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3. The interviews are slated for 22nd June during ISKSAA GLOBAL SUMMIT LEEDS UK 2018 in Leeds , UK .
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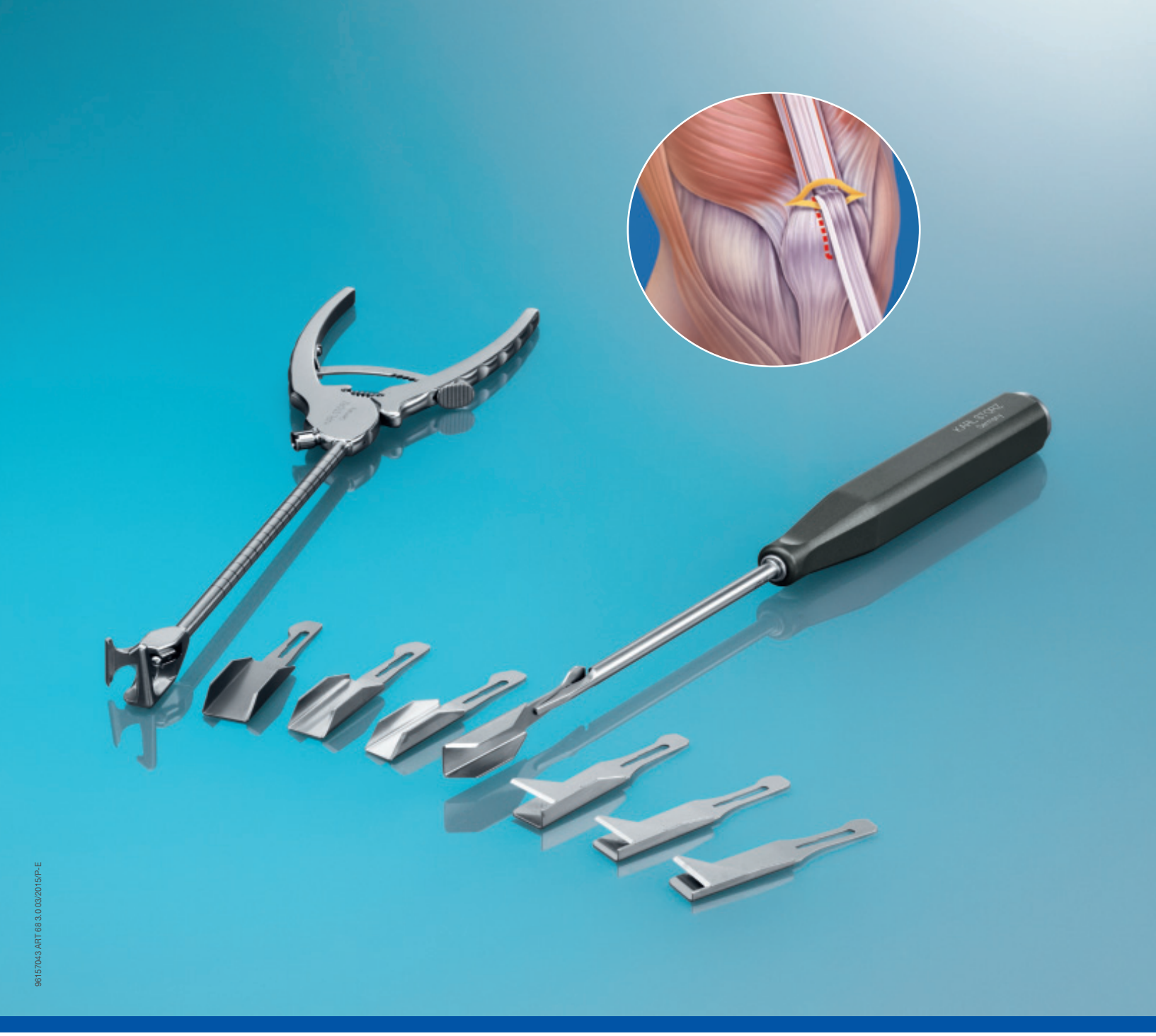

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Aims and Scope

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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Editorial

Simsalabim**—Simulation in (Orthopaedic) training

Recently, on a day of 'Open Doors' at the University Hospital I am working at, we showed the newly built surgical theatre to the public. Many visitors strolled through the rooms and were impressed by the technology which was on display.

An arthroscopy simulator (knee, shoulder) was on display. And it created interesting discussions with the audience. Some were potential patients. After the demonstration one visitor said:

'Let the trainees work on simulators before they touch my knee – and everything will be fine'

Really?

Teaching and learning is a complex task. Especially in technical professions.[2,6,7,9]

Simulation is standard in teaching and training of many professions which do require specific skills – and in which failure to master those skills may result in costly and life-threatening disasters: Airline pilots, train drivers, captains of cargo ships and oil tankers, nuclear power plant controllers, as a few examples.

It is not yet standard in medical education. Some exceptions are known, however.[11]

All the professions mentioned above do heavily rely on simulation based training. As early as 1910 the first 'simulators' were utilized in aviation pilots training.

In avionic simulators normal interpersonal functioning in the cockpit as well as any imaginable disasters and catastrophic scenarios can be trained and can be repeated as many times as necessary; until the trainee and/or his group are able to master the complication.

Airline pilots are re-certified at pre-defined time intervals and recertification does take place on simulators.

Simulator training is a well established part of the structured training and re-evaluation procedures. This is in contrast to most surgical specialties in most countries of the world,

Shouldn't we introduce more formalized simulator training in orthopaedic surgery?

Actually simulation based training has a long history in orthopaedic and trauma surgery, Since 1958 the AO (Arbeitsgemeinschaft Osteosynthesefragen) has revolutionized fracture treatment by standardizing surgical procedures and by training numerous surgeons on plastic bones.[5] A crude simulation, sure. However it helped to get similar level of expertise worldwide. Training programs were clearly structured and are now being offered worldwide.

One procedure, one standard.

Today's trainees – and their teachers – are faced with several problems:

- Exposure to cases: Due to work-hour regulations in most countries of the world the trainees do get less exposure to actual surgical tasks than ever before.
- Patients expectations: Patients are today more aware of quality in surgery and they do less and less accept to be (mis)used as a training object for young trainees.
- Health care costs: There is increased pressure on health care providers to optimize any procedures. Hospital authorities do make every effort to streamline surgical procedures and to minimize any extra time on any surgical procedure. There is less and less time for teaching at the bedside, or as in our case, at the OR-Table. The procedure has to be completed as quickly and as efficient as possible.

Surgical simulation has shown to be able to give a solution to the problems mentioned above.

However: Simulation has to be tightly incorporated into a very well structured training program for trainees.[13,14] Intermediate and final (surgical skill) goals have to be outlined. Standards have to be defined. Simulation shall no longer be a nice 'add-on' to the curriculum but has to become an essential part of young surgeon's training – well supervised and regularly evaluated.[1,12]

And simulation may well become the most important tool for re-certification of our surgeons. To the safety and well-being of our patients.[3]

Newer technologies will evolve in simulation. There will be soon possibilities to train today on the virtual knee of the patient whom you will operate on tomorrow, based on the MRI the patient will present. Special haptic feedback will provide even more realistic simulations of arthroscopies of shoulders, knees, hips, ankles etc. 3D imaging will become even more realistic.[3,8,10]

However no simulation will be getting you to become not only an average surgeon but to become a very good surgeon. There is a

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parallel statement from the airline industry (Fred George) *Sim training has long been recognized as essential to safety of flight. It's so rigorous, it's almost gained the stature of a professional rite. But sim training alone does not guarantee you have all the knowledge and skills to be truly safe in the cockpit.*[4]

Let's get our trainee to the simulators.

And let's get our training curriculae be adapted accordingly.

Simsalabim**[1].

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[1] **Sim Sala Bim: Codeword used by magicians, after Ali Sim-sala-bim, a desert wanderer and a magician.

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Review article

Shoulder arthroplasty—Past, present and future

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ABSTRACT

Shoulder arthroplasty is one of the most successful procedures to treat end stage arthritis of glenohumeral joint. It was popularised and pioneered by Dr Charles Neer around 50 years ago but the indications, implant designs as well as techniques for performing this procedure are continuously evolving. Amongst all orthopaedic joint replacements, it is the most rapidly growing with a seven fold increase envisaged over the next 15 years. This article discusses the evolution, current trends and the future direction of shoulder arthroplasty.

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1. Introduction

Shoulder arthroplasty is one of the most successful procedures to treat end stage arthritis of glenohumeral joint. It was popularised and pioneered by Dr Charles Neer around 50 years ago but the indications, implant designs as well as techniques for performing this procedure are continuously evolving. Shoulder arthroplasty is the most rapidly growing procedure amongst all orthopaedic joint replacements with a seven-fold increase envisaged over next 15 years. This article discusses the evolution, current trends and the future direction of shoulder arthroplasty.

