzed using repeated measure ANOVA.

3. Results

A total of 50 patients with primary OA of the knee (46 female and 4 male) with an average age of 64.8 ± 3.7 years completed this study. The average body mass index of the patients was 22.3 ± 2.6 kg/m^2 (range from 19.8 to 26.5). All 50 participants received bilateral TKA with each knee receiving an either the SV or MP approach. Retropatellar pain, knee range of motion, and quadriceps muscle strength were documented pre-operation, at 6 months post-operation, and at 12 months post-operation in order to compare the outcomes of each surgery. Participants' pre-operation pain was not taken into consideration for data analysis.

This study found no significant difference between the pre-operation, 6 month, or 12 month post-operation range of motion, quadriceps strength, or retropatellar pain for knees operated on using the SV approach (SV group) versus the MP approach (MP group) (Tables 1–3).

The range of motion findings are presented in Table 1. In both groups, range of motion was slightly decreased 6 months post-operation. The range of motion in the SV group measured 98.5° ± 12 pre-operation and 94.9° ± 8.3 at 6 months post-operation, while the range of motion in the MP group measured 97.8° ± 11.9 pre-operation and 94.5° ± 8 at 6 months post-operation. This decrease in range of motion could be related to post-operation pain, weakness of the muscles, and/or fear of moving the operated site. At 12 months post-operation, range of motion of the knee in both the SV and MP groups was significantly higher ($p < 0.001$) compared to the 6 months measurements (SV: 104.5° ± 7.4; MP: 104.2° ± 7.2).

The quadriceps strength findings are presented in Table 2. In both the SV and MP groups, quadriceps strength was significantly improved ($p < 0.05$) at 6 and 12 months post-operation, except for one case of vastus medialis obliquus muscle atrophy which occurred in the SV group. In the MP group, quadriceps muscle strength was further improved at 6 months post-operation than that of the SV group, however this difference was not statistically significant. The quadriceps muscle strength was equal between the MP and SV groups at 12 months post-operation.

The retropatellar pain findings are presented in Table 3. Retropatellar pain was significantly decreased ($p < 0.001$) in both the SV and MP groups at 6 and 12 months post-operation. While the retropatellar pain in the MP group was more compared to the SV group, the difference was not statistically significant (Table 3).

Table 1
Comparing knee range of motion between patients who underwent total knee arthroplasty using the medial parapatellar approach versus the subvastus approach.

Knee's Range of Motion	Pre-op	6 Month post-op	12 Month post-op	6 Month post-op to re-op (*P* Value)	12 Month post-op to 6 Month post-op (*P* Value)
Medial parapatellar approach	97.8 ± 11.9	94.5 ± 8.3	104.2 ± 7.2	0.036	< **0.001**
Subvastus approach	98.5 ± 12.2	94.9 ± 8.3	104.5 ± 7.4	0.02	< **0.001**
***P* Value comparing MP and SV**	0.773	0.811	0.838	0.631	0.522

Table 2
Comparing quadriceps strength between patients who underwent total knee arthroplasty using the medial parapatellar approach versus the subvastus approach.

Quadriceps Muscle Strength	Pre-op	6 Month post-op	12 Month post-op	6 Month post-op to re-Op (*P* Value)	12 Month post-op to 6 Month post-op (*P* Value)
Medial parapatellar approach	3.9 ± 0.5	4.14 ± 0.4	4.6 ± 0.5	0.007	< **0.001**
Subvastus approach	3.8 ± 0.5	4.12 ± 0.4	4.6 ± 0.5	0.003	< **0.001**
***P* Value comparing MP and SV**	0.559	0.832	1	0.835	0.746

Table 3
Comparing retropatellar knee pain between patients who underwent total knee arthroplasty using the medial parapatellar approach versus the subvastus approach.

Retropatellar Knee Pain	6 Month post-op	12 Month post-op	12 Month post-op to 6 Month post-op (*P* Value)
Medial parapatellar approach	5.3 ± 0.7	5.3 ± 0.7	< **0.001**
Subvastus approach	4 ± 0.7	3.8 ± 0.7	< **0.001**
***P* Value comparing MP and SV**	0.566	0.151	0.412

4. Discussion

The primary aim of this study was to compare patient outcomes of TKA using the SV approach versus the more commonly used MP approach with respect to retropatellar knee pain, knee range of motion and quadriceps muscle strength. Study findings did not show a significant difference in retropatellar knee pain, knee range of motion or quadriceps muscle strength at 6 or 12 months post-operation between patients who underwent TKA surgery using the MP approach versus the SV approach.

There are theoretical benefits to using the SV approach in place of the MP approach. For instance, some researchers believe that the absence of damage to the extensor mechanism in the SV approach could result in faster rehabilitation of quadriceps muscle strength. However, there are also potential disadvantages to the SV approach. Some studies have shown that the incision of the distal tendon of the vastus medialis oblique muscle in the SV approach increases the chance of neurovascular damage to the distal part of the vastus medialis oblique muscle. Given that patients' activities post-operatively induce tension, stretch and pressure on the vastus medialis oblique muscle, the SV approach could increase the chance of neurovascular damage, pain, and hematoma.[20,21] Another relevant disadvantage of the SV approach is the limited exposure many orthopaedic surgeons have to it, which consequently increases the difficulty of the surgery compared to the MP approach and predisposes surgeons to using the MP approach over the SV approach.[22]

There is no consensus in the literature regarding the superiority of the SV versus MP approaches. Some studies have concluded that patients who received the SV approach rehabilitated faster, had improved range of motion, and improved patellar tracking.[8,15,19] Another study found that the SV approach lead to faster return of straight-leg raise, lower consumption of opiates, less blood loss, and greater knee flexion at 1 week post-operation.[14] In contrast, Bourke et al. found no significant difference in range of motion between SV and MP groups at 18 months post-operation[19] and a meta-analysis carried out by Li et al. found no differences in knee range of motion and flexion between SV and MP groups at 12 month post-operation.[22]

This disparity in findings could potentially be explained by the time frame used in the study. Studies that examined earlier (<3 months) outcomes often show the SV approach yielding significantly better outcomes than the MP approach. While studies with later time frames (>3 months) show similar outcomes between the two groups. A study conducted by Dutka et al. found that the SV and MP approaches had the same outcomes at longer follow up (6, 12, and 24 months), while the outcomes at shorter follow up (12 days, 6 weeks, 12 weeks) showed full active extension, better range of motion, and better Knee Society Score results in the patients who received the SV approach.[23] Similarly, Fauré et al. found that quadriceps muscle strength was significantly better in the SV group at 1 week and 1 month post-operation, but was not significantly different at 3 and 12 months post-operation.[21] These findings indicate the need for further evaluation of the differences between the SV and MP approach in the short term (<3 months).

5. Conclusion

The randomized controlled trial detailed in this paper found no significant difference between outcomes of the SV and MP groups at 6- and 12-months post-operation. One possible limitation of the study is that participants' outcomes from earlier in their recovery course were not recorded. The findings of this study were consistent with the literature in showing no significant difference between outcomes of the SV and MP approaches after 6 months, however the possibility of better outcomes in the short term (3 months or less) has not been fully elucidated. This study provides further evidence that the SV approach yields comparable results to the more frequently utilized MP approach, however subsequent studies should focus on more immediate timeframes in order to determine if short-term outcomes are truly better in patients who receive the SV approach as opposed to the MP approach.

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Ethics approval

Approved.

Informed consent

Obtained.

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Declaration of competing interest

The authors declare no potential conflicts of interest.

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Research paper

Subcutaneous barbed suture, as an adjunct to staples, reduces post-operative wound drainage in total knee arthroplasty

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ABSTRACT

Background: Prolonged wound drainage (>72 h), has been associated with increased risk of surgical site infection and prolonged hospital admission. This study reviews the outcome in three different wound closure methods, following total knee arthroplasty. We also analysed the cost effectiveness of these methods.

Methods: A total of 69 patients undergoing total knee arthroplasty: 22 with stapled skin closure; 21 with tissue adhesive and stapled skin closure and 26 with subcutaneous barbed suture instead of a non barbed suture with stapled skin closure, were studied to review the number of dressing changes, prolonged wound drainage (>72 h), length of hospital stay and delayed discharge (>5 days). Statistical analysis was conducted using Minitab Statistical Software® and statistical significance was set at $p < 0.05$.

Results: The median hospital stay for the staples only group was 4 days (inter-quartile range [IQR] 3–5), for the adhesive group was 4 days ([IQR] 3–6) and for the barbed suture group was 3 days ([IQR] 3–4) ($p = 0.009$). The rates of prolonged wound drainage for the staples only group was 8 (36.4%), for the adhesive group was 4 (19.0%) and for barbed suture group was 0 (0%) ($p = 0.004$).

Conclusion: The use of subcutaneous barbed sutures was associated with reduced number of wound dressing changes, reduced risk of prolonged wound drainage and shorter hospital stay, as well as conferring a saving of at least £236.60 per patient, compared to the other two skin closure methods.

1. Introduction

Prolonged wound drainage (>72 h) has been associated with increased risk of infection and prolonged hospital admission.[1,2] There is an association between superficial wound infection and risk of prosthetic joint infection, with the latter carrying significant morbidity and financial consequences.[2–4] Optimal wound closure in total knee arthroplasty (TKA) is essential and greater attention is being drawn towards methods of closure, speeding up theatre time, reducing wound associated complications and speeding up patient discharge.[5] However, there is no conclusive evidence for which method of wound closure is the most efficacious at overcoming prolonged wound drainage.[6]

Surgical wounds in arthroplasty have been closed with either staples or sutures; however there is much controversy over which method is better. Tissue adhesive has been used as a primary method of closure or as an adjunct to other methods of closure, but with caution in areas that are subject to high levels of tension due to risk of wound dehiscence.[7,8] Tissue adhesives have been successful in arthroplasty, with reduction in skin closure time and wound drainage in total hip arthroplasty (THA). However, this has not been proven in TKA.[5,9,10]

The use of barbed sutures has been shown to offer a more even distribution of tension along surgical wounds and in the context of TKA has been demonstrated as having a more water tight closure, faster wound closer times and a lower post-operative wound complication rate, in comparison to standard knotted suture, in a randomised control trial (RCT) by Chan et al. (2016).[11,12] However, in two RCTs by Ting et al. (2012) and Li et al. (2018) comparing standard knotted suture and barbed suture closure in TKA and THA, no significant difference in wound drainage between the TKA cases was demonstrated.[13,14]

A systematic review by Snyder et al. (2021) of RCTs and observational studies comparing types of sutured wound closure for TKA and THA noted that whilst post-operative wound drainage is a well

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known major risk factor in surgical site infection, it is one of the least measured outcomes in studies comparing barbed suture to standard suture closure techniques and therefore highlights an important topic for future study.[1,2,4,15]

The anterior midline skin incision used in TKA is subject to high tensile stresses, through various degrees of knee flexion during the post-operative period, as a result of early rehabilitation programmes.[16,17] These tensile forces can be disruptive and could cause prolonged wound drainage.

We conducted a retrospective cohort study to review outcomes in the following wound closure methods:

1. Skin closure with staples only.
2. Skin closure with tissue adhesive as an adjunct to staples closure.
3. Wound closure with subcutaneous barbed suture instead of a non-barbed suture, and staples to skin.

We opted to include both primary and revision total knee arthroplasty operations as the skin closure technique used was identical.

The primary outcome was number of dressing changes secondary to wound drainage. Secondary outcomes included, prolonged wound drainage, length of hospital stay, post-operative complications, and cost effectiveness.

2. Material and methods

69 consecutive TKA patients operated upon by one senior orthopaedic surgeon were identified. The data was collected and maintained in a database.

All patients received the same pre-operative, peri-operative and post-operative care. A dose of 1 g of Tranexamic Acid was given intravenously at induction of surgery and a further dose of 500 mg was given orally 6 h post-operatively. Peri-operative antibiotics and thromboprophylaxis were as per our departmental policy.

All TKA operations were conducted using an anterior midline skin incision without the use of a tourniquet. The skin incision extended from 8 cm above the upper pole of patella to 8 cm below the lower pole of patella, with the knee at 90° flexion. Meticulous haemostasis was conducted throughout the operations. Local infiltration analgesia was done by infiltrating 100 ml (2 mg/ml) Ropivacaine combined with 1 mg Adrenaline and 40 mg of Ketoralac into the capsule, retinaculum and extensor mechanism, with an extra 50 ml (2 mg/ml) Ropivacaine infiltrated into the fat and subcutaneous tissues.

All wounds were closed in three layers using the same technique. Three interrupted sutures were placed along the medial border of patella, followed by continuous suturing of the extensor mechanism. The subcutaneous layer was closed by continuous suturing and skin with staples.

There were three groups based upon the use of wound closure materials:

1. Staples only group (22 patients): Size (2) Vicryl to extensor mechanism, Size (0) Vicryl to subcutaneous layer and staples to the skin.
2. Adhesive group (21 patients): Size (2) Vicryl to extensor mechanism, Size (0) Vicryl to subcutaneous layer and staples to the skin. Liquiband® Optima (90% butylcyanoacrylate and 10% octylcyanoacrylate) tissue adhesive (Advanced Medical Solutions Ltd. UK) was applied topically along the entire length of the incision in a single layer allowing 20 s for polymerisation.
3. Barbed suture group (26 patients): Size (2) Vicryl to extensor mechanism, Size (0) V-Loc™ to subcutaneous layer and staples to skin. V-Loc™ 180 (polyglyconate) is a barbed wound closure device (Medtronic Ltd. UK) used in a continuous method without surgical knot ties.

No drains were used in any of the patients in this study.

Finally, a standard 30 cm × 10 cm Hydrofilm Plus® (Paul Hartmann Ltd., UK) occlusive dressing was applied, followed by a compression bandage, in the form of two layers of wool and crepe, the latter being left on until the next morning.

Thromboprophylaxis was administered in the form of a single dose of 4500 units of Tinzaparin on the night of the operation (Day 0), followed by Apixaban 2.5 mg twice daily on the following mornings for ten days subsequently. Mechanical prophylaxis in the form of thromboembolism-deterrent stockings and intermittent pneumatic compression devices were administered to all patients, unless contra-indicated.

All patients underwent the enhanced recovery after surgery (ERAS) protocol with immediate full weight-bearing and range of motion exercises under physiotherapy guidance. All patients had surgical staples removed at 14 days post-operatively and were followed up at six weeks and six months.

The data was collected by an observer blinded to the use of any wound closure material other than the staples, using a specifically designed pro-forma. Quantitative assessment of wound drainage was done on a daily basis for the need of dressing change, according to our hospital protocol (Table 1). A clear film template was designed and used to quantify wound drainage as a proportion of the dressing and several shapes of 2 cm × 2 cm size.

Cost effectiveness of closure methods were calculated according to the recourses used for closure, as detailed in the methods above, the costs of which were obtained from our operating theatres' financial records. Furthermore, the cost of an additional day of hospital admission was considered in the overall cost effectiveness assessment and was obtained from the clinical coding department.

Patients were only discharged from hospital as per the unit protocol; once wounds were dry, they could achieve full active extension and 90° of active flexion and had no other acute medical complications. As it is well documented that prolonged wound drainage is a risk factor for surgical site infection and potentially prosthetic joint infection, to help prevent this risk, patients were kept until wounds were dry and to monitor and treat any possible minor wound complications early.

Statistical analysis and graph generation was conducted using Minitab Statistical Software®. Statistical significance was determined when $p < 0.05$. Calculations for binary or categorical data such as gender, ASA (American Society of Anesthesiologists) grade, primary or revision surgery, co morbidities, day 1 & day 2 dressing change, prolonged wound drainage and delayed discharge were analysed using a χ^2 test. Statistical calculations for continuous non-parametric data such as BMI (body mass index), length of hospital stay and median dressing changes for more than 2 groups were analysed using the Kruskal-Wallis test, and between two groups was Mann-Whitney test with data reported with medians and interquartile ranges (IQR). Analysis of parametric data such as mean age was conducted using the analysis of variance (ANOVA) method.