2. Indications

Shoulder arthroplasty is indicated for Primary as well as secondary glenohumeral arthritis, inflammatory arthropathy (rheumatoid arthritis), osteonecrosis, post-traumatic arthritis, cuff arthropathy. It is also increasingly used for proximal humeral fractures. The two main types of shoulder arthritis are glenohumeral arthritis and rotator cuff arthropathy. These two conditions completely differ in terms of biomechanics as rotator cuff is mostly preserved in pure glenohumeral arthritis, whereas in the cuff deficient shoulder the humeral head subluxes superiorly due to unopposed deltoid force causing it to articulate with undersurface of acromion. Patients with glenohumeral arthritis usually require an anatomical replacement, whereas the patients with cuff arthropathy require reverse geometry shoulder replacement. Combined data from national arthroplasty registries to cover

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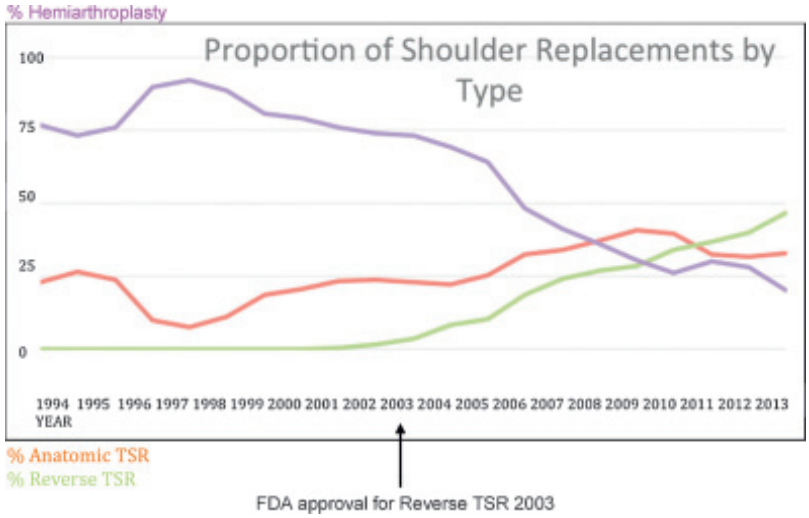

Fig. 1. Shoulder Arthroplasty Trends: Combined data from international shoulder registries- Presented at the Wrightington Arthroplasty meet March 2016. (E Griffiths, P Monga).
% Hemiarthroplasty FDA approval for Reverse TSR 2003.
% Anatomic TSR.
% Reverse TSR.

the period from 1994 to 2003 are depicted in Fig. 1 and reveal the changing trends over the recent years. It can be seen that since FDA approval of Reverse geometry TSR in 2003 there has been dramatic rise in the use of reverse TSR, where as the use of hemiarthroplasty has steadily declined and the anatomic TSR has remained the same. The resurfacing arthroplasty has steadily declined in popularity.

The American Academy of Orthopaedic Surgeons now recommends Total Shoulder replacement over hemi-resurfacing arthroplasty for glenohumeral arthritis.[1] The demand for shoulder arthroplasty is projected to increase by 755.4% by 2030.[2] Such an increase is not only related to improvement in prosthetic design, but also represents the influence of training. Surgeons with Fellowship training in shoulder surgery are more likely to perform total shoulder replacement over hemiarthroplasty for glenohumeral arthritis.[3] It has also been noted that fellowship trained surgeons are 5 times more likely to use arthroplasty for fractures and 20 times more likely to use a reverse polarity shoulder replacement.[4]

The exact reason for decline in resurfacing is difficult to explain. However there is growing evidence to show that long-term results of TSR are better than hemi-resurfacing arthroplasty for pain relief, range of motion and patient satisfaction.[29] The notion that the resurfacing will have advantage of preserved bone stock in a younger patient has to be weighed against potential glenoid erosion due to resurfacing making further revision surgery more challenging and difficult.

3. Evolution and design

The first recorded shoulder arthroplasty was carried out by Jules-Emile Péan in Paris in 1893 for a patient with tubercular arthritis. His prosthesis was made of rubber head and platinum stem. This prosthesis was removed at 2 years for persistent tubercular infection.[5] Thermistocles Gluck (1853-1942) was a Romanian surgeon working in Germany. He is widely credited as the first arthroplasty surgeon. He implanted Ivory prostheses in wrists, elbows, shoulders, hips, knees and ankles during 1880s.[6] However his results were not published and fate of these prostheses remains unknown.

The first generation humeral Implants were mono-block implants. In 1950, Krueger performed first modern shoulder arthroplasty with an anatomic shaped humeral implant for a patient with osteonecrosis.[7] Dr Charles Neer pioneered the modern era of shoulder arthroplasty. His mono-block stem was designed for proximal humeral fractures and such a prosthesis was in use from 1953.[8] It was in 1974, that he implanted the first Total shoulder replacement for glenohumeral arthritis.[9] Neer's original prosthesis had single fixed humeral head with variable stem diameters. But this was modified to articulate with glenoid resurfacing and 2 head size options were available in mono-block stem.

The second-generation humeral implants incorporated the concept of modular humeral head sizes and coating for bone ingrowth. Modular heads with different radii of curvature were available. These head components were articulated with the stem through a Morse taper mechanism. It was also possible to alter the height of prosthesis due to different length of stem sizes. Based on the hip joint implants some designs incorporated a collar at the neck of the stem to aid stability when resting against the calcar. These second generation implants, however, did not cater to normal proximal humeral anatomy.

The third generation humeral implants were modeled on anatomic study of proximal humeri. They allow for variability in humeral head diameter, articular surface thickness, inclination, retroversion, posterior offset, medial offset.[11] These components are commonly referred to as anatomic or adaptable. Boileau et al. in an anthropometric study defined these parameters of proximal humerus. According to this study the diameter of curvature of articular surface of humeral head is measured in both the coronal and axial planes. The articular surface diameter is defined as the diameter of articular surface at the level of margin of cartilage (in both coronal and axial planes). The articular surface thickness is defined as perpendicular distance from articular margin to the apex of the diameter of curvature. The inclination angle is the angle between proximal metaphysical axis and that perpendicular to the articular margin plane. The retroversion angle is the angle between a perpendicular to articular margin plane and the trans-epicondylar axis. The medial offset is the perpendicular distance between axial plane containing the center of epiphyseal sphere and the central axis of metaphysical cylinder. The posterior offset is the perpendicular distance between coronal plane containing center of epiphyseal sphere and the axis containing the central axis

of metaphysical cylinder. The hinge-point distance is the distance between axial plane containing the axis of the cylinder and the upper border of the articular surface. This study proposed the new concept of prosthetic adaptability in shoulder arthroplasty that allows the correct placement of the prosthetic head, with restoration of normal glenohumeral anatomy and shoulder joint kinematics.[10] These humeral prostheses are anatomic (adaptable) and adapt prosthesis to patient rather than vice versa (Fig. 2).

One can say that currently we are in the era of fourth generation humeral implants, which are platform based. Such systems allow for conversion from anatomic to reverse geometry shoulder replacement without a need to exchange the humeral stem.

There is a wide variety of choice available in context of humeral component design and fixation, ranging from resurfacing of the humeral head to metaphyseal bearing implants, short stemmed implants and classic stemmed prosthesis. Both cement fixation, press-fit fixation and bone ingrowth/on-growth have been used successfully in humeral component fixation. Cemented fixation of humeral component offers immediate stability, is associated with low rate of mechanical failure and allows better implant positioning in osteoporotic bone, proximal humeral fractures and deformity. It also allows addition of antibiotic to prevent infection.

Stemless humeral implants were introduced in clinical practice since last 14 years. They are designed to be implanted in humeral metaphysis with cementless fixation with some form of anchorage. This concept seems quite attractive in younger patient with good bone stock where this type of implant will preserve bone for subsequent revision surgery. The stemless humeral component would be beneficial in cases of proximal humeral deformity (malunion) where a conventional stemmed implant may not be appropriate. The violation of medullary canal is avoided, as well with stemless implant that may have implications in future revision surgery where a risk of humeral shaft fracture would be minimal. However long-term studies are lacking and we need more data to confidently advocate the use of these implants in routine clinical practice.

Neer implanted his glenoid component for glenohumeral arthritis in 1974. This was a keeled, rectangular metal backed prosthesis cemented on a congruous articular surface.[9] Since then various design changes have taken place to improve the component survivorship. The surgeon carrying out shoulder replacement needs to understand the key concepts involved in glenoid design including the back surface shape & convexity, conformity and fixation technique.

Convex back design is bone conserving, resists shear forces and is associated with less radiolucent lines on long-term follow-up. Anglin et al. carried out laboratory testing and recommended that glenoid component loosening can be reduced by having a non-constrained, non-conforming, curved-back design with macro-structure on the cemented surface.[12] Szabo et al. compared flat-back and curved back glenoid components and concluded that though radiolucency was present in all implanted prostheses, flat-back glenoid components were significantly worse.[22] Iannoti et al. conducted a Finite Element Analysis and concluded that curved-back glenoid components are less susceptible to malposition-related failure modes.[28]

The articulation between glenoid and humeral head components can be conforming or non-conforming. This articular conformity commonly known as radial mismatch is defined as difference in curvature between humeral head component and glenoid component. The implants having a reduced radial mismatch have greater conformity but are at risk of increased constraint and are at risk of limiting humeral head translation during movement. This leads to increased shear forces leading to edge loading and hence compromising the fixation. In contrast, less conforming implants with larger radial mismatch allow grater humeral head translation but have a lower surface area that can lead to increased wear, polyethylene fracture and instability. The optimal radial mismatch is considered to be between 6–10 mm diameter.[13]

For cemented glenoid component fixation technique the common types of fixation method are keeled, pegged and fluted. There is still a debate as to the best fixation technique and the evidence is limited in terms of superiority of one design over the other. Nuttall et al. carried out a RSA study to compare fluted vs. pegged glenoids and concluded that both components migrated by RSA, but fluted components had rotation in 3 planes and migrated at a greater rate.[14] Gartsmann et al. carried out a prospective randomised study to compare pegged and keeled glenoids and reported radiolucent lines in 39% keeled components and only 5% pegged components at 6 weeks after surgery.[15] Such choice is currently guided by surgeon preference and training.

Glenoid component can be cemented or non-cemented. Boileau et al. in a study of 40 shoulders compared outcomes of cemented vs. metal back glenoids.[16] They stated that the incidence of implant loosening requiring revision surgery was significantly higher in

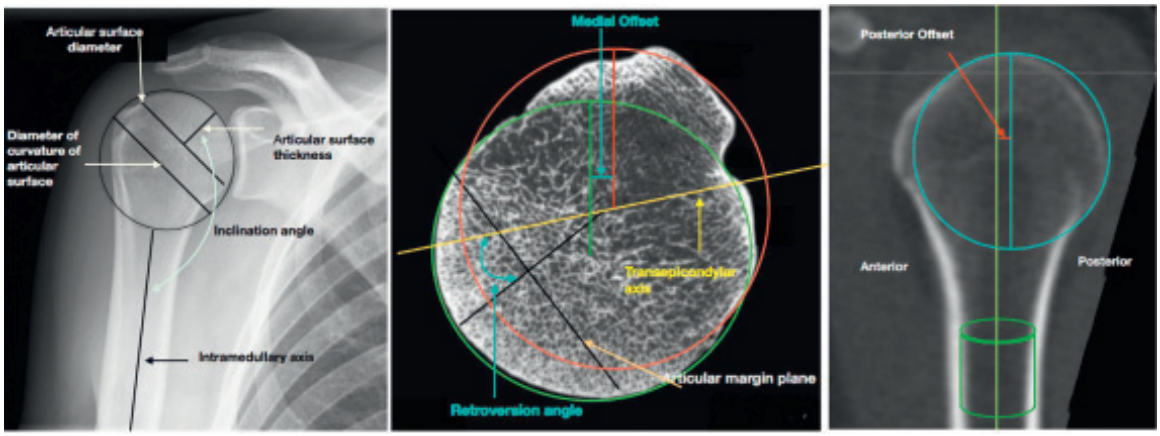

Fig. 2. AP, Axial and Lateral views showing parameters of proximal humerus.

non cemented (metal back) group. The primary modes of failure for metal-back glenoids are insufficient polyethylene thickness, excessive thickness of component that in turn over-tensions the rotator cuff, rigidity of component that accelerates polyethylene wear and stress-shields the glenoid bone and posterior/eccentric loads on glenoid that lead to polyethylene dissociation.

4. Complications and survivorship of anatomic TSR

In a recent current concepts review, Bohsali et al. have studied complications of shoulder arthroplasty. According to this review the most common complications following anatomic TSR are component loosening (4%), glenoid wear (2.3%), instability (1%), rotator cuff tear, periprosthetic fracture, neural injury, infection, haematoma, deltoid injury and VTE. It can be seen that glenoid component wear and loosening remain a common cause of failure after anatomic TSR, despite advances in surgical technique and implant design. Even though radiological loosening around the humeral component has been in 49% of shoulders in this review, this was asymptomatic.[21]

Torchia et al. reported on long-term results of Neer prosthesis in patients with osteoarthritis, rheumatoid arthritis and post-traumatic arthritis. They reported 93% implant survival after 10 years and 87% implant survival at 15 years. Relief of moderate to severe pain was reported in 83% shoulders in this series with improvement in active abduction by an average of 40 degrees to average of 117 degrees. They reported bone-cement radiolucencies in 75% glenoid components and 44% definite radiologic loosening of glenoid components.[24] Sperling et al. reported on 15 year follow-up of Neer Hemiarthroplasty and TSR in patients 50 years or younger. In this study the survival of TSR was 97% at 10 years and 84% at 20 years. It was noted that humeral periprosthetic lucency was present in 60% of patients with TSR and glenoid periprosthetic lucency was present in 76%. The hemiarthroplasty survival was 82% at 10 years and 75% at 20 years. Glenoid erosion was present in 72% patients with hemiarthroplasty. According to this study there was no significant difference between TSR and hemiarthroplasty with regard to pain, relief, abduction or external rotation.[23]

5. Reverse geometry shoulder replacement

Neer recognised that cuff arthropathy patients did not do well with standard arthroplasty. He designed the Mark I (Reverse geometry) prosthesis with large head but this prosthesis did not allow for cuff repair. The Mark II was designed with smaller head but had a disadvantage of increased excursion and motion. He came up with Mark III with axial rotation to gain movement however dislocation and scapular fixation were major concerns and this prosthesis was abandoned. There were similar attempts by Reeves (Leeds shoulder prosthesis, 1972), Beddow and Elloy (Liverpool prosthesis, 1975), Beuchel (1978) and unfortunately none of these had reproducible survivorship. The most successful design introduced in 1985 by Paul Grammont, the Delta prosthesis, forms the basis of current generation of reverse geometry shoulder implants.[17] His implant differed from early designs by making the implant stable, the weight bearing component (glenoid) was convex and supporting humeral articulation was concave, the center of weight-bearing sphere must be at or within glenoid neck and the center of rotation (COR) was to be medialised and distalised.

In contrast to the anatomical Total shoulder arthroplasty, where there is a radial mismatch between humeral and glenoid components to allow for translation and rotation, the glenosphere and humeral component socket in a reverse geometry TSR have exactly same radius of curvature. This results in a concentric motion arc. Newer designs of implants have larger convex component allowing for greater range of motion before impingement occurs, and such a large diameter also increases the stability of the construct.

According to Grammont's principle, the center of rotation of reverse geometry shoulder replacement is medial to anatomic center of rotation (COR). This results in recruitment of more deltoid fibers and also reduces shear forces on glenosphere. Based on this theory the center of rotation should be at implant-bone interface of glenoid. This medialisation of COR however, has been associated with scapular notching, reduction of range of movement of shoulder and leads to a loss of shoulder contour. In the early designs of the reverse shoulder replacement, scapular notching was a significant concern. Scapular notching results from mechanical impingement of superomedial humeral prosthesis against the inferior scapular neck during adduction. Levigne et al. retrospectively reviewed 448 patients who received Grammont type reverse geometry shoulder arthroplasty (461 shoulders) for cuff tear arthropathy and noted scapular notching in 68% of cases. Scapular notching can be avoided by inferior placement of glenoid component, increasing the lateral offset, inferior inclination of glenosphere and varus position (varus neck-shaft angle) of humeral socket.[18,19] Design changes in the humeral component with a relatively steep neck angle (135° compared in new designs compared to 155 degrees in convention humeral sockets) reduce scapular notching as well.

6. Complications and survivorship of reverse geometry TSR

Bohsali et al. [21] have reviewed complications of reverse geometry TSR. According to this study the main complications following reverse geometry TSR are instability (5%), periprosthetic fracture (3.3%), infection (2.9%), component loosening (1.8%), neural injury (1.2%), acromial and/or scapular spine fracture (1%), haematoma, deltoid injury, rotator cuff tear, and VTE. It is noteworthy that this study has not mentioned scapular notching which was one of the most common complications reported in earlier results of reverse geometry TSR. This is because, as our understanding of this issue and biomechanics of reverse TSR has improved, newer designs of implants have been introduced that have reduced the incidence of scapular notching significantly. Bacle et al. have reported long term outcomes of reverse geometry TSR. In this retrospective analysis they found 73% patients had scapular notching. 12% of patients underwent revision surgery. The 10-year survival rate using revision as end point was 93%.[27]

7. The future of shoulder arthroplasty

It is evident that the glenoid has been the weak link in shoulder arthroplasty. It is often the reason for complexity of shoulder arthroplasty and also seen commonly as the reason for revision. As with most surgeries, avoiding complications relies on successful pre-operative planning. Hence, successful implantation of shoulder replacement relies on careful evaluation of glenoid wear pre-operatively in the first place. The most popular classification system for glenoid wear as been described by Walch et al. and further modified but Bercik et al. Using 3-D reconstructions of scapula improves the inter-observer and intraobserver reliability.[20] Indeed a pre-op CT scan and evaluation of glenoid bone loss are highly recommended.

3D printing technology offers a new age solution to assessment of glenoid bone loss. Modern desktop 3D printers allow printing of CT scan using additive manufacturing and provide exceptional 3 dimensional visualisation of bone defects. It is envisaged that such prints would be a routine part of pre-operative planning for complex and revision shoulder replacements. It is also now possible to create a negative image of such 3D models, which then

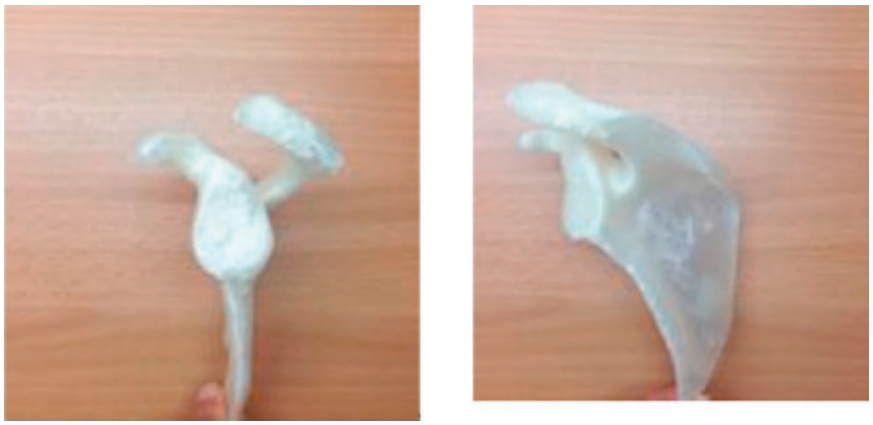

Fig. 3. 3D printed scapula.

serve as a intra-operative jig for placement of the initial glenoid guide wire. Such custom – made jigs increase the accuracy of glenoid placement and are likely to improve implant survivorship and function (Fig. 3).