This research has been approved by the IRB of the authors' affiliated institutions.

3. Results

A total of 69 patients were identified. Staples only were used in 21 patients, staples with tissue adhesive were used in 22 patients and staples with barbed V-Loc™ suture were used in 26 patients (Table 2).

There was no statistically significant difference between the

Table 1
Hospital's protocol for wound drainage.

Day 1: Change dressing if soakage >50%
Day 2: Change if >50%, apply pressure dressing, hold anticoagulation
Day 3 (72 h): Change if > 2 × 2cm, continue to hold anticoagulants, bloods check (Full blood count, C-reactive protein and clotting)
Days 4–6: Discuss with consultant to apply negative pressure dressing
Day 7: Discuss with consultant regarding early debridement, antibiotics and implant retention (DAIR) procedure

groups regarding sex distribution, age, type of surgery (primary vs revision) and co-morbidities (Table 2).

The median BMI for staples only group was 30.0 (IQR 27.0–34.25), for adhesive group was 30.0 (IQR 27.5–34.5) and for barbed suture group was 35.5 (IQR 32.75–38.0). The difference between these groups was found to be statistically significant ($p = 0.004$) (Table 2).

The predominant ASA grades of the patients in staples only group were grade two (54.5%) and grade three (36.4%), for adhesive group were grade two (57.1%) and grade three (42.9%) and for barbed suture group were grade one (46.2%) and grade two (46.2%). The differences between these groups were statistically significant ($p = 0.0004$), with barbed suture group having a greater proportion of ASA grade one patients compared to groups one and two (Table 2).

The number of dressing changes on day one for staples only group was 14 (63.6%), for adhesive group was seven (33.0%) and for barbed suture group was four (15.4%). The result was found to be statistically significant ($p = 0.002$) (Table 3).

The number of dressing changes on day two for staples only group was eight (36.4%), for adhesive group was four (19.0%) and for barbed suture group was zero (0.0%). The result was found to be statistically significant ($p = 0.004$) (Table 3).

The median total number of dressing changes for staples only group was one (IQR 0–3.25), for adhesive group was zero (IQR 0–1.5) and for barbed suture group was 0 (IQR 0-0). This result was statistically significant ($p = 0.001$) (Table 3).

The median hospital stays for staples only group was four days (IQR 3–5), for adhesive group was four days (IQR 3–6) and for barbed suture group was three days (IQR 3–4). This result was found to be statistically significant ($p = 0.009$) with barbed suture group demonstrating a shorter post-operative hospital stay and there being no difference in the hospital stay between the adhesive and staples only groups (Table 3 & Fig. 1).

None of the patients in the study suffered from a post-operative medical complication such as a urinary tract or lower respiratory tract infection that might have otherwise affected length of hospital stay.

The number of patients exhibiting prolonged wound drainage for staples only group was eight (36.4%), for adhesive group was four (19.0%) and for barbed suture group was zero (0%). This result was found to be statistically significant ($p = 0.004$), with patients in barbed suture group exhibiting no prolonged wound drainage, however the difference in prolonged wound drainage between staples only group and adhesive group was not statistically significant ($p = 0.206$) (Table 3 & Fig. 2).

The number of patients with delayed discharges (≥5 days) due to wound drainage in staples only group were three (13.6%), for adhesive group were three (14.3%) and for barbed suture group were zero (0%). This result was not statistically significant ($p = 0.137$), despite barbed suture group displaying a reduced proportion of delayed discharges post TKA (Table 3).

Costs of closure resources were as follows: Vicryl size (0) and size (2) sutures were £3 each, V-Loc™ 180 size (0) suture was £30.40 each, surgical staples were £25 for each case and Liquiband® Optima tissue adhesive was £1 for each case. Furthermore, an extra day of hospital admission cost £264.

The total costs of closure for each case according to closure method were: £31 for staples only group, £32 for adhesive group and £58.40 for the barbed suture group.

Table 2
Patient demographics for all 3 groups.

Parameters	Staples only	Adhesive	Barbed suture	*p* value
Number of cases	22 (31.9%)	21 (30.4%)	26 (37.7%)	
Sex				0.115
Male	8 (36.4%)	11 (52.4%)	6 (23.1%)	
Female	14 (63.6%)	10 (47.6%)	20 (76.9%)	
Age				
Mean	70.5	72.2	69.4	0.601
Standard deviation	±10.4	±9.3	±9.2	
Range	50–95	52–89	55–90	
BMI[a]				
Median	30.0	30.0	35.5	0.004
IQR [b]	27.0–34.25	27.5–34.5	32.75–38.0	
Range	23–45	26–40	18.5–43	
ASA grade[c]				
1	2 (9.1%)	0 (0%)	12 (46.2%)	0.0004
2	12 (54.5%)	12 (57.1%)	12 (46.2%)	0.0004
3	8 (36.4%)	9 (42.9%)	2 (7.6%)	0.0004
Surgery				
Primary	19 (86.4%)	17 (80.9%)	19 (73.1%)	0.514
Revision	3 (13.6%)	4 (19.1%)	7 (26.9%)	0.514
Co-morbidities				
Anticoagulation	2 (9.1%)	4 (19.0%)	2 (7.7%)	0.503
Diabetes Mellitus	1 (4.5%)	3 (14.3%)	2 (7.7%)	0.503

[a] Body mass index.
[b] Inter-quartile range.
[c] American society of anaesthesiologists.

4. Discussion

The use of subcutaneous barbed suture in wound closure of TKA resulted in reduction of number of dressing changes ($p = 0.001$), prolonged wound drainage ($p = 0.004$) and hospital stay ($p = 0.009$) compared to the use of tissue adhesive with staples or staples only (Table 3 & Figs. 1 and 2). Whilst the subcutaneous barbed suture group had a reduced overall delayed discharge rate (≥5 days) ($p = 0.003$), when analysed further, the number due to wound drainage was not statistically significant ($p = 0.137$) and the delayed discharges for the other two groups were due to inability to achieve adequate range of motion as per the discharge protocol described in the methods section.

The reduction of prolonged wound drainage with the use of barbed suture is a clinically significant and desirable result given the cost of prolonged hospital stay and potential complications of superficial wound infection, wound dehiscence and potential for deeper extension of any infection causing prosthetic joint infections.[1,2,4]

To our knowledge there are no studies comparing subcutaneous barbed suture to tissue adhesive and staples for wound closure in TKA.

Comparison of the adhesive versus staples only group showed no statistically significant reduction in the total number of dressing changes ($p = 0.063$), prolonged wound drainage ($p = 0.206$) or length of stay ($p = 0.950$) (Table 3). Whilst there was a statistically significant reduction in the number of dressing changes on day one ($p = 0.047$) in the adhesive group, this was not the case after day one, with no statistically significant difference in number of dressing changes on day two ($p = 0.176$). As established by Johnson et al., the anterior midline skin incision used in TKA is subjected to significant tensile stresses during knee flexion, in the post-operative rehabilitation.[18] These significant tensile stresses could

Table 3
Outcomes for all 3 groups.

Parameters	Staples only	Adhesive	Barbed suture	p value (comparing 3 groups)	p value (comparing adhesive & staples only)
Dressing changes					
Day 1 (median)	14 (63.6%)	7 (33.0%)	4 (15.4%)	0.002	0.047
Day 2 (median)	8 (36.4%)	4 (19.0%)	0 (0%)	0.004	0.176
Hospital stay (days)					
Median	4	4	3	0.009	0.950
IQR[a]	3–5	3–6	3–4	n/a	n/a
Range	2–6	2–7	2–4	n/a	n/a
Total dressing changes					
Median	1	0	0	0.001	0.063
IQR[a]	0–3.25	0–1.5	0–0	n/a	n/a
Range	0–5	0–8	0–1	n/a	n/a
Prolonged drainage (>72hrs)	8 (36.4%)	4 (19.0%)	0 (0%)	0.004	0.206
Delayed discharge (≥5 days)					
Total	6 (27.3%)	8 (38.1%)	0 (0%)	0.003	n/a
For wound drainage	3 (13.6%)	3 (14.3%)	0 (0%)	0.137	n/a

[a] Inter-quartile range.

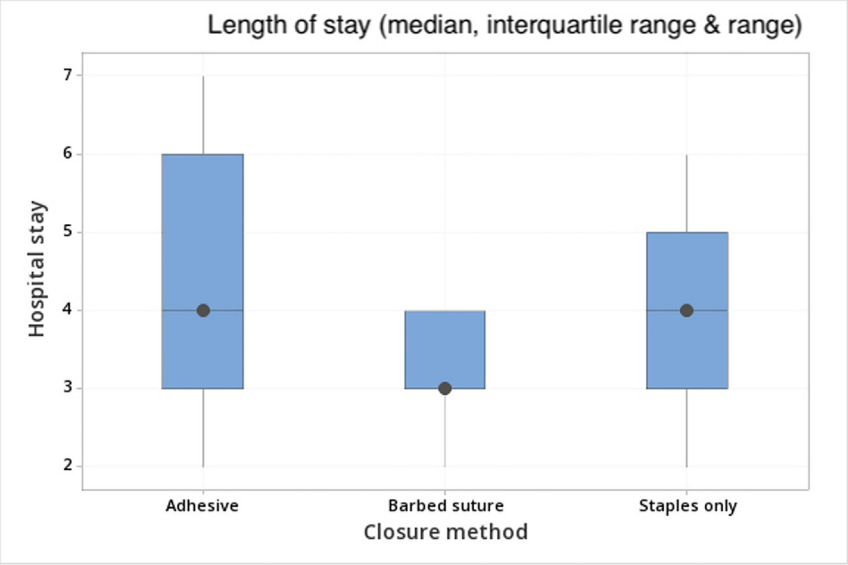

Fig. 1. Hospital stay.

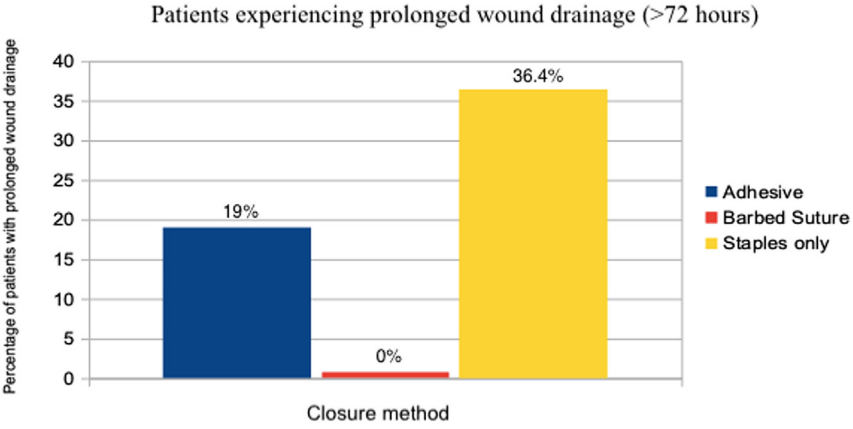

Fig. 2. Prolonged wound drainage.

explain why the wound drainage on day one post-operatively is significantly lower for the adhesive group compared to staples only group, but once the patient is flexing the knee during rehabilitation, as is the case after day one, the wound adhesive is not able to withstand these tensile forces and therefore does not exhibit better results than the staples only group. The latter is demonstrated by no significant difference in prolonged wound drainage between these two groups.[19]

The benefits of a continuous barbed suture method achieving a more water-tight closure has been shown in cadaveric knee arthrotomy models comparing closure with either continuous barbed suture or interrupted traditional knotted suture. Furthermore, barbed sutures have been said to enhance the equal distribution of tension across the wound, creating the possibility of improved healing.[20] The shorter and stiffer barb design of V-Loc™ 180 device, used in our study, has been proven to hold in the tissue better with significantly higher wound strength at the critical phases of wound healing, absorbing more of the tensile forces.[21] The absorption of the tensile forces by the barbed suture during knee flexion in the post-operative period might explain why there is reduced wound drainage.

The demographic profiles of all three groups were well matched except for BMI ($p = 0.004$) and ASA grade (0.0004), which were found to be statistically significantly different (Table 2). It has been demonstrated by Wood et al. that lower BMI values have been associated with reduced wound drainage post-operatively for arthroplasty and that difference in ASA grade had no significant effect.[22] The patients in barbed suture group were shown to have the highest median BMI values, however given that higher BMI has been associated with worse wound drainage results and that this cohort had the shortest median hospital stay, lowest median number of dressing changes and lowest percentage of patients with prolonged wound drainage, it could be inferred that the results of reduced dressing changes and reduced prolonged wound ooze rates were not an artefact of demographic difference. However, the result of shorter hospital stay for the barbed suture group, despite being statistically significant and no acute medical complications delaying discharge for any of the patients in the study, could have potentially been affected by the lower ASA grade of the patients in this study cohort.

Across the entire three cohorts, no patients in our study experienced any wound infections or re-operations for prolonged wound drainage, demonstrating that the combination of arthroplasty without the use of tourniquet, meticulous operative and haemostasis technique, Tranexamic Acid and periarticular local anaesthetic and local adrenaline administration is a reliable method of performing TKA. This is supported by Butt et al., demonstrating shorter tourniquet times and periarticular local anaesthetic and adrenaline administration confers reduced wound drainage post-operatively for TKA.[23]

The cost effectiveness of barbed suture in TKA is supported by a systematic review and meta-analysis by Zhang et al. (2016), which concluded that knotless barbed sutures (KBS) conferred lower mean total operative costs £237.93 ($290.72) compared to traditional knotted sutures (KTS).[24] A more recent randomised controlled trial by Chan et al. (2017) comparing arthrotomy and subcutaneous closure with barbed or traditional knotted sutures for 109 TKA patients, further supported Zhang et al. conclusions of reduced operative cost by £39.58 ($48.80) in the barbed suture group, as well as reduced wound complications (2 vs 9) ($p = 0.03$).[12] The total cost of closure for the barbed suture group in our study was £58.40 per case, compared to £31 for the staples only group and £32 for the adhesive group. However, the use of barbed suture closure resulted in a shorter hospital admission of 3 days compared to 4 days for the staples only and adhesive groups. Therefore, subtracting the difference in closure cost between the barbed suture group and staples only group from an extra day of admission yields a potential overall saving of £236.60 per patient, and a potential total saving for the barbed suture cohort of £6151.60.

The strengths of this study include all patients had the same operating surgeon, had a blinded single observer, a standardised objective method of measuring wound drainage, a standardised protocol for changing wound dressings and standardised pre-operative, peri-operative and post-operative care.

The limitations of the study included the lack of patient randomisation, the retrospective nature of the study, relatively small sample sizes and the potential confounding demographic data of BMI and ASA not being controlled for. Furthermore, as the data was of a non-parametric nature and the sample size was small, power calculations were not possible in order to rule out type two error.

This study highlights the need for randomised controlled trials of barbed sutures versus alternate methods of closure with larger patient groups, exclusion of potential confounders and validated technique of measuring wound drainage.

5. Conclusions

The use of subcutaneous barbed suture is associated with reduced total number of wound dressing changes, reduced risk of prolonged wound drainage and a shorter hospital stay. Moreover, its use conferred a saving of at least £236.60 per patient. Therefore, based upon these results we propose the use of subcutaneous barbed sutures for closure in TKA.

Authors' contributions

SWC performed the formal analysis, and prepared the original draft. KE contributed in conceptualization, data collection and final manuscript preparation. MK collected part of the data, RA supervised the investigation, methodology and editing the final manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics declarations

Conflict of Interest:

All authors have no conflicts of interest and have no affiliations with or involvement in any organisation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Ethical approval

The research has been approved by the IRB of authors' affiliated institution, and the work carried out in accordance with 'The Code of Ethics of World Medical Association' for experiments involving humans.