Modern technology is also likely to help in management of the most challenging problems in shoulder arthroplasty involving glenoid bone loss. Currently, treatment strategies advocated for these glenoid defects include asymmetric reaming, bone grafting and posterior augments. It is now possible to manufacture custom made glenoid components, which match the deformity rather than making the bone to fit the implant. It is still early days for such revolutionary technology, however initial results observed by the senior author are promising. They offer a chance to reconstruct shoulder, which would otherwise not be suitable for such surgery (Fig. 4).

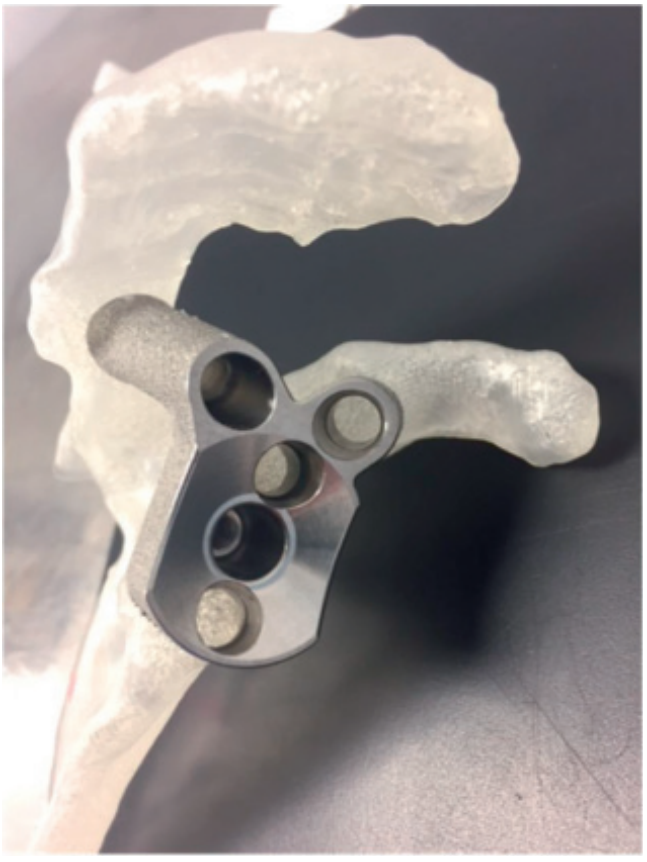

Fig. 4. Custom Made glenoid base plate.

The other area of development in future seems to be intra-operative navigation. The role of navigation is well established in in hip and knee replacement surgery. Kircher et al. carried out a prospective randomised study of 20 patients with osteoarthritis of shoulder treated with total shoulder arthroplasty with or without intraoperative navigation. They found improved accuracy in glenoid positioning in the transverse plane using intraoperative navigation.[26] However this study had very small number of patients and the group advocated larger study with longer follow-up to substantiate results. Such navigation techniques certainly hold promise and technological advances are likely to make them user friendly and more accurate in future.

There has been a rise in use of patient specific targeting instrumentation by shoulder surgeons in complex primary shoulder arthroplasty as well as revision surgery with significant bone loss especially on the glenoid. Throckmorton et al. compared the accuracy of patient-specific guides for TSR with traditional instrumentation in arthritic cadaver shoulders. In this study they found the TSR glenoid components placed with patient specific instrument guides averaged 5-degree deviation from intended position in version and 3° variation in inclination. However the TSR glenoids implanted with standard instruments averaged 8° deviation in version and 7° in inclination. These differences were significant for version ($p = 0.04$) and inclination ($p = 0.01$). They concluded that Patient specific targeting guides were more accurate and had fewer instances of component malposition for glenoid component.[25]

8. Summary

The design and outcomes of shoulder arthroplasty have dramatically improved since its inception in 1950s. There has been a steady evolution of shoulder arthroplasty design and surgery now offers consistent and reproducible outcomes and excellent survivorship. The reverse geometry shoulder replacement has proved to be a revolutionary technique for management of complex shoulder conditions, especially since the changes suggested by Paul Grammont. The key future challenge remains robust methods for managing glenoid bone loss and management of future increases in revision workload. 3D printing technology, patient-specific instrumentation, intraoperative navigation and custom made shoulder components offer promise for the future along with improvements in biomaterials but need to be rolled out with caution under carefully controlled clinical environments.

Conflict of interst

None.

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Review article

Manangement of ACL tear in paediatric age group: A review of literature

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ABSTRACT

The anterior cruciate ligament (ACL) is a stabilizing structure to both anterior translation of the tibia with respect to the femur as well as rotation of the knee joint. The incidence of ACL tears is rising in the pediatric and adolescent populations as these individuals succumb to traumatic and non-traumatic athletic injuries. Pediatric ACL injuries are typically seen in several forms: tibial avulsion fractures, partial ACL tears, and full thickness ligament tears. Management of this condition in the skeletally immature patient poses a challenge and is controversial.

Operative reconstruction carries the concern for damage to the physis with resultant limb length inequality and angular joint deformity but provides stability to the knee and allows return of function in most patients. On the other hand, nonoperative treatment has been shown to carry an increased risk of meniscal and articular cartilage damage. Several factors must be considered during pediatric and adolescent ACL reconstruction, including: status of the physis, reconstruction technique, and graft source.

This paper aims to address the natural course of ACL injuries in the skeletally immature patient, treatment options with associated complications, and current preventive strategies.

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1. Introduction

Anterior cruciate ligament injuries can be a devastating injury, with significant time lost from sport as well as potential degeneration of the knee in the future.[1] The treatment of anterior cruciate ligament (ACL) injuries has spawned a great deal of

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research. However, the majority of the literature on the topic deals with adults. Far fewer studies have focused on the management of this condition in the pediatric and adolescent patient. Consequently, the management strategy for ACL injuries in this population is not as clearly elucidated as it is for their skeletally mature counterparts.

There are several factors that can make treating a pediatric or adolescent ACL injury more challenging. Making an accurate diagnosis can be difficult as there is a spectrum of injuries including tibial avulsions, partial ACL tears, and complete tears, and there can be multiple barriers to performing an accurate examination in this patient population. If surgery is chosen, there is debate over the appropriate technique as well as graft choice. Finally, the pediatric and adolescent population may have difficulty adhering to a detailed rehabilitation protocol.

Historically, significant debate regarding the proper management of ACL injury in the skeletally immature patient has existed. Two basic options are available, surgical reconstruction and conservative management, each with their own potential sequelae. Theoretically, there has been concern that operative management would violate the growth plate resulting in concomitant growth disturbance and angular or rotational deformity of the limb.[2–6] Consequently, many patients have been treated conservatively via activity modification and bracing with postponement of surgery until skeletal maturity.[7–9] Yet conservative treatment is not without risk.

The prognosis of the ACL&HIPHEN;deficient knee in young active individuals is poor because of secondary meniscal tears, persistent instability and early-onset osteoarthritis. The aim of surgical reconstruction is to provide stability while avoiding physeal injury. Techniques of reconstruction include transphyseal, extraphyseal or partial physeal sparing procedures.

Several “physeal sparing” and “physeal respecting” ACL reconstruction techniques have been developed for use in skeletally immature patients to minimize the risk of growth disturbance, with favorable clinical outcomes. ACL injury prevention strategies include neuromuscular conditioning and may be performed to prevent both initial ACL injury as well as reinjury and injury of the contralateral ACL after reconstruction.In a recent systematic literature review, Vavken and Murray[10] identified only 1 study with level II evidence and 10 with level III evidence on this topic. This understates the need for further prospective studies on the subject.

This paper aims to discuss ACL tears in the skeletally immature patient, specifically focusing on the natural history, nonoperative management, operative management including complications, and prevention of these injuries.

2. History

Most commonly, ACL tears are non-contact injuries caused by a pivoting mechanism with the knee partially flexed and the foot planted.[11] A hyperextension of the knee with a valgus or rotational force has also been described. Patients will typically report an audible “pop” in the knee, followed by relatively quick (12–16 h) development of a hemarthrosis, and inability to return to sport. Weight bearing may be challenging initially, but typically is regained shortly after the injury.

In the pediatric and adolescent patient, the location of the ACL injury is an important determinant of management. Common in this population, tibial spine avulsion injuries, if nondisplaced, can be treated nonoperatively with satisfactory outcomes. However, displaced avulsion injuries require arthroscopic reduction and internal fixation.[12,13] Similarly the extent of the ACL tear is important to differentiate. Nonsurgical management of partial tears may yield acceptable results in this population when paired with a structured rehabilitation program. However, children and adolescents with greater than 50% tears of the ACL have been shown to have poor outcomes if not surgically reconstructed and may progress to a complete tear.[14]

3. Examination

In children with a history of trauma to the knee, radiographs should be performed first to rule out tibial eminence fracture. Once this has been ruled out, a more standard knee examination can be performed. While the Lachman maneuver has classically been the test of choice for examination of ACL, the pivot shift may actually be a better determination of whether the knee is stable and the ACL is functioning.[15] Patellar dislocations can mimic ACL tears, and thus patellar stability must be assessed. Also, a complete ligamentous examination should be performed.

4. Diagnosis

AP and lateral radiographs should be obtained to rule out any bony injury. Special attention should be used to assure a perfect lateral radiograph, as this is often the best way of evaluating for and classifying tibial eminence fractures. Examination in the acute setting may be difficult, and thus MRI may have a more important role in a child or adolescent with a traumatic hemarthrosis. While MRI can be a useful adjunct in making an accurate diagnosis with a complete ACL tear, reports have shown poor sensitivity of MRI in detecting partial ACL tears.[16,17] MRI can also be useful in diagnosis of tibial eminence fractures, especially non-displaced, type I fractures.

5. Management

5.1. Partial ACL tear

Partial ACL injuries should be treated based on the degree of instability in the knee. If the knee is grossly unstable with a positive pivot shift on examination, then reconstruction should be offered to the patient. In a patient where no pivot shift can be elucidated, a trial of non-operative care consisting of a physical therapy program as well as proprioception/neuromuscular re-education program can be prescribed.[11]

Partial ACL tears in patients with symptomatic instability that have failed conservative management can be taken to the operating room for an examination under anesthesia. The patient should be consented for and the surgeon should be prepared to perform an ACL reconstruction. A pivot shift should be performed with the patient relaxed to determine the status of the ACL. The remainder of the ligament examination of the knee should be performed, including varus and valgus stress testing at 0° and 30° of flexion, as well as dial testing at 0° and 90°. If there is a 2+ pivot shift, meaning a true shift is felt rather than a glide, the surgeon should proceed with reconstruction of the ACL.[18] Intraoperatively, if only 1 bundle of the ACL is disrupted, some authors are reporting excellent results with reconstruction only of this injured bundle.[11]

5.2. Tibial avulsion fractures

Type I, non-displaced, tibial eminence fractures are typically treated with cast immobilization, yet there is some disagreement amongst authors regarding the degree of flexion. During arthroscopy, one can see the ACL taking up tension as the knee is brought into full extension. Cadaveric work has found the greatest ACL tension at 0° or at 45° of flexion [19]; therefore, many authors recommend immobilization with casts at 10°–20° of flexion.[20–22] However, when each ACL bundle is examined independently, the

AM bundle seems to tighten at about 60° of flexion, and the PL bundle tightens with extension.[23] In type II injuries with small displacements, aspiration of the hemarthosis may aid in reduction. If adequate reduction is not achieved closed, surgery is then indicated.

5.3. Complete ACL tear

5.3.1. Nonoperative

For complete tears of the ACL, nonoperative treatment generally carries an unfavorable prognosis. It has been shown in numerous studies to lead to increased intraarticular damage in the form of meniscal tears and damage to the cartilage.[7,8] In a study of 39 pediatric and adolescent patients with an average age of 13.6 years at injury, Millett et al. retrospectively compared acute surgical reconstruction (less than 6 weeks from time of injury), to chronic reconstruction (more than 6 weeks after injury). A highly significant relationship was found between time to surgery and medial meniscal tears. 36% of patients in the chronic group sustained medial meniscal tears versus only 11% of acute group, which led the authors to support early operative intervention.[18]

Therefore, most pediatric orthopedic physicians would strongly recommend surgical reconstruction once the diagnosis of a torn ACL is made with confirmation of a pivot shift during the examination under anesthesia. This holds true even for the prepubescent athlete, as results of operative management has yielded excellent outcomes without angular deformity or growth arrest.[24]

Also, in a recent comparative study, Streich et al.[25] compared 28 children with intraligamentous tears of the ACL, of which 12 were treated nonoperatively and 16 operatively. All were Tanner stage 1 or 2 with a mean age of 11 years at time of treatment. Interestingly, the surgery group was selected to include only patients who had concomitant damage to the meniscus or articular cartilage. The nonoperative group included only isolated ACL ruptures. At a mean follow-up time of 70 months, the patients had grown an average of 20.3 cm with no evidence of leg length inequality or angular deformity in either group. However, the surgical group had significantly better clinical and functional results than did the nonoperative group. Additionally, 58% of the nonoperatively managed patients went on to require surgical intervention due to persistent instability.

Few studies have shown conservative management to be a viable treatment option. A recent systematic review found only 1 study that showed no increase in secondary intra-articular injury in conservatively treated patients in whom surgery was delayed until skeletal maturity.[10] The identified study by Woods and O'Connor[9] retrospectively compared two groups of adolescents with ACL rupture. One group of 13 adolescents with a mean age of 13.8 years at time of injury, presented with open physes. Surgery was delayed until skeletal maturity and performed at a mean of 70 weeks following injury. The other group of 116 adolescents had a mean age of 15.0 years at time of injury, presented at various time intervals after ACL rupture, and were skeletally mature on presentation. The skeletally mature group was not intentionally delayed and had a mean time interval from injury to surgery of 14.1 (0.3–355.1) weeks. No significant difference with respect to overall additional knee injuries, meniscal injuries, and articular cartilage injuries was noted between the delayed patients and the skeletally mature patients. The authors attributed the lack of additional knee injuries in the delayed group to strict adherence to nonoperative treatment including, complete abstention from sports activities and daily use of an ACL brace.

Another study by Moksnes et al.[26] examined ACL rupture in children 12 years of age and younger comparing 20 nonoperatively treated patients to 6 delayed reconstruction patients at a minimum of 2-year postinjury or postoperative followup respectively. Patients were classified as "copers," if they had returned to preinjury activity level and performed above 90% in all hop tests, or as "noncopers." Of the nonoperative group 65% returned to preinjury activity level and 50% were classified as "copers" at follow up. Only 9.5% of the nonoperative group suffered secondary meniscal injury. Based on the large number of "copers" in the nonoperative group and relatively low number of meniscal injuries, a treatment algorithm based on functional and patient subjective measures was suggested that could identify patients who could be allowed to participate in their desired activities until skeletal maturity when ACL reconstruction could be considered.

Due to the substantial amount of literature showing risk of further damage to the joint and recurrent instability requiring surgical intervention, prolonged nonoperative therapy for complete ACL rupture remains controversial. In addition, from a compliance standpoint, the pediatric and adolescent population will likely have significant difficulty with stringent activity restrictions. However, if nonoperative treatment is chosen, the protocol should include bracing of the affected knee, restriction of sports participation and other activities involving jumping and pivoting, and structured physical therapy and rehabilitation.[27]

5.3.2. Operative

The primary concern with ACL reconstruction in the skeletally immature patient is disruption of the tibial or femoral physis with resultant growth disturbance and deformity of the joint. Approximately two-thirds of the length of the lower extremity is derived from growth at the knee joint, specifically from the distal femoral and proximal tibial physes. The distal femoral growth plate is actually the largest and fastest growing physis in the human body accounting for roughly 70% of the length of the femur and 40% of the length of the entire lower limb.[28] Similarly the proximal tibial growth plate contributes 55% of tibial length and 25% of leg length. On average, the two growth plates add approximately 1 cm and 0.6 cm of length, respectively, to the lower extremity per year. They do so until final skeletal maturation takes place, usually between age 14–16 years in girls and 16–18 years in boys.[28,29]

Once the decision to proceed with operative intervention is made, several other decisions must be made. First, surgical timing must be discussed. Most surgeons would agree that ACL reconstruction should only be performed once full motion has been regained, unless in the setting of a tibial eminence fracture or a bucket-handle meniscus tear.[30,31] Recently a report of increased risk of meniscal damage with delay in treatment of greater than 12 weeks may indicate that these injuries ought to be treated more urgently, however.[32] Secondly, the reconstruction technique must be determined. For some authors, technique may be predicated on physeal closure status. Finally, the choice of graft must be discussed with the patient, and may partly be based on reconstruction technique chosen.

There are multiple techniques described, ranging from extra-articular reconstructions to all-physeal reconstructions to transphyseal reconstructions with various hybrid techniques described. Milewski et al.[33] proposed a treatment algorithm based on bone age. This algorithm recommends the Micheli-Kocher technique[34] for patients with a skeletal age of 6, the modified Anderson technique for skeletal age of 8, the Ganley-Lawrence All-Epiphyseal technique[35] for skeletal age of 10, a hybrid technique for skeletal age of 12, and a transphyseal technique for those of skeletal age 14 or older.

5.3.2.1. Transphyseal reconstruction. The transphyseal technique for ACL reconstruction is the standard operative method for treating adult patients. Consequently, when adolescents are nearing skeletal maturity, it is commonly accepted that they may be managed as adults. McCarroll et al.[36] reported good to

excellent results in a cohort of 60 athletes with a mean age of 14.2 years, using transphyseal ACL reconstruction with bone-patellar tendon-bone (BTB) graft.

Of note, BTB grafts are typically avoided in the skeletally immature patient as growth arrest can be induced from bone bridges resulting from insertion of the bony portion of the graft across the physis. For this reason, Kocher et al.[37] advocated the use of soft-tissue grafts in ACL reconstruction of skeletally immature pubescent adolescents. In their study of 59 patients with a mean age of 14.7 years, excellent functional results were reported with a low revision rate and minimal growth disturbance using transphyseal ACL reconstruction with autogenous hamstring grafts.

Transphyseal techniques have shown satisfactory results even in less mature patients. Mcintosh et al. described good clinical results and return to previous activity level in patients with wide open physes who had undergone transphyseal reconstruction. Even in Tanner stage 1 or 2 patients, two studies have shown satisfactory results with transphyseal procedures in patients with a mean age of 12.1 years and 11 years, respectively.[25] No growth disturbance was noted in either study, and only one patient was noted to have an angular deformity, which was not deemed to cause any functional impairment. When utilizing transphyseal techniques in these patients, of paramount importance is the avoidance of fixation devices or hardware crossing the physis.