Consent to publication

All authors have read the final version and give consent for the article to be published.

No patient-identifiable details were included in this manuscript and therefore explicit consent for publication was not required.

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Research paper

Impact of HbA1c level on perioperative hemodynamics, recovery room stay and postoperative discharge time in diabetic patients undergoing total hip arthroplasty

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ABSTRACT

Background & aim: Diabetic patients are susceptible for surgical site infections, periprosthetic infections, and increased hospital stay. Present study was aimed to determine the influence of HBA1c level on perioperative hemodynamic, recovery room stay and postoperative discharge times in patient undergoing total hip arthroplasty.

Methods: After institutional ethical clearance, this prospective, observational, study was conducted on 70 diabetic patients aged 18–65 years of either sex. Patients under study were enrolled into either group A (<7.5 HbA1c) or group B (≥7.5 HbA1c). On the morning of surgery fasting blood sugar and serum potassium levels were checked. Random blood sugar (RBS) at time of incision, at the time of closure, and postoperatively at 6, 12, 18, and 24 h were measured. Intraoperative hemodynamic variables, recovery room stay and hospital stay times were noted.

Results: Association of hypertension (p value 0.001), gm intake (p value 0.003), post-operative blood glucose levels (p value < 0.001), duration of recovery room stay and total duration of hospital stay were found significantly higher in group B (p value < 0.001). Surgical site infection (SSI), duration of illness, ECG changes, and postoperative complications were not significant. Although incidence of SSI was more in group B (p value 0.303).

Conclusion: Diabetic patients, not on insulin therapy, with no renal impairment, with ASA grading II-III, and with no other contraindication for spinal anaesthesia; 7.5% can be used as a new cut-off for level of HbA1c for total hip arthroplasty.

1. Introduction

Diabetes mellitus is one of the most prevalent comorbidities among patients undergoing hip surgeries and patients suffering from diabetes are more likely to undergo orthopedic surgeries than are those without diabetes.[1] Coexistence of diabetes is associated with higher risk of postoperative complications.[2,3] Existing literature states that patients undergoing total hip replacement are at higher risk of developing infections at surgical sites, periprosthetic infections, loosening of implants without infection, increased duration of hospital stay, and higher hospital expenses.[4–9] This furthermore has raised concern regarding control of diabetes and optimization of patient prior to surgery by determining cut-off values for glycosylated hemoglobin (HbA1c).[10] However, many of diabetic patients remain unable to attain desired cut-off thresholds for HbA1c and they will still go for the hip arthroplasty with raised HbA1c.[3] The HbA1c level <6.5% shows good control of glycemic status, while American Diabetes Association (ADA) guidelines suggest that diabetic patient having HbA1c level of less than 7.5% can undergo elective surgery.[11] On the other side suggestions from the UK (JBDS) advocate postponement of elective surgery only if the HbA1c is ≥ 8.5%. One study has shown that patients with HbA1c value more 8% who underwent non cardiac surgeries had longer

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hospital stay. Therefore, they suggested HbA1c level of 8% as a good optimal cutoff limit prior to surgical procedures.[12]

The glycated hemoglobin level is an easy laboratory measure that gives a cumulative view of the patient's glycemic control for a period of 2or 3 months.[1] Desired HbA1c level for patients of diabetes mellitus is 6.5–7.5%, however, higher levels may be accepted with fact that patient undergoing surgery can have risk of hypoglycemia and other perioperative complications.[13] Therefore, aim of present study was to establish the association between preoperative HbA1c concentration and perioperative hemodynamics, recovery room stay, surgical site infection and furthermore its impact on postoperative discharge time after total hip arthroplasty.

2. Materials and methods

This prospective study was conducted after approval of the ethical committee of the university. All patients included in the study were explained about their participation in the study and a written informed consent was taken. Patients aged 18–65 years, of either sex, having diabetes, belonging to American Society of Anesthesiologist Physical Status II-III, scheduled for elective hip arthroplasty were included. Exclusion Criteria included patients on insulin treatment, patients with renal dysfunction or any other comorbidities except diabetes and hypertension and contraindications for spinal anaesthesia. Patients were categorized into two groups on the basis of level of HbA1c in preoperative period: Group A - HbA1c < 7.5 and Group B - HbA1c ≥ 7.5.

A routine preanesthetic check-up was conducted one day prior to surgery. History of comorbidities was taken while history of diabetes and its treatment was taken in detail. No preanesthetic medications that would affect the recovery profile were administered. All the patients are kept fasting prior to procedure as per ASA fasting guidelines. Patients were asked to omit one dose of metformin on the day of hip arthroplasty surgical procedure.

On the day of surgery: fasting blood sugar and serum potassium level were checked. In the operation theatre, vital monitoring including ECG, blood pressure, and pulse oximetry was done and a wide bore IV cannula was placed in a large vein. Baseline heart rate, blood pressure, SpO2 and ECG changes (if any) were noted. After giving subarachnoid block and achievement of required level of regional anaesthesia, blood sugar level was checked. Patients who were converted to general anaesthesia for any reason were excluded from this study. Patients were monitored for any significant changes in vitals and any intraoperative cardiac events. In intraoperative period hemodynamic variables like heart rate, blood pressure, and ECG changes were monitored continuously and noted down at regular interval. Blood sugar level was again checked at time of closure of surgical incision. Patients were also monitored in recovery room for duration of stay. Postoperative blood glucose level was measured at 6, 12, 18 and 24 h after surgery. Patients were followed up till discharge of patient from hospital and duration of hospital stay was recorded. Patients were also followed-up for surgical site infection, if any in postoperative period.

3. Statistical analysis

Sample size calculation was done on the basis of variation in the duration of hospital stay in two groups based on a previous study[1] with type I error $\alpha = 5\%$ corresponding to 95% confidence level and type II error $\beta = 10\%$ for detecting results with 90% power of study. Data loss factor of 10% was assumed. The calculated sample size was 35 patients in each group. Chi-Square test, paired student's *t*-test and Unpaired 't' tests were used for data analysis. A p value of <0.05 was taken as statistically significant.

4. Results

Age of the patients in Group B was significantly more as compared to Group A. The proportion of hypertensive cases was more in group B than in group A and this difference was statistically significant (40% vs 5.7%, $p = 0.001$) and patients with ASA class > II were also significantly more in Group B (5.75 vs 62.9%, $p < 0.001$) [Table 1]. HbA1c was significantly higher in group B but the difference observed in duration of illness between the two groups was not significant [Table 2].

The basic medicines taken by the patients were metformin, glimiperide, pioglitazone and acarbose. The medicine glimiperide was taken significantly more in patients of group B in comparison to group A ($p = 0.003$) (data not shown). The blood sugar levels were significantly more in group B as compared to group A in the morning of surgery, preoperative and before surgical incision [Fig. 1].

No significant difference was noted in heart rate at various time points except at 120 min [Fig. 2]. Statistically, significant difference was observed in SBP at all observed points except at 75 and 90 min, and in DBP the difference was statistically significant at preoperative time and at 60 min [Fig. 3].

The significant differences in blood glucose levels were noted between the groups at all the postoperative time periods [Fig. 4]. The duration of recovery room stays and duration of hospital stay was more in group B in comparison to group A and this difference came out to be statistically significant [Table 3].

No postoperative complication was observed in both groups. However surgical site infection was found in 1 (2.9%) case of group A and 3 (8.6%) cases of group B, but difference of proportion of surgical site infection between the two groups ($p = 0.303$) was not statistically significant.

5. Discussion

With a rapid increase in the prevalence of diabetes across the world along with simultaneous rise in hip arthroplasty in these patients, we are dealing with diabetic patients on a daily basis for hip surgery. More studies need to be done for better optimization of perioperative glycemic status and to reduce the morbidity and mortality of diabetic patients, which will result in better outcomes of surgery. Although optimization has become a part of standard preparation before proceeding to any elective orthopedic surgery, there is no universal guideline on limit HbA1c above which there is a considerable rise in perioperative adverse outcomes. Increased perioperative morbidity and mortality in diabetic patients are due to deglycation and comorbidities like ischemic heart disease, impaired renal function and hypertension.

This study indicates an association between preoperative poor control of blood glucose level assessed by HbA1c value and increased risk of poor perioperative glycemic control, surgical site infections, duration of postoperative recovery and length of hospital stay. In our opinion, the common practice of using target HbA1c of 7% is not the optimal cut-off value for glycemic control as for as hip arthroplasty is concerned. It has been suggested that routine HbA1c testing should be done in all elective cases for

Table 1
Demographic characteristics.

Variable	Group A	Group B	P value
Age (in years) (Mean ± SD)	45.83 ± 12.84	58.24 ± 10.65	**<0.001**
Sex (Male: Female)	24:11	26:9	0.597
ASA grade > II	5.7%	62.9%	**<0.001**
Associated hypertension	5.7%	40%	**0.001**

Table 2
HbA1c and Duration of illness.

Variable	Group A		Group B		p-value
	Mean	SD	Mean	SD	
HbA1c	5.76	0.32	8.97	0.45	**<0.001**
Duration of Diabetes (yr)	4.63	3.54	5.66	3.82	0.369

vascular and orthopedic surgery because of high prevalence of undiagnosed diabetes in vascular and orthopedic surgery.[14] Routine screening of HbA1c is performed in all patients undergoing joint arthroplasty and patients with HbA1c > 7% are referred to concerned specialties for optimization. However, according to UK-JBDS (Joint British Diabetes Society), postponement of elective surgery is recommended at or above HbA1c of 8.5%.[15] Similarly, Australian society has set a cut-off of 9% for postponement of surgery in diabetic patients.

We have taken HbA1c cut-off value of 7.5%. There is no definitive evidence in support as various studies have been conducted using different cut-offs for HbA1c levels. A study conducted on diabetic patients subjected to total joint arthroplasty concluded that postoperative blood glucose level >200 mg dl^{-1} had more risk of prosthetic joint infection. And HbA1c cut-off of 7.45% for patients undergoing total joint arthroplasty was recommended.[16] However, in a metanalysis, the subgroup of study with a cut off of 7% had insufficient control of blood glucose that imposed increased risk for surgical site infection after total joint arthroplasty. Collected data in this study did not support the traditional 7% threshold limit of HbA1c for risk stratification.[17] The Diabetes UK Position Statements and Care Recommendations advocates keeping blood glucose in the range of 108–180 mg dl^{-1} if safely attainable. Otherwise, a wider target range of 72–216 mg dl^{-1} is admissible.[18]

In this study, height, weight, sex distribution and ASA grade were comparable between the groups, however the age in group B was significantly higher; this could be explained by the fact that higher number of total hip arthroplasty cases are being done in the geriatric population in whom the prevalence of diabetes is rapidly going up. The Centre for Disease Control and Prevention estimated that 310,800 total hip arthroplasties were carried out in 2010 among in patients aged more than 45 years, increasing from 138,700 THAs in 2000.[19] The studies have mentioned that the worldwide burden of diabetes is predicted to rise rapidly during the next few decades, with the highest burden in geriatrics population.[20,21]

None of the studies in the past have compared perioperative

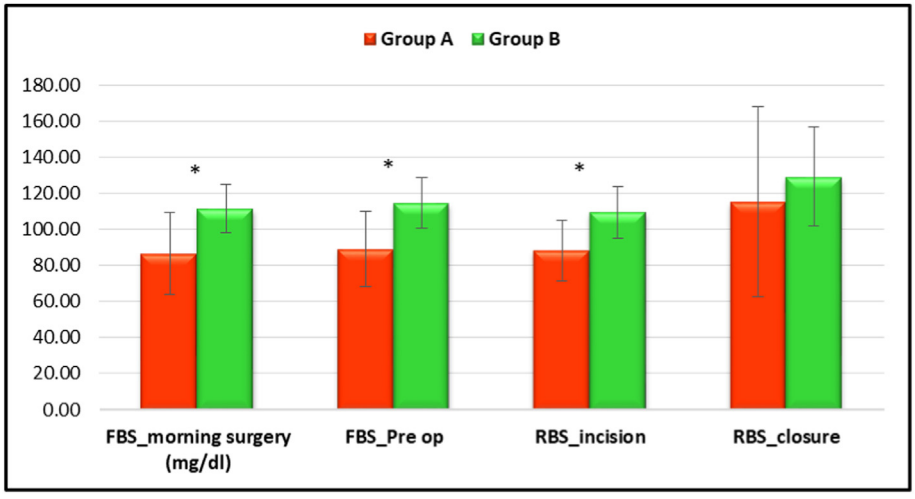

Fig. 1. Fasting and intraoperative Blood Sugar level. *Statistically significant difference.

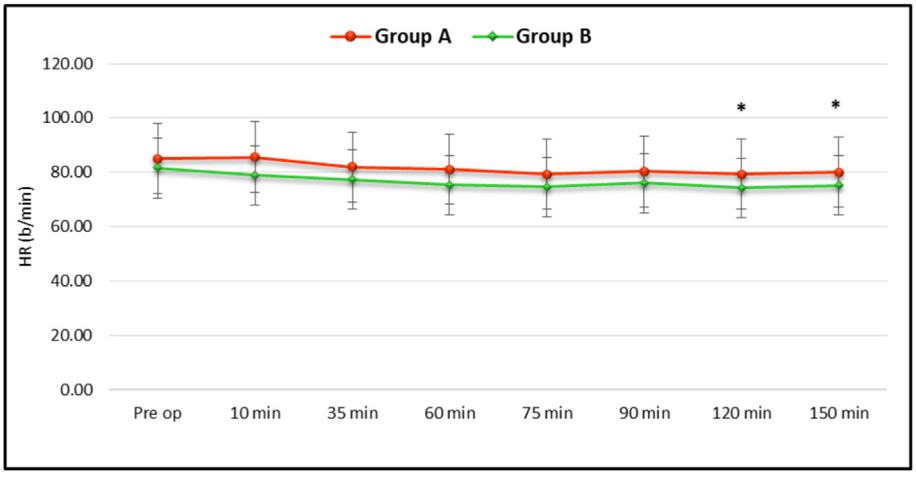

Fig. 2. Intergroup comparison of Heart Rate at various time periods. *Statistically significant difference.

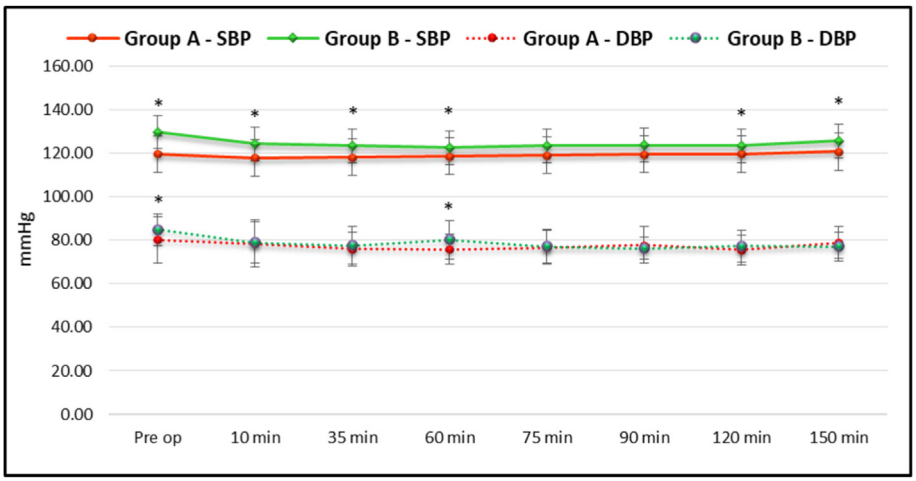

Fig. 3. Intergroup comparison of SBP and DBP at various time periods. *Statistically significant difference.