A study by Shea et al.[38] found that even with anatomic ACL transphyseal reconstruction, the maximum percentage of disruption of the epiphysis was 8.8 %, which occurred when using a 9 mm tunnel, yet the mean for 9 mm tunnels was 5.4 %. On the tibial side, the maximum volumetric disruption was 6.6 % using a 9 mm tunnel, with a mean of 3.8 %. The femoral tunnel was more oblique, thus accounting for the difference, as the authors simulated independent tunnel drilling which allows the tibial tunnel to be almost completely round. The obliquity and the larger amount of physis disrupted was the rational for the development of the Lawrence-Ganley all-epiphyseal technique. Less anatomic and more vertical femoral tunnel placement also decreases the percentage of the physis disrupted. However, this may lead to restoration of less desirable knee kinematics. As the purpose of ACL reconstruction in the skeletally immature patient is to provide the patient a rotationally and translationally stable knee, anatomic ACL reconstruction may be more desirable than non-anatomic vertical tunnel positioning. That said, several studies have demonstrated that even the non-anatomic reconstruction to the over the top position with an extra-articular IT band augmentation can restore near normal knee kinematics[39,40] although 1 study found that this may overconstrain the knee.[40]

Transphyseal ACL reconstruction has been found to be safe by a number of authors.[41–45] In a multi-center study, Gebhard et al. found no difference between hamstring grafts, bone-patellar tendon-bone, quadriceps tendon, and fascia lata grafts in terms of outcomes, failure, or growth disturbance.[42] These authors also found that 66 of 68 patients returned to the same level of preoperative sport participation.

5.3.2.2. Physeal sparing reconstruction. As an alternative to the transphyseal approach, a number of physeal sparing techniques, both intra-articular and extra-articular, have been described. Theoretically, these techniques should minimize the risk of growth disturbance or angular deformity by avoiding violation of the physis. Though a number of retrospective studies exist with the majority achieving excellent results, there is a scarcity of prospective or comparative data that would advocate the superiority of one method over the other. One of the first to use a physeal sparing approach,Macintosh and Darby[46] in 1976 described good results using a portion of the iliotibial band looped around the lateral femoral condyle, through the knee and attached to the proximal tibial metaphysis distally to reconstruct the ACL. This technique has been modified by others for use in the skeletally immature patient. A recent systematic review identified 6 studies using modifications of this physeal sparing, extraosseous reconstruction technique, and showed no growth deformity at an average 47.3 month follow up in patients with a mean age of 12.1 years.[10] An all-epiphyseal technique was described by Guzzanti et al.[47] in which the tunnels were drilled through the distal femoral and proximal tibial epiphyses. 5 preadolescents (Tanner stage 1) at a minimum of 4-year follow up demonstrated excellent stability and no leg length discrepancy or angular deformity. Other studies have also shown all epiphyseal techniques to be safe and efficacious.[48] A hybrid of physeal sparing and transphyseal approaches, partial transphyseal techniques utilize only one tunnel through the physes thereby limiting, in theory, the possibility for growth disturbance. Several studies utilize this method, which has been described both with tunnels drilled only through the femoral epiphyses and with tunnels drilled only in the tibia. Both techniques have demonstrated satisfactory results.

Graft choice is somewhat dependent on reconstruction technique chosen. In the case of all-physeal or transphyseal reconstructions greater options may be present.

5.3.3. Complications

Growth disturbance and angular deformity after ACL reconstruction in the skeletally immature patient have been a primary area of concern for surgeons treating patients in this demographic. In animal studies, various technical factors have been associated with physeal injury and subsequent growth disturbance, including fixation of the graft near or across the physis,[2] increased tunnel diameter in relation to physeal diameter,[3,5] overtensioning of the graft[2], placement of bone blocks across the physis,[22] inadequate filling of the tunnels with graft material[23], and tunnel malposition. An extensive discussion of these technical aspects is beyond the scope of this review.

In a survey of The Herodicus Society and The ACL Study Group, Kocher et al.[4] identified 15 reported cases of growth disturbance/angular deformity in human patients.

The main factors associated with these cases were hardware fixation across the physis and spanning the physis with graft bone plugs. Large tunnel size was also associated with these undesirable outcomes. Though growth deformities have been clearly demonstrated in scientific studies using animal models, the vast majority of these reports in skeletally immature humans are from case studies and survey data[4]. Vavken and Murray[10] in their recent systematic review of ACL tears in the skeletally immature patient identified 31 studies (479 total patients) of ACL reconstruction with at least 1 transphyseal tunnel and noted only 3 angular deformities and 2 limb-length discrepancies.

They identified 6 reports (106 total patients) of extraphyseal reconstruction with no growth deformities described. In comparison, the same systematic review identified 12 articles (476 total patients) reporting nonoperative management with a mean of 50.2% of patients who required later surgical stabilization due to unstable knees with severe meniscal and cartilage damage.

When comparing operative techniques, few studies actually contrast the various operative procedures. In a recent review, Kaeding et al.[49] identified 13 case series of various ACL reconstructionmethods in 187 Tanner stage I, II, and III patients. They concluded that there was no clinical difference between transphyseal and physeal sparing techniques as both produced excellent clinical results in Tanner stage II and III patients with a very low incidence of growth abnormalities in either group. Due to a lack of studies in Tanner stage I patients, no firm conclusions could be reached regarding this patient subset. Frosch et al.[50] recently performed a metaanalysis of operative treatment in the skeletally immature

patient. This included 55 studies and 935 patients with a mean age of 13 years, and a mean followup of 40 months.

They determined the rate of leg-length discrepancy or axis deviation to be 1.8% (95% confidence interval [CI], 0%–3.9%). Also of note, transphyseal techniques were associated with a lower risk of leg-length discrepancy or axis deviation than were physeal sparing procedures (1.9% versus 5.8%;relative risk, 0.34; 95% CI, 0.14–0.81). The authors theorized that this phenomenon may have resulted from drilling close to the growth plate in the physeal sparing techniques potentially leading to heat damage and early closure.

5.3.4. Summary

Managing ACL tears in the skeletally immature patient is a complicated and at times challenging undertaking. Anterior cruciate ligament injury can present as tibial eminence fractures, partial ACL injuries, and complete ACL tears. Surgical treatment has led to improved results in those with displaced eminence fractures, partial tears with a positive pivot shift under anesthesia, and complete ACL tears. Operative intervention has consistently been shown to increase knee stability and decrease the risk of further damage to the meniscus and articular cartilage with minimal risk of growth disturbance. Technique for ACL reconstruction is typically based on the status of the physis, yet there is an increasing body of evidence supporting transphyseal reconstruction even in the very young patient. As there is little data supporting one surgical technique as superior, patient age and surgeon familiarity and comfort should guide the choice.

Graft source can depend on technique used, but should be performed with autograft tissue.

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Research paper

Press fit condylar cobalt chrome sigma total knee arthroplasty: No difference to original design at five year point

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ABSTRACT

Background: Total knee arthroplasty (TKA) is an established procedure for relieving pain and improving function. The Press Fit Condylar Cobalt Chrome Sigma (PFCSCC) Total Knee System was introduced by Depuy, Johnson & Johnson in 2006, as an update of their existing PFC Sigma design intended to reduce backside wear.

Methods: To identify any significant early failures following the introduction of this knee system, we prospectively identified all patients undergoing TKA with the PFCSCC over a one-year period. Clinical and demographic patient data, American Knee Society scores, Oxford Knee scores, SF-12 scores and radiographic data were recorded pre-operatively and at three and five years post-operatively.

Results: 233 patients underwent 249 primary TKA's with the PFCSCC. Seventeen patients (19 TKAs) died before the last review and 29 patients (30 knees) were lost to follow up. The mean age was 66.6 (range 34–80) with 47.6% male. Mean five year follow-up was 1836 days (range 1530–2307). Five knees (2.2%) were revised for infection with three revised for pain. The 5-year survival rate was 96.6% and 98.6% for aseptic failure. American Knee Society Score (AKSS) was 32.6 (0–86.6) preoperatively and 80.7 (29–95) 5 years post-operatively $P < 0.001$. OKS was 20.9 (7–38) preoperatively and 36.4 (10–48) at 5 years $P < 0.001$.

Conclusion: We report the first five year outcome of this design change, which demonstrates a good early survivorship when compared to the previous PFC Sigma design.

1. Introduction

The improvement in mobility and the relief of pain following Total Knee Arthroplasty (TKA) is now clearly established.[1,2] The Press Fit Condylar (PFC) Sigma TKA (Depuy, Johnson & Johnson) is the most widely implanted knee prosthesis in England and Wales, and accounted for 36% of all the TKAs performed in 2009.[3–5] The PFC Sigma Cobalt Chrome (PFCSCC) Total knee system was introduced in 2006 and features a modified design of the original PFC sigma. The PFCSCC incorporates a tibial tray made of a cobalt chrome alloy instead of the titanium featured in the older design. The theoretical advantage of this modification is that microscopically the cobalt chrome alloy is smoother than titanium and therefore less likely to produce backside wear of the polyethylene insert.[5] Theoretically, the PFCSCC also has an extended lifetime due to the polyethylene insert being exposed to a higher radiation dose than the original PFC Sigma insert. Improvements in the design of the locking mechanism between the insert and tibia tray it is believed will also help in reducing backside wear.

Minor changes in arthroplasty can lead to unexpected early catastrophic failure and survivorship of implants.[6] The publication of early clinical results in peer-reviewed journals represent an important method of informing surgeons about early survivorship and outcomes with new implant designs. The aim of this study was to assess the survival, clinical and radiological outcomes of the Press Fit Condylar Sigma Cobalt chrome implant at five years in a district general hospital setting. We provide the first medium term follow-up of the PFCSCC, done by multiple surgeons at a district general hospital, which we believe gives a true reflection of its survivorship outside of specialist centres.

2. Patients and methods

The Press Fit Condylar Sigma Cobalt Chrome Total Knee system by Depuy, Johnson & Johnson was introduced in our hospital in February 2006. Over the next 12 months, 249 primary TKA with the

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PFCSCC were performed on a total patient cohort of 233. All patients were included in the analysis, with no exclusions. Statistical analysis was performed on best and worst case assumptions for patients lost to follow-up.