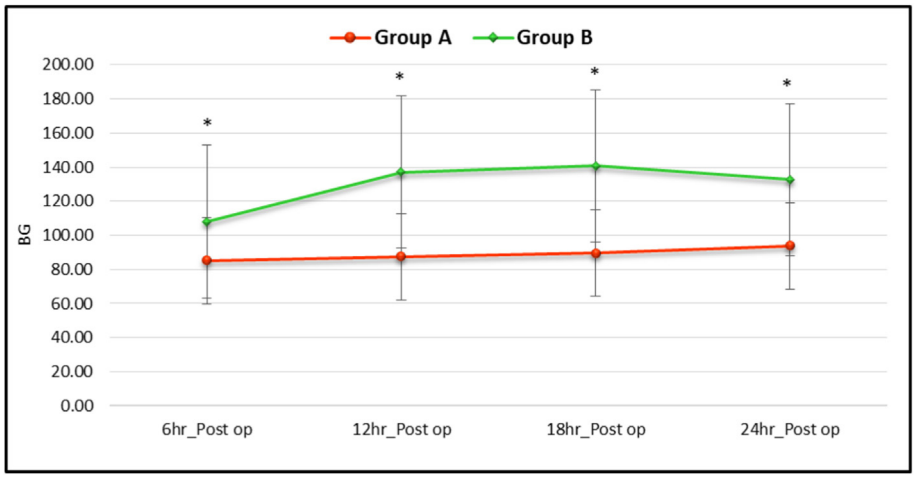

Fig. 4. Blood Glucose level in postoperative period. *Statistically significant difference.

Table 3
Duration of recovery room and hospital stay.

Duration of Stay	Group A		Group B		p-value
	Mean	SD	Mean	SD	
In recovery room (hours)	1.43	0.50	1.97	0.54	**<0.001**
In hospital (days)	3.72	2.79	11.00	5.64	**<0.001**

hemodynamic parameter in diabetic patients undergoing hip arthroplasty. However, we didn't find any clinically significant intraoperative hemodynamic changes in our study which can be explained by the fact that hip arthroplasty is a short duration day-care procedure nowadays. Moreover, we have not included patients on insulin which has further decreased the incidence of cardiovascular instability. There could be other reasons which can cause changes in perioperative hemodynamic variables. The occurrence of orthostasis (rise in heart rate >15 per min, or decrease in systolic blood pressure >20 mm Hg few minutes after changing posture from supine to standing) indicates autonomic neuropathy and suggests possible operative hemodynamic instability.[22]

Perioperative management of diabetic patients undergoing major surgery has been discussed in many studies but no quality studies before SAMBA (Society of Ambulatory Anaesthesia) have discussed perioperative management of ambulatory surgery. It was found that inflammatory response due surgical procedure can lead to relative insulin insufficiency due to increased insulin resistance and decreased insulin secretion, which can lead to hyperglycemia, dehydration, electrolyte imbalance, higher risk of infection, and poor wound healing, as well as acidosis.[23,24] These complications can happen anytime in operation theatre, most likely to occur immediately after induction of anaesthesia leading to changes in hemodynamic variables. Anesthetic agents can increase this risk further by electrolyte disturbances caused by nausea and vomiting. This aggravated electrolyte disturbances may cause arrhythmia.

In present study also higher incidence of hypertension with uncontrolled diabetic group patients (≥7.5%) was noted as mentioned previously. Hypertension is closely related to the development of progressive nephropathy and frequently progresses within 3 years of the commencement of microalbuminuria.[25] Diabetic patients have higher chances of perioperative adverse cardiac events like unexplained hypotension, arrhythmias, and myocardial ischemia, this is in contrast to our study. We didn't find perioperative myocardial ischemia or any cardiovascular complications even on continuous ECG monitoring in any of the patients of the two groups which might be due to limitation of small sample size or could also be due to exclusion of

patients taking insulin (one of the exclusion criteria). Patients who have controlled blood glucose level with OHA alone are supposed to have better metabolic status then those who require treatment with insulin or combination therapy.[26] Regional anaesthesia is very effective in mitigating cardiovascular responses to surgery which results from sympathetic activation.[27] Risk of acute myocardial infarction (AMI) in diabetic patients who had no prior AMI is same as a non-diabetic patient with previous AMI.[28,29]

Anesthetic drugs, analgesics, benzodiazepines, and sympatholytic drugs can interfere with symptom presentation subsequently causing masking of symptoms of hypoglycemia. Normal glucose homeostasis mechanism becomes inefficient in perioperative period leading into hyperglycemia due to surgical stress along with relative deficiency of insulin along with insulin resistance. Regional anaesthesia with local anesthetic drugs inhibits stress response to surgery influencing postoperative outcome with positive effect on organ function.[30] Moreover, most of general anesthetic agents interfere with glucose metabolism while spinal anaesthesia facilitates blood glucose control in the perioperative setting.

In both the groups of our study, post-surgery patients were shifted to recovery room for blood glucose and hemodynamic monitoring, pain relief and postoperative care. Oral intake can be restored early by using prophylactic drugs for nausea and vomiting, and also by avoiding drugs (such as opioids) that may cause postoperative vomiting and nausea.[16]

In our study, no significant fluctuations were found in heart rate, blood pressure or random blood sugar in both the groups. Hence, there was no need for prolonged recovery room stay in either of the groups with the mean duration being 1.43 and 1.97 h in group A and group B, respectively. Although this difference was statistically significant but was of no clinical relevance. In our study, group B patients stayed in hospital for longer duration then group A, as rate of surgical site infection was more in group B (8.6%) which required longer in-hospital care like regular intravenous antibiotic therapy, anti-inflammatory and pain control drugs. Regular blood sugar levels were checked and euglycemia was maintained according to recommendations and also due to increased propensity of adverse cardiovascular events, more commonly between 48 and 72 postoperative hours. Increased length of hospital stays in group B seen in our study could be due to deleterious effects of poor glycemic control in perioperative period of THA.

Conclusion: We conclude that HbA1c is a useful tool to assess the glycemic control in diabetic patients undergoing hip arthroplasty and we can significantly reduce the postoperative morbidity and mortality by preoperative assessment and optimization. Moreover, poorer outcomes are in part due to higher rates of comorbid conditions such as myocardial ischemia, renal dysfunction, and hypertension in diabetic patients but in our study, we have excluded patients of renal impairment and on-insulin therapy, and in our sample size there was no known case of ischemic heart disease subsequently we have not found any postoperative complication. For diabetic patients, not on insulin therapy, with no renal impairment, of ASA grading II-III; we can use HbA1C of 7.5% as a new cut-off for total hip arthroplasty. Also, hip arthroplasty being a short duration surgery can be done under regional anaesthesia in uncomplicated diabetic patients for better outcome.

Limitations of present study: It is single centric study with small sample size and only uncomplicated diabetic patients were included. Observer bias may be there due to non-blinding and follow-up period was relatively short and large number of drop-outs on follow-up was encountered due to COVID-19 pandemic.

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Author's contribution

All authors contributed during process of study at different stages.

Declaration of competing interest

Nil.

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Evaluation of clinical outcome of cementless ceramic on ceramic primary total hip replacement in young patients of avascular necrosis of femoral head

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ABSTRACT

Objective: To evaluate clinical outcome of cementless ceramic on ceramic primary total hip arthroplasty in young patients of Avascular necrosis of Femoral head.
Methods: A total of 30 hips undergoing cementless ceramic on ceramic primary total hip arthroplasty using S-ROM femoral stem were prospectively and retrospectively evaluated.
Results: Pre-operatively the mean HHS was 32.73 which increased to a mean of 87.8 post-operatively. The difference was statistically significant (p value < 0.0005) with relatively minor complaints.
Conclusion: Based on our study, we recommend ceramic on ceramic THR for younger patients in the age group of less than 50 years of age.

1. Introduction

The human hip joint is extremely complex on account of the functional demands placed on it by the body. The mechanics of hip joint and various forces generated in day-to-day activities render the hip joint an extremely complicated engineering design. This complexity is further enhanced by the various conditions affecting the joint such as congenital, traumatic, infective, degenerative and paralytic. Considering these points, it is not surprising that several procedures have been described in the literature for the reconstruction of the hip, one of them being Total Hip Arthroplasty.

Artificial hip arthroplasty has become a widely accepted treatment in orthopaedic surgery. Many varieties of Total Hip Arthroplastys have been done in the past few decades. A variety of implant designs, sizes and materials used in Total Hip Arthroplasty are available e.g. highly cross-linked polyethylene, metal on metal and ceramic on ceramic, and are constantly evolving.

The young population with high activity levels has an increased risk of wear debris production at bearing surface and subsequent implant failure. Changes in bearing technology have typically focused on increasing implant survival by decreasing wear, resulting in osteolysis and reducing the dislocation rate. Alternative bearing surfaces are of two types: low wear metal on polyethylene articulations and bearing surface using couples such as ceramic on ceramic.

Recently, interest and use of ceramics with high wear resistance has been growing. An alumina/alumina couple was first used as an acetabular implant in THR in 1972 by Boutin in France and since then many authors have demonstrated its advantages over other bearing surfaces.

Early reports on ceramic on ceramic THR have demonstrated excellent clinical and radiological results. The theoretical advantages of ceramic on ceramic are represented by its remarkable sliding characteristics and its very low wear debris generation.

We, in the department of Orthopedics, PGIMSR, ESIC Hospital are doing a clinical, functional and radiological evaluation of cementless ceramic on ceramic femoral prosthesis in the management of complex hip pathologies during the period of 2013–2015.

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2. Materials and methods

The present study was carried out in the Department of Orthopedics, ESI PGIMSR, Basaidarapur, New Delhi.

A total of 30 hips of either sex undergoing total hip arthroplasty using S-ROM femoral stem were prospectively and retrospectively evaluated from 2013 to 2015.

(i) Inclusion criteria-
- Patients showing osteonecrotic changes on X-rays and MRI.
- Age less than 50 years.
- Both male and female

(ii) Exclusion criteria-
- Age more than 50 years.
- Patients having active infection of hip.
- Hemophillia and other bleeding disorders.
- Progressive neurological disease.
- Patients for revision THR.
- Any other hip pathology other than osteonecrosis.

(iii) Preoperative work up- After taking informed consent, all the patients underwent detailed clinical and radiological examination along with all routine investigations.

Pre-operative Harris hip score[1] was calculated for all the patients.

(iv) Radiological Assessment- An anteroposterior (A-P) view of the pelvis with both extremities in 15° of internal rotation to position the head and neck parallel to the coronal plane was obtained. A direct lateral radiograph of hip joint with thigh also obtained. MRI of the pathological hip is done and grading of Avascular Necrosis of femoral head done depending on X-ray and MRI findings

(v) Pre-operative templating-
a. Determination of leg length discrepancy- Preoperative leg length discrepancy was determined, clinically and with a radiographic analysis. A reference line was drawn along the inferior aspect of the ischial tuberosities. The difference in the distance from the lesser trochanter to the reference line on each side was measured as the radiographic leg length discrepancy.
b. Acetabular cup size and position- Acetabular templating was performed first because the acetabular component establishes the centre of rotation of the arthroplasty. Acetabular templating was done by placing the template of the cup of the appropriate size, extending from the superolateral margin of the acetabulum upto the lateral margin of the teardrop infero-medially. The template which matched the contour of the acetabulum without removing excess subchondral bone, was chosen. This centre of the acetabulum component determined the centre of rotation of the hip joint (Fig. A.1).

For the templating exercise, the acetabulam centre of rotation is considered the fixed reference and the femoral head centre is considered variable.

c. Femoral component selection- An index mark was made above the acetabular centre of rotation at a distance equal to the amount of leg length correction required. The vertical distance between the planned centre of rotation of the acetabular component and the centre of rotation of the femoral head constituted the distance the leg length that would be adjusted. If the femoral head centre of rotation is above the acetabular centre of rotation then relative lengthening would occur when it is surgically executed. Similarly, if femoral centre of rotation is below the acetabular centre of rotation then relative shortening would occur. The femoral component template size that fitted the distal femur and equalised leg lengths was selected. Proper offset was determined by matching the cups centre of rotation with the desired head centre of rotation (Fig. A.2).

The neck resection line was drawn at the point where the selected stem provided the desired amount of leg length. The stem size chosen in the A-P plane was also verified in the lateral plane.

(vi) Surgical technique- All patients were operated in the lateral position using the standard posterior approach.

(vii) Post-operative management- Periodic assessment of vital signs, suction drain collection and soakage of dressing was done. Depending on the Intra-operative blood loss and collection in suction drain, on an average one to two units of whole blood were transfused.

On first post-operative day, in bed radiographs were done to check position of the implant. Isometric quadriceps and gluteal exercises were started from 2nd post-operative day. The suction drains were removed after 48 h.

All patients were immobilized with an abduction splint for 48 h and thereafter an abduction pillow was given.

Active flexion at hip and knee while maintaining abduction was allowed after 7 days. Intravenous antibiotics were administered for 72 h post-operatively.

All wounds were routinely inspected on fifth day and at the time of suture removal on fourteenth day unless there was a specific indication e.g. fever.

All these patients were kept in the ward at least till the time of suture removal and then discharged.

Advice given to patients on discharge-

- Not to squat or sit cross legged.
- Not to use low level chairs.
- Not to lie on the operative site.
- To continue using abduction pillow for 6 weeks.

All patients were kept non-weight bearing for 6 weeks after which partial weight bearing started and gradually increased as tolerated by the patient. Full weight bearing was generally started after 3 months.

The patients were followed up at 6 weeks, 3 months, 6 months and 1 year and then annually.

(viii) Follow up- At each visit patients were assessed for:
a. Clinical assessment -

Clinical assessment was performed based on the preoperative and postoperative Harris hip scores.[1] Scores of more than or equal to 90 points were assessed as 'excellent'; scores of 80–89 points were assessed as 'Good'; scores of 70–79 points were assessed as 'Fair'; and scores of less than 70 points were assessed as 'Poor'.

b. Radiographic evaluation-

Post-operative radiographs were evaluated for alignment of femoral stem, loosening of stem, presence of heterotopic ossification, loosening of acetabular component.

Varus and valgus positioning of the stem was determined as stated by Johnston et al.[2] Varus or valgus alignment was used to describe a femoral stem with more than 5° of malalignment with respect to neutral axis of femoral canal.

Periprosthetic osteolysis was defined as a non-linear radiolucency of >5 mm. These lesions were classified according to the seven zones around the femoral implant-bone interface as described by Gruen et al.[3]

Vertical migration (subsidence) of the femoral component was evaluated by measuring change in the distance between the most proximal point of the lesser trochanter and the most superomedial point of the femoral component and also the top of the greater trochanter and the lower edge of the stem on sequential radiographs. As described by Callaghan et al.,[4,5] 5 mm or more was considered to indicate subsidence.

Heterotrophic ossification, when present, was graded according to the classification of Brooker et al.[6] which is as follows: Grade 0 = No heterotopic ossification, Grade 1 = Islands of bone within the soft tissue about the hip, Grade 2 = Bone spurs from the pelvis or proximal end of the femur leaving at least 1 cm between the opposite bone surface, Grade 4 = Bony ankylosis of the hip.

The osteolysis around the acetabular cup was analysed based on three areas that was classified by Delee and Charnley.[7] Vertical migration of the acetabular cup was determined by measurement of change in vertical distance from the centre of the acetabular component to a horizontal line drawn through the inferior aspect of both teardrops. Horizontal migration of acetabular component was determined by measurement of change in the horizontal distance from the centre of the acetabular component to a vertical line from the centre of ipsilateral teardrop. The inclination of the acetabular cup from the horizontal (the cup angle) was measured by drawing a horizontal line through both teardrops and another line through the plane of the opening cup. Cup loosening was defined as radiolucent lines on the entire circumference, a change in inclination angle of at least 5° or migration of at least 5 mm.[4,5]

3. Results

After applying the inclusion and exclusion criteria, a total of 30 hips undergoing total hip arthroplasty using S-ROM femoral stem were prospectively and retrospectively evaluated in the present study.

3.1. Patient distribution

1. Age distribution

Majority of the patients belonged to the age group of 21–30 years (36.67%). Mean age of presentation was 45.08 ± 14.28 years (Mean ± S.D.).

2. Sex distribution

There was a male preponderance (83.33%) with male to female ratio being 5:1.

3. Diagnosis

Out of a total of 30 hips, majority (93.33%) were cases of unilateral AVN and 2 (6.67%) had bilateral AVN.

4. Side of surgery

In case of unilateral AVN, majority (53.33%) were operated on the right side.

5. Harris Hip Score

Pre-operatively the mean Harris hip score was 32.73 which increased to a mean of 87.8 post-operatively (Table A). The difference between mean pre and post-operative scores was statistically significant. (p value < 0.0005) (Fig. B.1).

6. Post-operative Harris hip score

Post-operatively, excellent score was seen in 15 (50%) patients; good in 12 (40%) patients; fair in 2 (6.67%) patients and poor in 1 (3.33%) patient (Fig. B.2).

7. Squeaking

1 patient (3.33%) complained of squeaking post-operatively.

8. Complications

Majority of the patients (29; 96.67%) had no complication while one patient (3.33%) complained of chronic thigh pain.

9. Radiographic evaluation

Alignment of stem - Majority (27; 90%) of the total femoral stems were in central alignment while 3 (10%) were in valgus.

None of the patients showed heterotopic ossification, osteolysis or stem loosening.

10. Comparison between age distribution and post-operative hip score

There was no significant difference (p value = 0.901) between the rates of improvement in post-operative scores among different age groups (Table B.1).

11. Comparison between sex distribution and post-operative hip score

There was no significant difference (p value = 0.323) between the rates of improvement in post-operative scores among male and female patients (Table B.2).

12. Comparison between alignment and post-operative hip score

There was no significant association (p value = 0.774) between the rates of improvement in post-operative scores and alignment pattern (Table B.3).

13. Comparison between side and post-operative hip score

There was no significant association between the rates of

improvement in post-operative scores and unilateral (Left/Right) or bilateral AVN (Table B.4).

4. Discussion

Ceramic bearings are widely used in total hip arthroplasty along with metal and polyethylene bearings. There were several studies in the past few years accessing the advantage of one over the other. Our study aimed to evaluate clinical outcomes of primary total hip arthroplasty in young patients of avascular necrosis of the femoral head. The study was conducted in Department of Orthopedics in ESI-PGIMSR, Basaidarapur, New Delhi. A total of 30 hips in 28 patients undergoing total hip arthroplasty with ceramic on ceramic bearings were included.

The mean age of patients in our study was 45.08 with age ranging from 17 to 49 years, majority of them being from the age group 21–30 years. A case study was reported by Capello and Feinberg (2009)[8] where ceramic-on-ceramic joints were implanted in a 13 year-old child with bilateral end-stage arthritis of the hip. Seven and eight years post-operatively the patient had no pain, no limp, and was able to walk long distances. The radiographs showed no implant loosening, osteolysis or wear. This is a very encouraging result, however, it was stated that the patient is still very young (20 years of age at the time of the report) and, therefore, the need for revision surgery will be more than likely. Other studies on younger patients have not had as good results as those reported by Capello though Nizard et al.(2008)[9] reported on ceramic-on-ceramic hips that had been implanted in a group of 101 patients (132 hips) younger than 30 years old (mean age: 23.4 years, range: 13–30 years). In our study, age was not associated with any significant difference in the clinical outcome as suggested by age distributed mean Harris hip scores.

In our study out of 30 hips, 5 were that of females, with a male: female ratio of 5:1. A study conducted by AvishaiReuven et al.[10] included 10 males and 40 females. No significant statistical differences were seen comparing pre and post-op Harris hip scores. We too did not find any correlation between the sex of the patient and clinical outcome.

The mean period of follow up in our study was 11.76 months (ranging from maximum of 25 months and a minimum of 4 months). Lins et al.[11] reported 81% of femoral components and 97% of acetabular components were stable at mean follow-up of 60 months following uncemented fixation, while Mont et al.[12] reported good to excellent results in 94% of patients at short-term follow-up.

We evaluated the clinical outcomes based on Harris hip score as has been done by various authors. The mean Harris hip score in our study increased from 32.73 pre-operatively to 87.8 post-operatively at the latest follow up with 90% hips having good to excellent results. This improvement was statistically significant ($p < 0.005$). Our results are comparable to a study done by AvishaiReuven et al.[10] in which pre and post-op HHS was 45 and 88 respectively with 80% patients with good or excellent scores. In another study by Neal L. Millar et al.,[13] pre and post-op HHS were 29.4 and 85.7 respectively at minimum of 24 months of follow up.

On evaluation of the alignment of femoral stem 27 stems were central (90%) and 3 stems in valgus (10%) and none in varus position. There was no significant correlation between stem alignment and clinical outcome based on Harris hip score.

No cases of focal osteolysis or heterotopic ossification were seen in our study. This is in contrast with the study of Jean-PierreSimon[14] et al. where osteolysis was seen in 6 of 34 hips 3 being grade 1, 2 grade 2 and 1 grade 3. This study has got a longer follow up so we suggest longer follow might be needed for ossification changes to occur.

Stem loosening was not seen in any patients until recent follow up. This is in accordance with study of Jean-PierreSimon[14] et al. where osteolysis was seen in only 1 of 34 cases with long follow up without clinical signs of loosening.

Squeaking was seen in 1 out of 30 hips in our follow up. The patient complained of sound while working however he couldn't reproduce it during our evaluation. Jarrett et al. (2009)[15] described a group of 131 patients from which 14 (10.7%) suffered an audible "squeak" during normal activities (however, only 4 of these patients were able to reproduce the "squeak" during the clinical review session). After 10 years of follow-up Chevillotte et al. (2012),[16] discussed the performance of 100, third generation ceramic-on-ceramic joints. By the use of a questionnaire, 5% of these patients reported the occurrence of "squeaking". All of these patients were active, sporty and heavy men.

None of the major threatening complications were noticed during the evaluation of our cases except minor chronic hip pain in one patient which did not restrict his daily living activities with maximum patient satisfaction at the end of the follow-up.

5. Conclusion and recommendation

In our study, we found results of ceramic on ceramic THR for younger patients comparable to previous studies with no serious complication found in any patient. Only one minor complication of chronic thigh pain was found in one patient. Strategies change as more advancement and refinement occurs in the field of arthroplasty. Based on our study, we recommend ceramic on ceramic THR for younger patients in the age group of less than 50 years of age.

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None.

Presentation

None.

Declaration of competing interest

None.

Acknowledgement

None.

Appendix

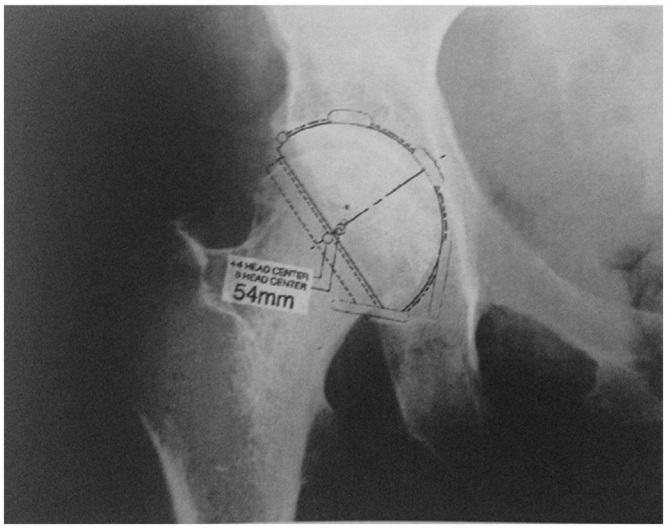

Fig. A.1. Acetabular templating.

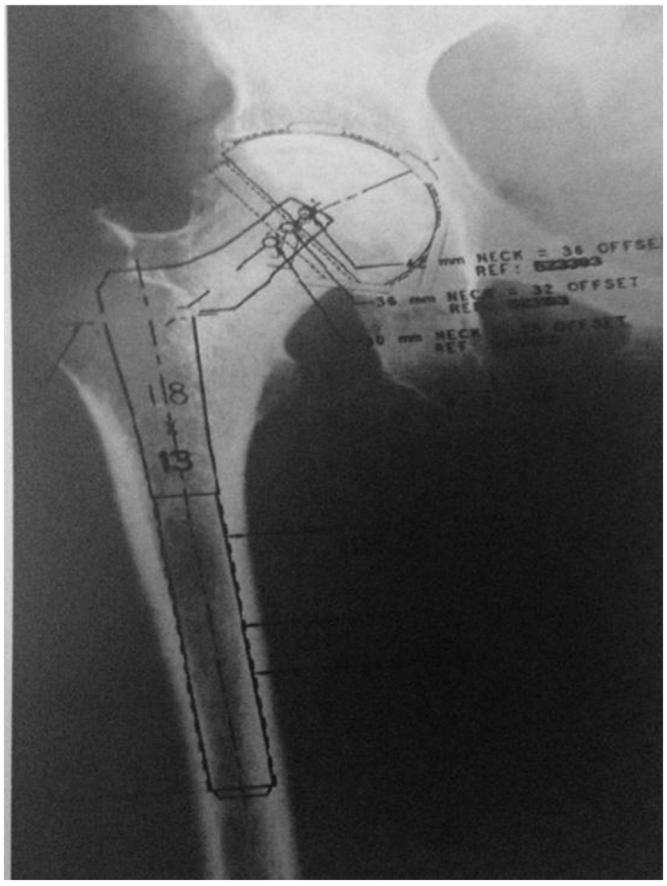

Fig. A.2. Femoral stem selection.

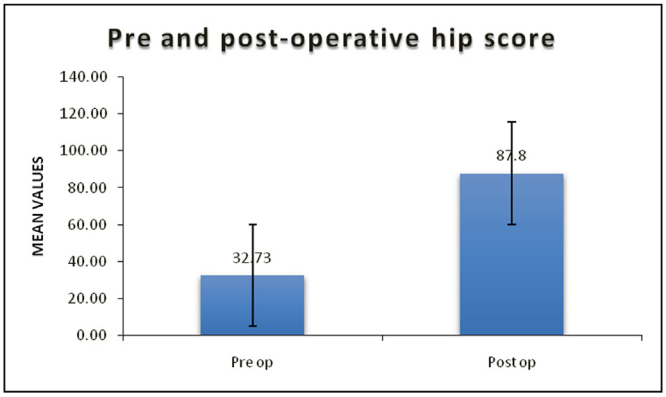

Fig. B.1. Comparison between pre and post-operative Harris hip score.

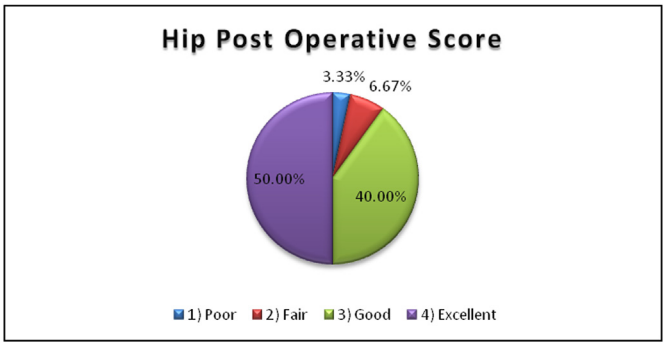

Fig. B.2. Post operative Harris hip score.

Table A
Comparison of Pre-operative and Post-operative mean Harris hip score.

	Mean ± Stdev	Median	Min-Max	Inter quartile Range	P value
HHS Pre op	32.73 ± 9.27	33	18–53	26.000–40.000	<.0005
HHS Post Op	87.8 ± 6.48	89.5	68–99	84.000–92.000	

Table B.1
Comparison between age distribution and post-operative hip score.

		Hip Post Operative score				Total	P value
		1) Poor	2) Fair	3) Good	4) Excellent		
Age grouping	≤20	0 (0.00%)	0 (0.00%)	1 (8.33%)	1 (6.67%)	2 (6.67%)	0.901
	21–30	1 (100.00%)	1 (50.00%)	4 (33.33%)	5 (33.33%)	11 (36.67%)	
	31–40	0 (0.00%)	0 (0.00%)	3 (25.00%)	6 (40.00%)	9 (30.00%)	
	41–50	0 (0.00%)	1 (50.00%)	4 (33.33%)	3 (20.00%)	8 (26.67%)	
Total		1 (100.00%)	2 (100.00%)	12 (100.00%)	15 (100.00%)	30 (100.00%)	

Table B.2
Comparison between sex distribution and post-operative hip score

		Hip Post Op				Total	P value
		1) Poor	2) Fair	3) Good	4) Excellent		
Sex	female	0 (0.00%)	1 (50.00%)	3 (25.00%)	1 (6.67%)	5 (16.67%)	0.323
	male	1 (100.00%)	1 (50.00%)	9 (75.00%)	14 (93.33%)	25 (83.33%)	
Total		1 (100.00%)	2 (100.00%)	12 (100.00%)	15 (100.00%)	30 (100.00%)	

Table B.3
Comparison between alignment and post-operative hip score

		Hip Post Op				Total	P value
		1) Poor	2) Fair	3) Good	4) Excellent		
Alignment	Central	1 (100.00%)	2 (100.00%)	10 (83.33%)	14 (93.33%)	27 (90.00%)	0.774
	Valgus	0 (0.00%)	0 (0.00%)	2 (16.67%)	1 (6.67%)	3 (10.00%)	
Total		1 (100.00%)	2 (100.00%)	12 (100.00%)	15 (100.00%)	30 (100.00%)	

Table B.4
Comparison between side and post-operative hip score

		Hip Post Operative Score				Total	P value
		1) Poor	2) Fair	3) Good	4) Excellent		
Side	Left	0 (0.00%)	2 (100.00%)	8 (66.67%)	4 (26.67%)	14 (46.67%)	0.058
	Right	1 (100.00%)	0 (0.00%)	4 (33.33%)	11 (73.33%)	16 (53.33%)	
Total		1 (100.00%)	2 (100.00%)	12 (100.00%)	15 (100.00%)	30 (100.00%)	

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Research paper

Unilateral total hip arthroplasty in bilateral ankylosed hips: A case-series of eight patients of ankylosing spondylitis

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ABSTRACT

Introduction: In approximately one-third to half of patients of ankylosing spondylitis (AS), involvement of the hips may occur with 50–90% of these presenting with bilateral hip involvement. Total hip arthroplasty (THA) in these patients provide mobile hip, which significantly improves their functional capability and lifestyle. Aim of our study was to assess the clinical outcome of unilateral THA in AS patients with bilaterally ankylosed hips in terms of pain, hip mobility, ability to perform functional activities like sitting and walking and radiological evaluation in terms of position of acetabular cup, heterotrophic ossification (HO) and any sign of osteolysis.

Methods: Eight male patients (8 hips), between 25 and 40 years with ankylosed hips and spine in which only unilateral cemented THA was done due to financial constraints, were studied with average follow-up of 18.25 months (Range- 12–30 months). Results were assessed by walking ability, Harris Hip Score (HHS) and radiological findings.

Results: Mean pre-op HHS was 31.3. All these patients were more or less dependent on others for daily activities. None of the patient was able to sit on chair and all were able to walk indoor only. Mean HHS at final follow-up was 76.4. At final follow-up, all the patients could sit comfortably on a chair for more than 1 hour and were walking independently, although with a limp. Radiologically, acetabular cup inclination and anteversion was within Lewinnek's safe zone in all the patients.