Eight different operating surgeons, either consultant grade or a trainee under direct supervision, performed the operations in a filtered air operating theatre with laminar flow, waterproof single use gowns and drapes. A tourniquet was used routinely, and the femoral and tibial cuts were performed using intramedullary and extra medullary alignment, respectively. The patella was not routinely resurfaced, but this was carried out at the discretion of the operating surgeon when patella wear was severe. All surgeons used the same instrumentation and patients underwent the same postoperative regime.

Demographic and clinical data was collected prospectively from all patients on admission and at follow up clinics run by arthroplasty nurses at three months, one year, three years and five years. The clinical data included the American Knee Society Score (AKSS)[7] the oxford knee score (OKS)[8] at the five year point along with the Short form-12 health questionnaire (SF-12)[9] at the three year point. Patients who were revised were removed from the outcome score measures at subsequent review points A. At the three year review standard short leg anterioposterior and lateral radiographs were obtained to allow measurements of varus and valgus angulation, flexion or extension of the tibial and femoral components. Radiographs were also reviewed for defects at the bone-implant interfaces and radiolucent lines.

2.1. Statistical analysis

A life table was constructed to demonstrate the cumulative survival rates. The endpoints were "re-operation for any reason" and "revision for pain, aseptic loosening or mechanical failure". A standard analysis was perfomed along with A "worst case" survival analysis was performed based on the assumption that all those lost to follow up failed immediately after the time of their last appointment. 95% confidence intervals were calculated using the Rothman method.[10,11]

3. Results

Of the 234 patients (249 knees) that were in the study, at the five year review 17 patients (19 knees) have died, leaving 217 patients (230 knees).

Sixteen patients underwent bilateral primary procedures. The mean patient age was 66.6 years (34–80 yrs.) with 47.6% male. The mean patient body weight was 83.2 kg (49–130 kg) and the mean body mass index (BMI) was 30.0 kg/m2 (20.7–40.1 kg/m2). The indications for surgery were primary Osteoarthritis (OA) in 226 (97%) patients, rheumatoid arthritis (RA) in five (2.1%) cases and avascular necrosis in two cases (0.9%). A total of 29 patients (30 knees) have been lost to follow up. In all, there has been eight revisions in total, five of which were revised within the first three months due to deep infection (primarily *S. Aureus*).

Of the three aseptic revisions, one had a patella replacement after 17 months due to patellofemoral articulation. There were two more revisions, one in the third post-operative year due to pain which had cement removed, polyethylene liner changed and manipulation under anaesthesia (MUA). The last revision occurred in the fourth post-operative year due to pain and loosening.

At five years the cumulative implant survival rate from the life table calculation was 96.6% (CI 97.1 to 94.4) with revision for failure for any reason as endpoint. With revision for aseptic failure as the endpoint, the cumulative survival at five years as 98.6% (CI 100.0 to 97.0). The worst-case scenario in which all those lost to follow up are presumed to have failed is 83.8% (CI 58.7 to 80.6) (Table 1, Fig. 1)

The mean American Knee Society Score (AKSS) pre-operative (249 knees) part 1 knee score was 32.6 (0–86.6) with a mean pain score of 11 (0–45). The mean AKSS at the five years post-operatively (190 knees) was 80.7 (29–95) with a mean function score of 71.8 (100-0) and pain component of 41.1 (0–50). At the one year point the best pain score recorded (233 knees) was 45.8 (0–50) and at the three year point a score of 43.0 (0–50). Though at the five year point, 61.4% (129/210) of patients reported no pain at all (pain score of 50) (Fig. 2).

At five years (180 knees) post-operatively the mean Oxford Knee Score (OKS) was 36.4 (10–48) with 67% (120 / 180) being in the excellent (42–48) or good (34–41) range. Pre-operative results (245 knees) included only six results in this range. (Fig. 3).

The mean Medio lateral alignment was 6.6° valgus (4° varus to 11° valgus) at the three month review (244 knees). At five years the mean of the remaining 192 knees was 6.8° valgus (5°−9° valgus) with only 14% (27 of 192) of knees outside of the (−3° to +7°) suggested range.[12] Radiographic data for 219 knees (88.0%) was examined at the three year review point. Of those reviewed 17 radiolucencies were noted in 17 (8%) cases.[3]

4. Discussion

We present the first mid-term clinical, radiological and patient reported results for the PFC Sigma Cobalt Chrome TKA carried out in a district general hospital by multiple surgeons. We have previously reported on the medium- to long-term follow up of the PFC Sigma TKA.[13] The PFC Sigma Cobalt Chrome TKA design incorporates a number of minor modifications over the original PFC Sigma TKA and these initial results show that at five years post-operatively, the prosthesis survival rate stands at 96.6% with revision for any reason and 98.6% with revision for aseptic failure. These results were similar to the PFC sigma which recorded a 97.2% success rate for any revision at five years and a 99.5% rate for aseptic failure.[13] Our results compare favourably with those reported by Munziger et al. 2010,[14] whose 5 year results for the Innex total knee replacement demonstrated a 97% success rate for aseptic revision and a 95.2% success rate for revision for any revision.

The five year aseptic revision results for the PFC sigma by Dalury et al.[15] reported 99.6% and Zaki et al[16] 99.4%, remain very close to these results for the PFC sigma cobalt chrome of 99.5%. However in a systematic review of the PFC sigma, there is a detectable drop off between 5 and 10 years and for this reason we intend to carry this study forward to identify the future trend for the PFCSCC. At up to five years the PFCSCC demonstrates similar results to the PFC and

Table 1
Life table for cumulative survival of the PFC Sigma Cobalt Chrome total knee replacement.

Year since Operation	Number at start	Death	Lost to follow-up	Total Failure	Aseptic Failure	Period Failure Rate	Period Success Rate	Number at Risk	Cumulative survival for all failures	Cumulative worst case	Cumulative survival for aseptic failures
0–1	249	1	4	6	1	2.4	97.6	246.5	97.6	95.9	99.6
1–3	238	8	10	0	0	0	100	229	97.6	91.8	99.6
3–5	220	10	16	2	2	1	99	207	96.6	83.8	98.6

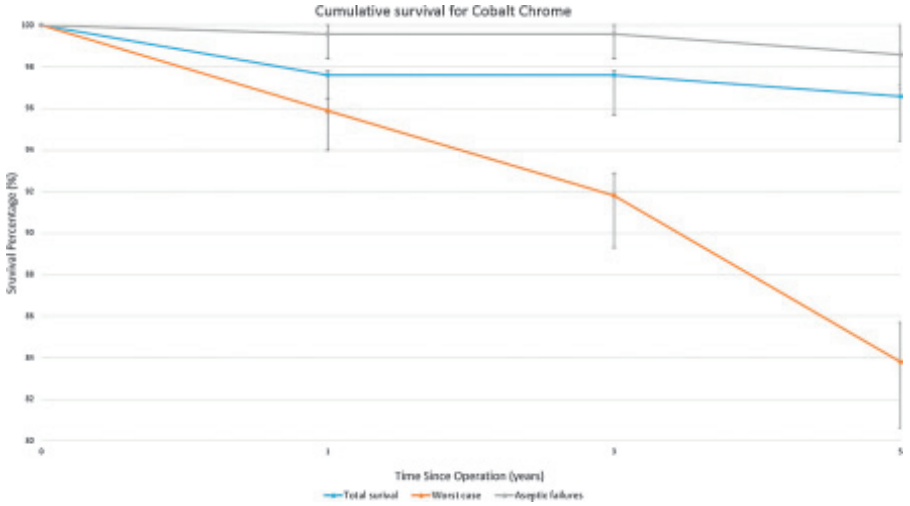

Fig. 1. Cumulative five-year survival rates for the PFC Sigma cobalt chrome total knee replacement by all revisions, revision for aseptic failure and worst case. Including 95% CI.

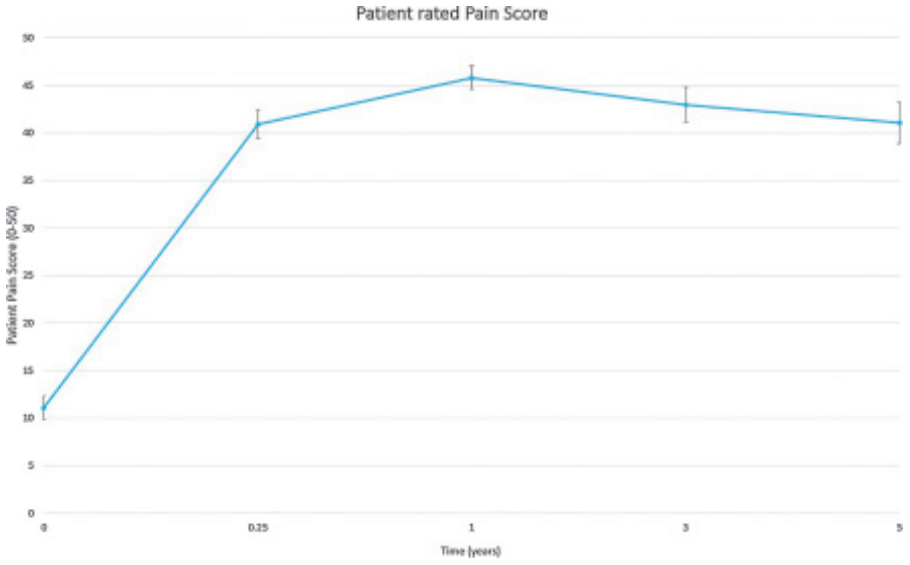

Fig. 2. Patient rated pain scores for PFC sigma Cobalt Chrome total knee replacement including 95% CI.

from a clinical governance point of view close follow-up is required to ensure any early failures like the ASR Metal and Metal hip resurfacing are detected early. [Medical Devices Alert for ASR hip 2012].[17]

There were 29 patients (30 knees), 12% of total, lost to follow-up during the study period, this was despite multiple attempts at patient contact. This may reflect that the patients had moved out of the area and highlights a potential weakness in longitudinal studies. As revision rates are extremely low, failure to identify a revision from the study group would have a significant effect on the results. If we take a "worst case" scenario, assuming all lost knees required revision, this gives a survival rate of 83.8% at five years, which represents an unacceptably high level of revision at the this point. We have attempted to mitigate for this risk by checking the Scottish radiological archive and demonstrated that no knees were revised in the NHS in Scotland although this will not account for any knees revised in the private sector or NHS England.