Conclusion: Unilateral cemented THA is a potential option in rehabilitation of patients of AS with bilaterally ankylosed hips, who cannot afford bilateral THA. But these young patients with rigid spine, who are very much dependent upon hip mobility, must be kept under observation to discover complications like loosening and for maintaining hip mobility.

1. Introduction

Ankylosing spondylitis (AS) is a chronic inflammatory disease primarily affecting the sacroiliac joints, spine, hips and, less commonly, the knee joints. In approximately one-third to half of AS patients, involvement of the hips may occur, and among those with affected hips, 50–90% present with bilateral hip involvement.[1,2]

Ankylosing spondylitis (AS) affects mainly the age group of physically and economically active men. Fused hips, loss of lumbar lordosis, and progressive thoracic and cervical kyphosis all contribute to the functionally disabling stooped posture typical of AS patients.[1–3] Aim of surgical treatment of these patients is to reduce disabling pain and improve function. Conversion of ankylosed hip to total hip arthroplasty (THA) provides painless, mobile and stable hip, which helps rehabilitating patient to gainful occupation. THA is the benchmark treatment in such patients and provides good pain relief and improved quality of life.[2–10] In ankylosed hips, functional disability is more problematic than pain and THA in ankylosed hips is technically challenging, with higher incidence of ectopic ossification and reankylosis.[2,4,5,11]

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THA in AS differs from other inflammatory arthropathies in that upper limbs are usually spared which is helpful in post op rehabilitation as it helps them to use walking aid effectively. Stiffness is bigger problem than pain and decreased vital capacity and stiff spine are problematic for the anaesthetists.[7]

In developing countries like India many patients belong to poor socio-economic group and universal health-insurance scheme is still not implemented. In all those cases where bilateral hip involvement is there, patients are advised for bilateral THA (either simultaneous or staged), which is the treatment of choice. Lin et al., in a systematic review said that arthroplasty on a single side alone will not restore mobility and independence to this group of patients.[11] But in developing nations, due to financial constraints, some of these patients end up spending considerable period of time with unilateral THA before they are able to arrange money and come back for THA in the contralateral hip. As the launch of universal healthcare scheme for poor patients (Ayushman Bharat Pradhan Mantri Jan Arogya Yojana) is currently underway, unilateral THA in patients of AS having bilateral hip involvement may become a thing of the past.[12] There are many studies regarding THA in AS, [1,3–5,7,9–11] but we found no study measuring outcome of unilateral THA in bilaterally ankylosed hips.

Aim of our study was to measure the clinical outcome of unilateral THA in AS patients with bilaterally ankylosed hips in terms of pain, hip mobility, ability to perform functional activities like sitting and walking and radiological evaluation in terms of position of acetabular cup, heterotrophic ossification (HO) and any sign of osteolysis.

2. Materials and methods

2.1. Study design and study population

The study was carried out at J N Medical College and Hospital, Aligarh Muslim University, Aligarh, India. Patients with clinically and radiologically diagnosed ankylosing spondylitis having bilaterally ankylosed hips in which unilateral cemented THA was done between November 2015 and November 2018 and the other side was not operated due to financial problems were included in the study. There were 8 patients (all males) between 25 and 40 years of age. The period of follow up ranged from a minimum of 1 year to 2.5 years duration. Results were assessed by walking ability, Harris Hip Score (HHS)[13] and radiological findings.

2.2. Preoperative evaluation

At the time of admission, detailed history was taken to evaluate severity of disease and amount of disability. Clinical examination was done to check gait, assessment of deformity of both hips and spine, range of movement, HHS, ambulatory status, use of walking aid, abductor weakness, gluteal wasting and limb length discrepancy. X-ray pelvis with both hips- Antero-posterior (AP) view was done in all patients at the time of admission and at follow-ups. X-rays of entire spine was also done in all cases for assessment of spinal deformity.

2.3. Anaesthetic considerations

Two patients were operated under general anaesthesia due to difficulty in giving spinal anaesthesia. Rest of the patients were given spinal or para-spinal anaesthesia.

2.4. Surgical technique

Six patients were operated by posterior approach and two by antero-lateral approach, depending upon surgeon's preference. Femoral neck was cut at two levels and bone block removed, which provided space for removing head. Cemented acetabular and femoral components were used in all the patients. Adductor tenotomy was done in four and iliopsoas was released in three patients.

2.5. Post-operative protocol

Skin traction was applied for 5–7 days to correct the deformity. Due to weak abductors and gluteal muscles, patients were kept on physiotherapy for 7–10 days, and subsequently walking was gradually initiated. Patients were kept on IV antibiotics till wound inspection, following which oral antibiotics were started. DVT prophylaxis was not used in any of the patients. To prevent heterotrophic ossification and reankylosis, Indomethacin 75 mg/day was given orally for 2 weeks.

2.6. Post-operative clinico-radiological assessment and follow up

In the post-op period, clinical assessment was done to see the degree of pain and to check for the possibility of major complications like infection, DVT, dislocation, etc. Radiological evaluation included assessment of acetabular cup inclination and version in the immediate post-op radiograph and any sign of loosening or heterotopic ossification in the follow-up X-rays. Acetabular cup inclination was measured by using inter-teardrop line as reference point.[4] Acetabular cup anteversion was measured by using Lewinnek's method in AP view.[9] Subjective clinical assessment was done by Harris Hip Score (HHS) at each follow-up.[14] Walking ability of all the patients were checked in the follow-ups. Patients were followed-up at 6 weeks, 12 weeks and 6 months thereafter.

3. Results

Patients were diagnosed as per the Modified New-York criteria.[15] Average age of patients at the time of operation was 34.6 years (range- 25–40 years). All the patients were males. In all the patients, spine was stiff and no possible movement was present in both the hips. Although spine was affected in most of our cases but in none of them, the deformity (kyphosis or scoliosis) was severe enough to require any specific procedure like spinal osteotomy. Unilateral cemented THA was done on left hip in 5 patients and right hip in 3 patients. (Table 1). The average period of follow up was 18.25 months ranging from a minimum of 1 year to 2.5 years duration.

Pre-operatively, all these patients were more or less dependent on others for daily activities, for more than 1 year. Mean pre-op HHS was 31.3 (Range- 26 to 38.8). None of the patient was able to sit on chair and all were able to walk indoor only with the help of walking frame, stick or cane. Hip and back muscles were wasted. But pain was not a prominent complaint and patients only complained of tolerable pain except in 2 where there was significant accompanying pain.

Post-operatively, significant clinical improvement was seen in all the patients in terms of functional outcome, movement, walking ability and posture. Mean HHS at final follow-up was 76.4, which was statistically significant at p value < 0.001 (Table 2). HHS was good in 3, fair in 4 and poor in 1 patient. (HHS 80–90 = good; 70–80 = fair; <70 = poor). But the results were successful in all the patients with improvement in HHS >20 points, with radiologically stable implant. At final follow-up all the patients were walking independently, although with a limp. 3 of them had moderate limping and rest of the patients had mild limping. (Table 3). For the purpose of illustration, Fig. 1 shows one of the patients who

Table 1
Demographic features and other particulars of the patients participating in the study.

No. Of patients participating in the study		8 (All males)
Bilaterality		All cases had bilateral hips affected
Mean Age (Range)		34.6 years (25–40 years)
Side operated		Right-3 Left-5
Type of ankylosis present in operated hips	Fibrous	3 patients
	Bony	5 patients
Mean Fixed Flexion deformity on the operated side		20° (10–35°)
Type of implant used		Cemented prosthesis in all
Surgical approach used		Posterior-6
		Anterolateral-2

Table 2
Detailed description of patients participating in the study.

Sl. No.	Age (years)	Operated Side	Follow-up (months)	PRE-OP HHS	HHS at final follow up	p-value	FFD Contralateral hip (degree)	Walking distance (metres)
1.	40	L	30	38.8	81.9	<0.001	15	300
2.	25	L	24	34	80.3		15	200
3.	35	L	20	26	78.8		30	500
4.	40	R	18	32.2	70.6		15	100
5.	36	R	15	26.4	68.6		20	200
6.	28	L	15	28.8	78		20	100
7.	38	R	12	34.3	80.8		15	100
8.	35	L	12	30	72.4		20	100
Average	**34.6**		**18.25**	**31.3**	**76.4**			

Table 3
Summary of the clinical and radiological outcome of the study.

Mean Pre-operative HHS	31.3 (Range- 26-38.8)
Mean Post-operative HHS at final follow-up	76.4 (Range- 70.6-81.9) p-value <0.05
Mean follow up period	18.25 months (12–30 months)
Radiological outcome (Anteversion/inclination of acetabular cup)	All of the cases had parameters within Lewinnek's safe zone.
Major immediate post-operative complications (like infection/dislocation/periprosthetic fracture/nerve palsy)	None noted
Heterotrophic ossification	None
Aseptic loosening	None

underwent THA on left side only. Preoperatively, fixed flexion deformity was around 30° in both the hips and patient was unable to sit without support (Fig. 2). Postoperatively, the left hip has regained its mobility and the deformity is not there. However, although the deformity is still present on the right side, patient is able to sit without support and can walk without support (Fig. 3**).**

Radiological evaluation was done on AP view of pelvis in supine position. Acetabular cup inclination and anteversion was within Lewinnek safe zone in all the patients.[14] Till our last follow up, we did not find any radiological signs of osteolysis or implant loosening.

Major complications like infection, heterotopic ossification, peri-prosthetic fracture, nerve injury, dislocation or aseptic loosening was not seen in any patient and no patient required reoperation till last follow-up. (Table 3).

4. Discussion

The involvement of hip in AS is between 19 - 36% with 90% having bilateral involvement which may be in the form of one or more of these- synovitis, enthesitis, avascular necrosis and secondary osteoarthritis leading to clinical presentation in the form of pain, stiffness, contractures (mostly flexion) and if untreated, bony ankylosis.[1,2] Once bony ankylosis sets in, hip joint is in itself painless but for mobility/ambulation, patient depends on spinal mobility or contralateral hip functionality which often lacks in these patients.[17] So, the indication of THA in patients are mostly stiffness/ankylosis and not pain. At times, THA may be required for pain in adjacent joints due to stiffness of hip.[11,16] In our study also, most of the patients required it for stiffness only. Only 2 patients had pain as their predominant complaint along with stiffness.

In patients with Ankylosing spondylitis, spine is the most common site of affection and in those patients in whom hip is involved, spine is also predominantly involved. Whether spinal osteotomy for kyphotic deformity or THA should be done first is still debatable. Recent literature favours correction of spinal deformity first. However in our series, we did THA only as none of the patients had kyphotic deformity severe enough to warrant spinal osteotomy in the first place. However, if at all the patient needs spinal osteotomy, it should be done first as advised by Zheng et al.[16–18]

Surgical planning is one of the important factors which determine the outcome of any surgery. This fact can't be overemphasized with respect to THA in AS. Apart from a thorough history, "the physical examination should mainly concentrate on limb-length discrepancy, pelvic obliquity, spinal involvement, range of motion, and stability of contralateral hip, bilateral knees, integrity of the femoral and sciatic nerves, and vascular status."[18] Proper radiographic evaluation of entire spine, pelvis and lower limbs should be done to assess the functional outcome that surgery will have. For

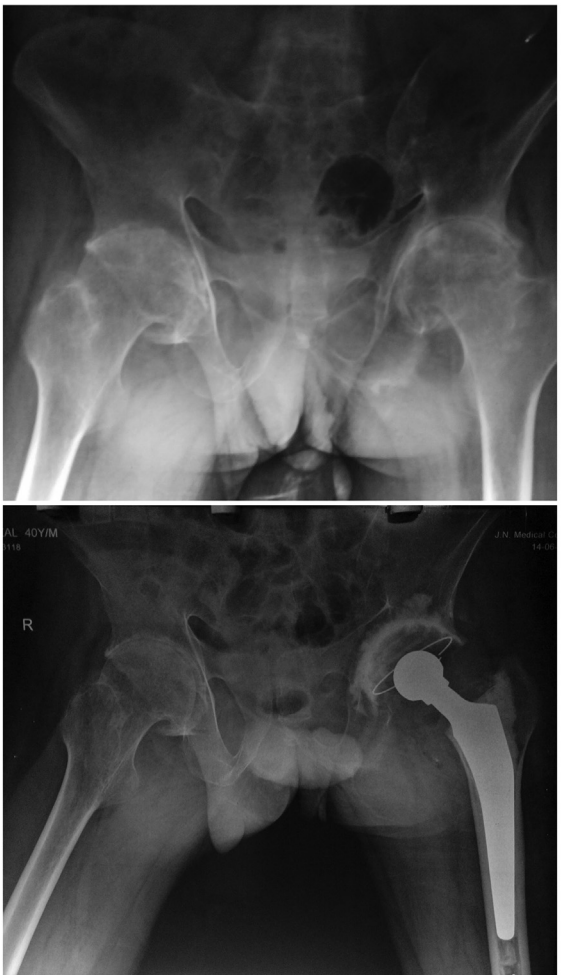

Fig. 1. Preoperative and postoperative radiograph of one of the patients in our study.

assessing postural alignment, standing antero-posterior and lateral long leg films are recommended. The pre-operative CT scan with 3D reconstruction of pelvis with spine should ideally be done in all cases to find out the degree of pelvic malrotation so that we can have correct cup positioning (inclination and version).[11]

The concerns from anaesthetists' point of view is four fold- (i) difficult intubation due to involvement of cervical spine, cricoarytenoid arthritis, vocal cord fixation and limited mouth opening due to problems related to temporomandibular joint, (ii) limited chest expansion leading to compromised pulmonary function, (iii) cardiac involvement in the form of conduction abnormalities and valvular involvement and (iv) difficulty in spinal anaesthesia due to the presence of ossified ligaments and difficulty in positioning.[17,19,20] In our study, spinal anaesthesia was used in all except two where General Anaesthesia was preferred.

THA in AS patients can be technically demanding. Intraoperative problems that may be encountered includes patient positioning, femoral neck osteotomy, joint line identification, adequate soft tissue release and positioning of the implants.[11,19] The identification and exposure of femoral neck and acetabulum is usually difficult due to external rotation deformity in posterior approach. Most of the studies have described using the posterior/posterolateral approach.[4,23] Some of the studies have described using direct lateral approach via trochanteric osteotomy[2,5] or the Hardinge approach without osteotomy.[5,24] However, the majority have mentioned that the choice of surgical approach depended on the preference and experience of the individual surgeon. Due care should be taken to prevent fracture of the trochanter and posterior wall of the acetabulum. For ankylosed hips, in-situ double neck osteotomy is the preferred choice which was done in all our cases. Joint line identification is done by the foveal soft tissue and incomplete grey ossifying cartilage.[20,21]

Implant positioning has to be modified depending upon sagittal or coronal pelvic obliquity. In order to compensate for the kyphosis, these patients need to hyperextend the hip. So, the cup should be placed in less anteverted position to begin with. Above all, its quite obvious, as pointed by Bhan et al., that exaggerated anteversion may lead to intra-operative difficulties including impingement of the prosthetic neck or the greater trochanter posteriorly as more of the cup will be protruding posteriorly and will thus lead to difficulty in its placement, reduction and may cause anterior instability.[4] Tang et al., concluded from a 3D-CT based study that for each 10° of sagittal pelvic malrotation above 20°, the cup position should be modified so that it is 5° less inclined and anteverted.[22] As regards to the coronal imbalance in the form of adduction or abduction deformity of the hip, if referencing is done with respect to the ground, may lead to incorrect inclination of the cup. If contralateral hip is in abduction deformity, the pelvis on the operative side is tilted superiorly and so we need to increase the inclination if referencing is being done with respect to the ground. Adequate release of the soft tissues (adductor tenotomy, iliopsoas release, anterior capsulotomy) depending upon the deformity, should be done before trial.[4,19]

As far as the right implant choice is concerned, its still debatable. Cementless implant will increase the lifespan of implant due to osteointegration. Bhan et al., in one of the largest studies of 92 cementless arthroplasties in AS patients found 98.82% survival at 5 years and 85.8% survival at 8.5 years follow-up.[4] Xu et al., in a study of 81 hips, at a mean follow up of 3.6 years found signs of stable fibrous ingrowth and bone ingrowth in 52 and 29 hips, respectively.[23] But, in many of these patients, bone quality is poor in the form of osteoporosis/disuse osteopenia which may not lead to sufficient osteointegration and thus cemented implants may be a better choice in them.[2,5,9,22] In our study, as cost was the major issue, we had to resort to cemented prosthesis, which is relatively cheaper. We are of the view that in younger patients with good bone quality, cementless prosthesis should be preferred and if bone quality is found to be osteoporotic, one should not hesitate in going for cemented ones. In Dorr's Type C femur, cemented stems should be preferred.[24]

Rehabilitation in these patients differs from the conventional THA and should be individualised based on the preoperative functional status and the disease activity.[11,16,18] Physiotherepy should focus on regaining hip mobility but should not be too aggressive in order to protect the prosthesis and reduce the chances of dislocation. Due attention should be paid to the spinal mobility and chest expansion.[18,19] Individualising postoperative physiotherapy becomes all the more important, in cases of unilateral THA in individuals with bilateral disease because the contralateral hip is still stiff or painful. In our study, we had a good coordination between the team of operating surgeons and physiotherepists, especially with regards to movements that needed to be avoided to prevent dislocation.

Heterotrophic ossification (HO) was mentioned to be quite common in earlier publications and hence the use of nonsteroidal antiinflammatory drugs (such as indomethacin) and radiotherapy for HO prophylaxis were recommended. Brinker et al., in a systematic review found that higher rates of HO after THA have been reported in AS patients who have undergone repeat operations, who have experienced postoperative infection, and, who were treated with a transtrochanteric approach. The incidence of

Fig. 2. Preoperative functional status of the same patient.

Fig. 3. Postoperative functional outcome of the same patient.

clinically significant HO (Brooker Class 3 or 4) is much lower.[3] We could not come up with any case of HO in our study, probably due to meticulous surgical dissection and careful handling of soft tissues. However, it must be stressed that we had a short follow up and may end up having HO in subsequent follow ups.

Clinical outcome is dependent on many factors-preoperative deformity/pain, extent of involvement of contralateral hip and spine, range of motion of hip achieved after THA, adherence to proper technical details, post-operative rehabilitation and development of HO postoperatively.[11,16,18] We could not come up with any study which has shown outcome of unilateral THA in cases with bilateral disease exclusively. Most of the studies have included both unilateral and bilateral THA.[2,4,] It is important to note here that studies that have included only bilateral THA[11] have shown

better improvement in HHS as compared to studies that have included both unilateral and bilateral.[2–7] There has been quite a large amount of variation in improvement of HHS across studies. In our study, as the side which was more disabling to the patient was operated first, we have seen appreciable improvement clinically in terms of HHS (a mean increase of score by 45.1). Lin et al., in a systematic review of bilateral THA in AS noted a mean increase of 60.6, which clearly shows the superiority of bilateral THA over unilateral THA. Hence, we do not propose unilateral THA in bilateral disease because a dysfunctional contralateral hip will give rise to more stress upon the implant and will affect the survivorship of the implant.

In most of the papers which have mentioned bilateral THA in some or majority of their patients, the timing has been either simultaneous or staged at an interval of 7–10 days.[3,11] In this regard, our paper helps us envisage performing THA in such patients at larger intervals on either side as a viable option. All the patients in our study had been advised for bilateral THA and we expect them to get their contralateral sides operated in near future.

Aseptic loosening and dislocation in the post-operative period are the major causes of revision surgery in cases of THA done in patients of AS.[11,18] Aseptic loosening has been found to be more in cases of cementless implant where due to poor bone quality, proper osteointegration did not happen. Although we had a relatively short follow up, we didn't find any case of aseptic loosening in our study. But, we believe that unilateral THA will put more stress on the prosthesis due to diseased contralateral hip and may lead to aseptic loosening in future if the contralateral hip is not replaced. Dislocations- both early post-operative and late ones are one of the most feared complications in this group of patients. Lewinneck safe zone has been the most cited parameter as a predictor of dislocation after THA.[14] But some recent papers, not specifically of AS, but THA in general, have focussed more on "functional safe zone" which incorporates spinopelvic balance and preserved spinal mobility rather than just the "static safe zone" based on AP X-ray as proposed by Lewinneck.[14,25] In our study, we have went ahead with the conventional Lewinneck safe zone and found that all of our eight cases were within the safe zone. Future studies should assess "functional safe zone" and assess its predictability for dislocations after THA.

THA is nevertheless a costly surgery. In many parts of the world, especially in developing world, most of the patients are not having health insurance and have to pay every penny from their pocket for treatment and thus, many patients are unable to get it done and remain crippled throughout their life. In such patients, replacing even one hip may bring substantial change in their functional capacity and may help them in getting some form of employment.

The strengths of the study were prospective data collection method and that no similar study has been done in the past. The limitations were small sample size, short duration of follow-up and the fact that it was a case series and no direct comparison was done between unilateral and bilateral THA. We believe that our study will prompt future large comparative studies so that one can implement the study results in their clinical practice.

5. Conclusions

Based on the results of our short term study, we conclude that even unilateral THA of more affected hip in cases of AS where both the hips have been involved has got good functional outcome. However, it is advisable to get both the hips operated mainly due to two reasons- (i) A better clinical, functional and radiological outcome is expected after bilateral THA as compared to unilateral THA and (ii) A dysfunctional contralateral hip will give rise to more stress upon the implant and will affect its survivorship.

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None.

Credit author statement

Arshad Ahmed- Conceptualization, Investigation, Formal analysis, Writing – original draft, Latif Zafar Jilani- Conceptualization, Methodology, Supervision, Project administration, Naiyer Asif- Methodology, Validation, Abdul Qayyum Khan- Methodology, Investigation, Vivek Kumar- Investigation, Writing – review & editing, Kumar Keshav- Data Curation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization

Declaration of competing interest

None.

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Technical note

Peacock crown feather technique for oblique flap tear of the meniscus - Technical note

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ABSTRACT

Options for meniscal repair are plenty, but optimal usage of these techniques is imperative to achieve meniscal healing and simultaneously minimize meniscal trauma. In this technical note, a particular suture configuration called the Peacock Crown feather stitch has been described especially for the oblique flap tears.

1. Introduction

Radial tears of the meniscus are common and occur in 12% with ACL injuries.[1] The tear disrupts the hoop stress and thereby increases the chance of tear progression and eventually leading to chondral changes.[2]

The repair of such tears has been emphasised and various techniques have described.[3] However, the oblique flap tears of the meniscus, a type of radial tears is less extensively described in the literature. The authors of this study present a novel technique to deal with this sub type of radial tear with minimal trauma to the meniscal tissue.

2. Surgical technique

2.1. Patient positioning

Patient is positioned supine after spinal anaesthesia. Examination under anaesthesia (EUA) is performed to co-existing anterior cruciate or posterior cruciate ligament instability. If concomitant injury of ligaments is detected a pneumatic thigh tourniquet is placed along with a lateral thigh post and a foot post with the knee in 60° of flexion. For isolated meniscal injury a pneumatic thigh tourniquet is placed and the affected leg is placed in a leg holder.

2.2. Surgical approach

A routine diagnostic arthroscopy is performed through standard anteromedial and anterolateral portals to confirm the oblique flap tear of meniscus. In case of an associated ligament injury meniscal repair is initiated after femoral tunnel preparation.

Surgical steps: (Fig. 1).; (Fig. 2)

Step 1:

The oblique flap tear is identified and is found whether it is amenable to repair.

Step 2:

Identify and Mark the points of needle insertion required for meniscal repair.

Step 3:

A needle loaded with double loop of no.2 fibre wire or mite wire suture is passed through the flap in an inside out fashion.

Step 4:

The needle is then retrieved outside the skin, avoiding damage to the neurovascular structures.

Step 5:

The double loop suture is then cut and is converted into four single strands of suture material.

Step 6:

Pass each suture through the pre-determined points on the

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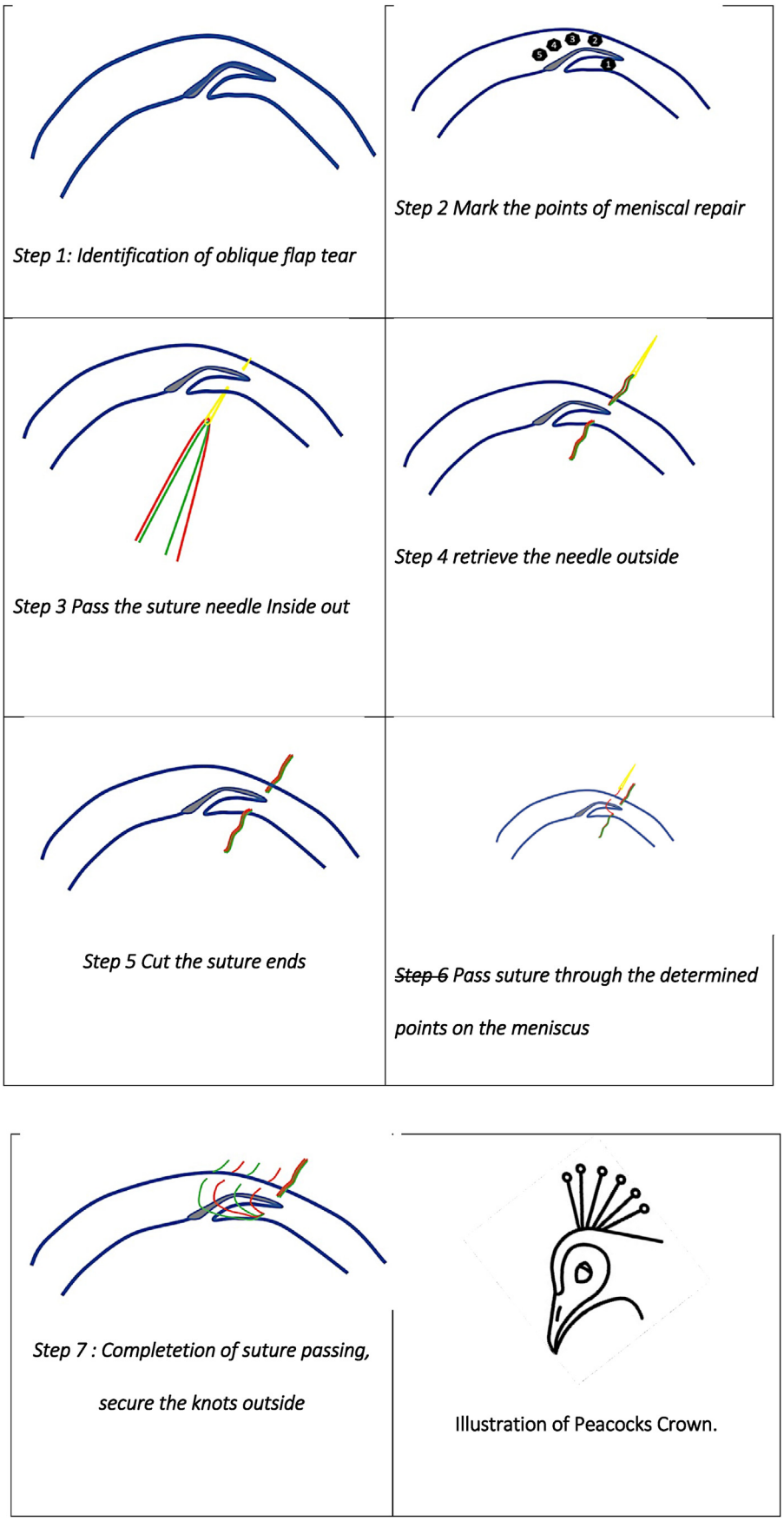

Fig. 1. Step wise illustration of the Crown feather stitch.

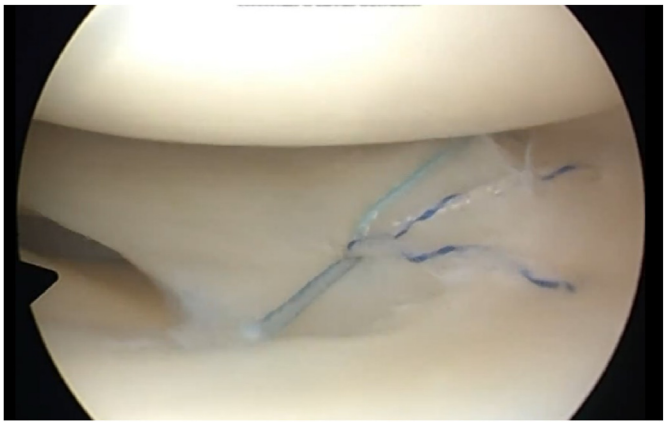

Fig. 2. Arthroscopic view of the peacock crown feather stitch.

intacr meniscal substance, using the conventional inside out technique.

Step 7:

The sutured ends are now retrieved outside and are tied under appropriate tension over the capsule through a small incision over the medial and lateral aspect of the knee accordingly.

2.3. Postoperative rehabilitation

Patients are allowed to do partial weight bearing mobilization with brace after 4–6 weeks. Knee bending is started from 3rd week and gradually increased to 90° by the end of 6th week. For first 3 months, open chain exercises with band, closed chain exercises and core exercises are initiated. Patients are allowed to return to sports usually at the end of 9 months.

3. Discusssion

This article describes the technique of repair on oblique flap tears of the meniscus. An anatomical repair increases the stability of the repaired construct and thereby can withstand the hoop stress post operatively.[4] Employing this strategy can preserve the articular cartilage and thereby prevent early osteoarthritis.

A radial/oblique tear of the meniscus causes disruption in the distribution of the hoop stress and can lead to early degeneration.[5] The repair of the radial meniscal tears has been described previously. However, the oblique flap tears are subjected to excision and balancing to distribute the loads evenly. Oblique radial tears are known to occur more frequently in lateral meniscus than medial meniscus following ACL injuries.[1] Methods of repair include outside -in technique, all inside technique and partial meniscectomy.

Partial meniscectomies are commonly performed and its indications have expanded to young adults and adolescents considering the early rehabilitation post operatively.[6] Biomechanical studies have demonstrated that the peak contact pressure increases by 235% after total meniscectomy and by up to 165% even after partial meniscectomy.[7] The clinical outcomes have been lower when compared to meniscal repair.[8] The possibility of cartilage destruction after meniscectomies in younger age group is detrimental and can cause significant morbidity. Of highlighting importance is that the partial meniscectomies have had no significance over sham surgeries.[9] Furthermore, there have been studies which indicate that meniscal repair should be performed wherever possible regardless of age.[10]

Radial tears/oblique tears treated with all inside techniques have favorable outcomes. There have been isolated studies reporting exclusive on radial tears treated with all inside technique. Successful treatment and prevention of progression to joint degeneration was studied by Furumatsu et al.[11] The risk factors for a poor outcome following all inside repair was obesity and complex tears.[12] Overall, the all inside technique was associated with a 15% failure rate Although technically less demanding, the cost of the device has been prohibitive especially in the developing world.

Different suture configuration has been described in the recent past with varying success.[13,14]

The inside out techniques are comparable to that of the all inside techniques. Various modifications have been made. The healing rates and good outcomes were reported by Logan et al. in elite athletes who were followed up for a period of minimum five years follow up study[15] Although a successful procedure, there have been wound related complication over the over the thigh and multiple suture bites over the oblique flap. To address this issue, the authors have described the crown feather technique which aim to minimize meniscal trauma. A potential limitation to this report is that a second look arthroscopy to evaluate the healing could not be performed and further studies will be required to validate our hypothesis to understand the long-term results and complications. The pearls and pitfalls of this technique has been highlighted in Table 1.

4. Conclusion

Inside out meniscal repair techniques preserve the remaining menisci and halts the cartilage degeneration. The device cost for all inside repair remains prohibitive. The inside out technique is a skill necessary for the knee arthroscopist and our technique can aid in minimizing meniscal trauma. We encourage further researchers to employ this technique and highlight the meniscal healing rates associated with this technique.

Table 1
Pearls and Pitfalls of Crown feather stitch.

Pearls	Pitfalls
1. Flap tears occurring in the anterior horn, and body are amenable for repair.	1.Posterior horn tears are not amenable for repair.
2. Avoids the need of meniscal debridement of WW Zone tears.	2.Chances of suture tangling if not appropriately placed
3. Minimal meniscal trauma as it involves a single prick on the meniscal flap Fragment.	3.Technical expertise

Credit author statement

Santosh sahanand was involved in idea, design and video technique, Ganesh kumar and Munis ashraf was involved in review of literature, manuscript preparation and final proofing, David V Rajan was involved in the idea, design and final proofing of the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jajs.2021.07.001.

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Case report

Hip arthroplasty in acetabular and ipsilateral neck femur fracture with central dislocation of femoral head -a rare floating hip injury

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ABSTRACT

A "floating hip" injury is a very rare presentation with an incidence of around 1 in 10,000 fractures. The combination of floating hip with a centrally dislocated femoral head makes the management even more challenging. Conservative treatment has no role except that in unfit patients and surgical treatment has no standard protocol. Literature suggests both internal fixation and arthroplasty as options depending on the acetabular congruity as well as the future chances of avascular necrosis of femoral head. Treatment has to be tailored according to the situation. We encountered one such difficult case which was managed by a combination of both internal fixation and arthroplasty as staged procedure and would like to show our experience which yielded good result and patient satisfaction.

1. Introduction

A "floating hip" injury—a fracture of the pelvis or acetabulum with a concomitant fracture of the femur irrespective of the location is a very rare presentation with an incidence of about 1 in 10,000 fractures. The combination of an ipsilateral acetabular fracture with a displaced femoral neck fracture with protrusion of separated femoral head fragment is an even rarer presentation. To the best of our knowledge only three cases of such injuries have been described so far and there is paucity in literature regarding the management of such cases. The treatment of such injuries remains challenging and poses surgical dilemma for the team. Here we present one such rare case following a road traffic accident and the challenges we faced while addressing all the fractures.

2. Case history

Our case is that of a 65 yrs. old male who sustained injury to his right hip following a road traffic accident. He had signs of local contusion with externally rotated and shortened right lower extremity with no movements permissible at hip and with no neurological deficit distally. An urgent Plain radiograph and 3D reconstructed CT scan of the Pelvis with bilateral hips (Fig. 1) showed evidence of a severely comminuted anterior column fracture (Letournel and Judet Type D) of acetabulum with fracture neck of femur with central dislocation of femoral head (right side). Since it was difficult to achieve a congruent weight bearing acetabulum with a vascular femoral head in a 65 yrs. old patient with multiple co-morbidities, a two stage procedure was planned.

The first stage utilised modified Stoppa's approach with a lateral window to expose the whole of comminuted anterior column along with the quadrilateral plate region. The protruding head of the femur lying in the pelvis was delivered out of the fractured quadrilateral plate into the pelvis (Fig. 2) and sent for storage in bone bank for possible use as autograft in stage 2. A lateral window with an anterior superior iliac spine osteotomy was used for better Iliac exposure. The fractures were fixed using multiple reconstruction plates. Postop Plain radiographs showed well reduced acetabulum with absent femoral head (Fig. 2).

Stage 2 (Fig. 3) was done at 04 weeks utilizing a posterior southern approach. The posterior column was found to be intact and anterior column was healing with fracture fragments well stabilised by earlier fixation. Acetabulum was reamed as usual. Femoral head bone autograft was morselized and used to fill the bony defects in the acetabulum. A Burch Schneider reinforcement cage (Fig. 4) was used to ensure a good pelvic support. Acetabular polyethylene inlay (Cup) was placed over the cage and fixed using bone cement. After acetabulum, the uncemented femoral

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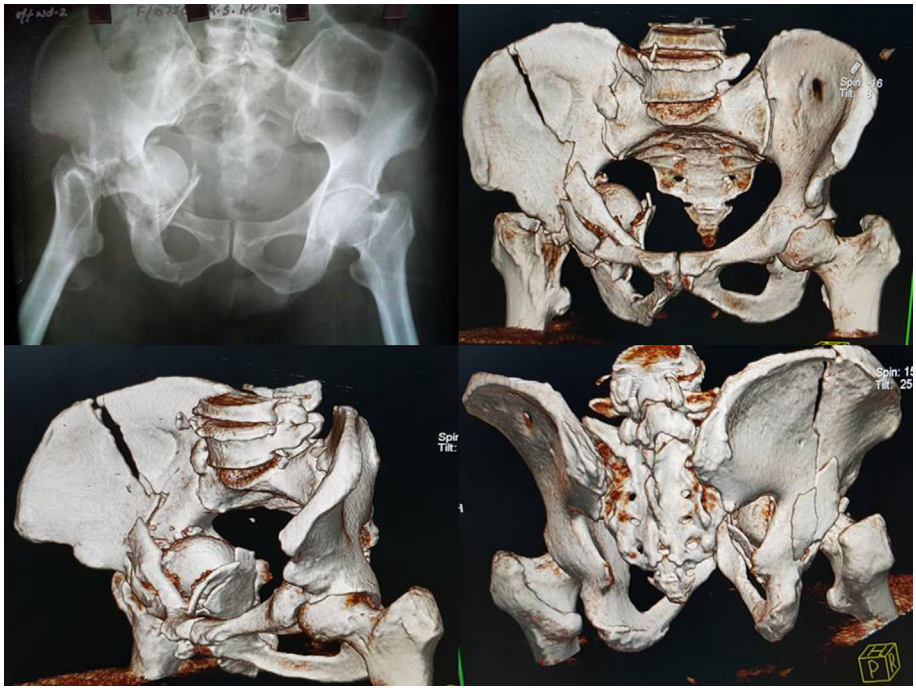

Fig. 1. Plain radiographs and 3D reconstructed CT scan shows severely comminuted fracture of anterior column of acetabulum with ipsilateral fracture neck of femur with central dislocation of femoral head. (Source: original photo).

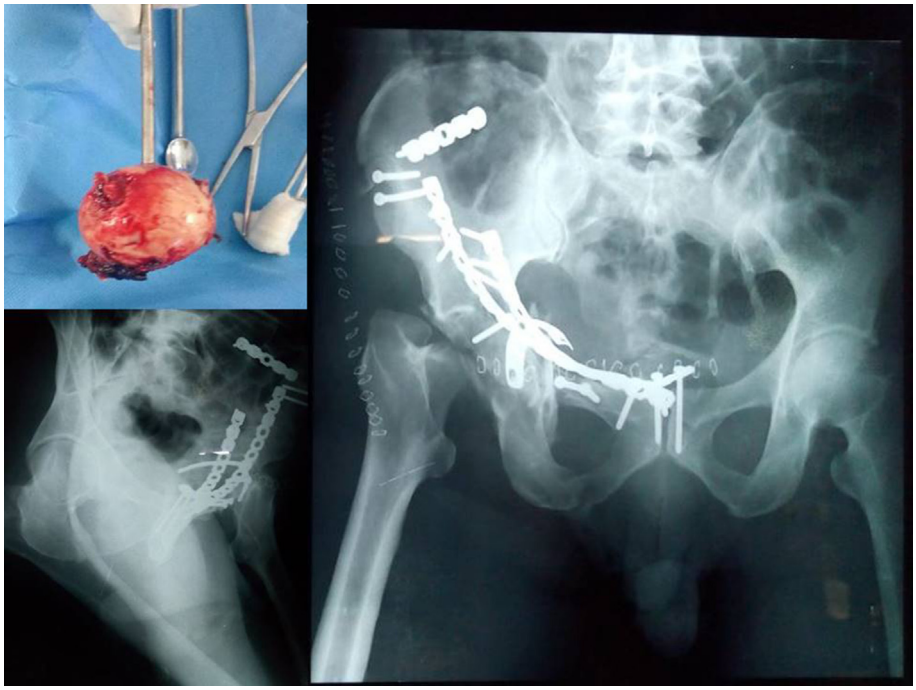

Fig. 2. Stage 1 post op Plain radiograph showing Internal fixation of acetabulum fracture and absent femoral head (Source: original photo).

component 'Zimmer Versys FMT' (Fig. 4) insertion was the same as that of a routine hip arthroplasty. Post op plain radiographs (Fig. 5) showed a well reduced hip prosthesis resting on reinforcement cage. Hip range of motion exercises were started from day 1. Non weight bearing ambulation with walker was allowed as soon as the patient became confident in standing with support. Patient had no neurovascular deficit postop. The patient was followed up regularly at 02 weeks (Stitch removal), 06 weeks, 03 months, 06 months and 01 year. The follow up plain radiographs showed a well-placed and reduced hip (right side) with healing of fracture acetabulum. There was no evidence of any collapse of acetabulum column or floor. Last time patient was reviewed at 12 months post-surgery with plain

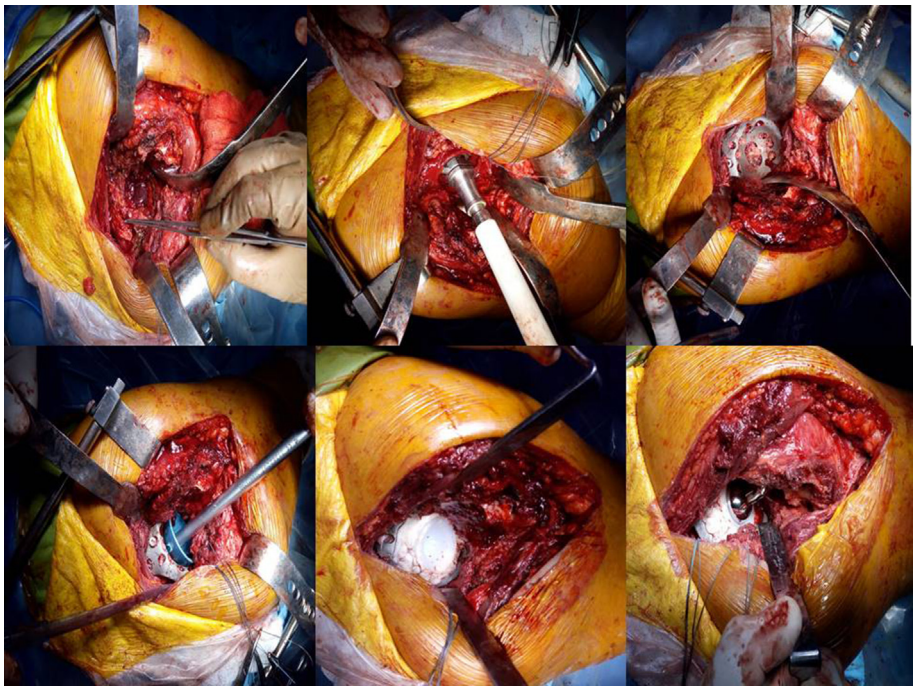

Fig. 3. Intraoperative Photos of stage 2 showing various stages of hip arthroplasty using cage. (Source: original photo).

Fig. 4. Burch Schneider cage and femoral stem used in hip arthroplasty. (Source: original photo).

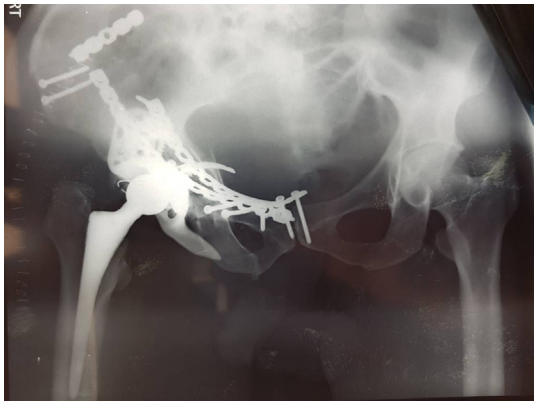

Fig. 5. Postop Plain radiograph after stage 2 showing well seated hip prosthesis with reinforcement cage in situ. (Source: original photo).

radiographs (Fig. 6). He has been living a pain free life and ambulant with a single walking stick as a measure of precaution (Fig. 6).

3. Discussion

The Floating hip injury has been described by M Liebergall et al.[1] as a fracture of the acetabulum and ipsilateral femur irrespective of location. The satisfactory treatment for these fractures remain challenging as open reduction and internal fixation has been associated with high prevalence of post traumatic arthritis and avascular necrosis of femoral head. These are extremely rare injuries. A large study by Wei L et al.[2] done over 18 yrs. found only 8 out of 502 acetabular fractures associated with ipsilateral fracture neck of femur (floating hip). Only 5 out of those 8 floating hip had dislocation of femoral head.

Even rarer are the fractures of acetabulum with ipsilateral fracture neck of femur with central dislocation of femoral head. To the best of our knowledge only 03 such case report exists as cited by Meinhard et al.,[3] Higgs et al.[4] and Mestdagh et al.,[5] but these too also were different from the experience we had.

In a young patient it is accepted that all attempts should be made to preserve the femoral head; by reduction of the femoral neck fracture under direct vision and rigid internal fixation. This method was employed by Meinhard et al.[3] Where possible the congruity of acetabulum should be restored. But the Wei L et al.[2] study showed that all the 5 patients with hip dislocations had developed AVN of femoral head and recommended of considering acute THR as primary treatment in such complicated injuries. Maintaining acetabular bone stock and achieving accurate reduction is vital for better long-term results as has been shown by many studies of Matta et al.,[6] Letournel E et al.,[7] Judet R et al.[8] Mears DC et al.[9] found that outcome after early fixation and late hip arthroplasty is predictably poor in patients with osteopenia, articular

Fig. 6. Follow up Plain radiograph of Pelvis – AP view at 01 year shows a well seated hip with no evidence of medialisation or collapse. Patient can be seen standing with the help of a support. (Source: original photo).

surface comminution and femoral head impaction.

Use of acetabular ring and cage is well known in acetabular fractures, be it for primary early hip arthroplasty or delayed hip procedure. We used Burch Schneider cage with autologous bone grafting similar to Tidemark et al.[10] to fill and augment the central defect.

In our experience single stage total hip replacement or fixation with THA in such difficult injuries would be challenging as the primary THA with unstable and displaced fracture fragments will certainly require a support like Burch Schneider cage which will also require a large bone graft because of acetabular quadrilateral plate and column defect. And any fixation with THA would make it an extremely demanding and lengthy procedure which may add to the surgical assault post trauma and can have disastrous results. Staged procedure however acts like a damage control as it allows the soft tissue to recover as well as prepare the acetabulum for a stage 2 arthroplasty which becomes much easier thru posterior approach.

Floating hip injuries gives very limited options to regain satisfactory function of the joint. Conservative approach probably has no role except in circumstances where patient is not fit for surgery. The rest of the cases will require open reduction internal fixation or primary hip arthroplasty or both depending on the type of injury. We presented an unusual and rare case of a floating hip injury which is one of its kind.

Patient declaration statement

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 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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Presentation at a meeting

Nil.

Contribution details

Dr Amresh Ghai: Concepts, Design, Manuscript review, Dr Lalit M Gupta: Definition of intellectual content, Literature search, Data acquisition, Formal analysis, Manuscript preparation, Manuscript editing, Guarantor

Declaration of competing interest

Nil.

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