Radiographs of 219 of the study group were available for review at the three year point which showed 22 knees (10%) were outside the suggested range (7 +/− 3○) for Medio lateral alignment. This compares well to other total knee replacements which used the same definition and reported 66–78% laying outside of this range.[3,18–21], however as these were taken on short leg films there is a possibility of overestimating the range.

Our mean patient reported pain score was 41.1 (0–50) at the five year point, which is less than the score of 44.3 at the five year point for the PFC reported from the our unit by Arthur et al.[13] However this score is less than the minimum significant clinical difference of 5 for the Oxford Knee Score[22]. (Fig. 2.) The overall mean AKSS knee score improved from 32.6 (0–86.6) pre-operatively to 70.0 (26–94) at the three year point and 80.7 (29–95) at five years, which is similar to the 18 months 79.9 (25–100) peak reported by Arthur et al., for the previous design PFC Sigma. The minimal significant clinical difference is believed to be in the region of 5–10 for the AKSS knee score. The mean function score rose from 54 (0–95) pre-operatively to a peak of 71.8 (0–100) at the five year point. Arthur et al[8] did report a steady decline over the next five years in function, potentially resulting from a proportion of the patients becoming increasingly infirm and developing other comorbidities, therefore future research looking at this for the PFCSCC is essential.[23]

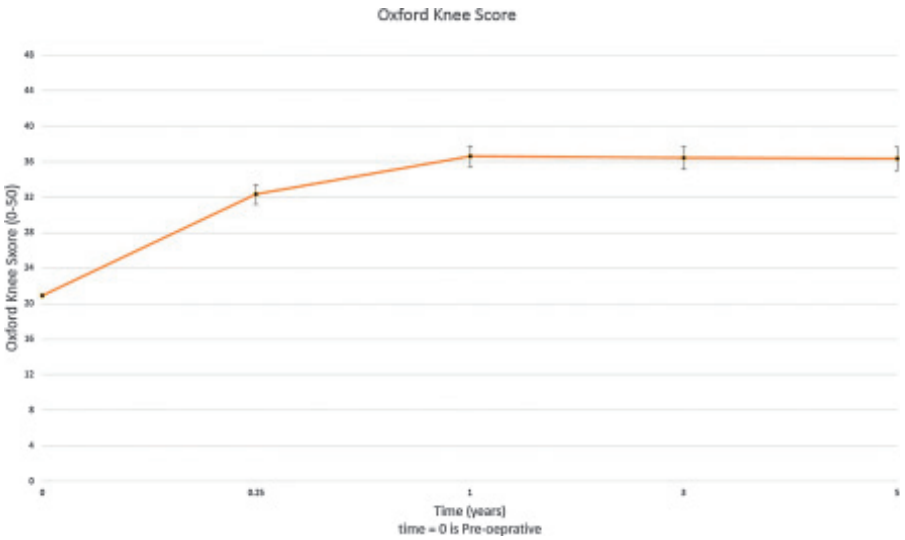

Fig. 3. Oxford knee scores for PFC Sigma Cobalt Chrome total knee replacement including 95% CI.

There was a significant improvement shown in the Oxford Knee Scores (OKS) from 21 (7–38) pre-operatively to a peak of 37 (7–48) at one year post-operatively, flattening to 36 (5–45) at three years and five years, 36 (10–48). The number of percentage of patients reporting an Excellent or good score peaked at 71.8% at three years post-operatively falling to 66.7% at five years. This compares favourably with the scores reported by Whitehouse et al[24] and hunter et al.[25]

5. Conclusion

The results from our study at 5 years for the PFC Sigma Cobalt Chrome are comparable with that of the previous design PFC sigma. Whilst these results are encouraging for users of this knee replacement, as with all changes to implant design it is important that regular reviews throughout the lifetime of the implant are conducted. Further study of this cohort at the 7 and 10 year point will be essential to ensure that any decreased survivorship may be identified and highlighted.

Conflict of interest

None.

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Research paper

Evaluation of anatomical knee joint line restoration in revision total knee replacement patients and its functional outcome: A retrospective cohort study

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ABSTRACT

Evaluation and correct reposition of joint line is ultimate challenge for arthroplasty surgeon during revision total knee replacement. Majority of landmarks had already destroyed while removing bone for either septic/aseptic loosening or for infection. This leads to poor outcome and post-operative dissatisfaction. There are various methods have been described but none is reliable. We are describing a method to evaluate joint line pre operatively and possible application intraoperatively. The medial and lateral epicondyle are easily identible landmark in radiograph as well as intraoperatively. We used Tran's epicondyle axial width (TEAW) method for the evaluation of joint line in AP view and Figgie's method for evaluation of joint line in lateral view. Patella position was diagnosed with Caton deschamps index. These measurements were tested for intra- and inter-observer differences. Then, the relationship between these two measurements was studied. All patients were called back for reevaluation and recording knee society score. The mean duration of follow up was 5.8 months. The mean Knee society score was 73.8 in preoperative period which increased up to 89 in postoperative period. The 3 patients in whom joint line was elevated more than 5 mm from native joint line shows less improvement in knee society score by 7 points compare to others. The difference of which is statistically significant with p value 0.0004 when measured by unpaired T test. Once the TEAW was determined preoperatively, the Joint line level is found during surgery by using a caliper This method leads to better pre-operative idea of joint line and can be reproduced intraoperatively and can leads to a reduced risk of re-intervention following revision total knee arthroplasty.

1. Introduction

Geometry, orientation and position of the tibio femoral joint interface determine knee function. This is intimately related to knee kinematics, kinetics and stability.

There are various reasons for surgeon to raise the joint line in revision Total Knee Arthroplasty like distal femoral bone loss, posterior femoral bone loss and larger flexion space in revision cases. When this bone loss is not compensated by augmentation on the femoral side, a thicker polyethylene insert will be required to obtain adequate ligament balance and an elevated joint line will be the result.[1] More than in primary TKA, joint line restoration is a well-known problem in revision TKA. Elevation of the joint line alters the flexion-extension axis which can subsequently lead to laxity of the posterior capsule, PCL and collateral ligaments at midflexion range i.e., 30–60 and thereby contribute to midflexion instability. Near anatomical restoration of joint line is critical to minimize the risk of mid-flexion instability, a reduction in range of motion, impingement of the patellar tendon against the tibial tray and gap imbalance. Use of anatomical landmarks around knee is widely studied for evaluation of joint line.

A number of landmarks can be used intraoperatively like a point 1.5 cm cranial to the fibular head, 2 cm cranial to the tibial

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Fig. 1. Medial and lateral epicondyle to joint line distance.

tuberosity.[2] Usually the normal joint line was reported to be approximately 25 mm caudal to the medial femoral epicondyle, 23 mm caudal to lateral femoral condyle and it has constant relation with trans epicondylar axial width (TEAW).[3]

The creation of a relative patella baja is another consequence of joint line elevation, especially in revision TKR. Mechanical impingement of the low riding patella against the tibia insert will cause pain and limited knee flexion.[4] This lower patella position can be measured by Caton deschamps index relative to the joint line[5] in lateral knee radiograph (Figs. 1–3).

In 1986, Figgie first identified three major parameters affecting the clinical result after TKA. The position of the joint line was one of them. He stated that a change in joint line of less than 8 mm will results in good outcome. Greater changes were associated with an inferior clinical result.[6]

Porteous et al.[7] reported on 114 revision TKA's. The height of the joint line before and after revision total knee replacement was measured and classified as either restored to within 5 mm of the preoperative height or elevated if it was positioned more than 5 mm above the preoperative height. The joint line was elevated in 41 knees (36%) and restored in 73 (64%).They recommended the greater use of distal femoral augments to help to achieve this goal. They concluded that patients with joint line elevation less than 5 mm has better clinical outcome compare to those whose joint line elevated more than 5 mm.

Romero et al.[8] then develop a constant method to evaluate joint line restoration transepicondylar axial width method (TEAW)

Fig. 2. Figgys method for joint line evaluation in lateral x ray knee joint.

Fig. 3. Caton deschamps index.

which can be applicable to revision total knee replacement patients. Griffin et al.[9] used an MRI technique to quantify a correlation between the Trans epicondylar axial width (TEAW) and the distance to the joint line. They found a nongender-specific linear correlation between the TEAW and the perpendicular distance to the joint line of 0.36 for the medial side and of 0.31 for the lateral side. We have taken griffins method for more accurate evaluation of radiographs for joint line evaluation in our study.

In addition, Periera[10] and Iacono et al.[11] emphasized use of adductor tubercle, medial and lateral epicondyle for evaluation of joint line restoration. However all this study includes normal knees for joint line evaluation.

So in this study we try to reproduce the TEAW method for accurate evaluation of joint line in revision TKR patients. With this method, we mainly use distal femoral augments to ensure the anatomical joint line restoration. We can further verify if our TEAW method is suitable for preoperative planning and its intraoperative application (Table 1).

1.1. Overview

This study is a retrospective study of radiological evaluation in post-revision TKR patients of 6 month duration and to evaluate their functional outcome done at sunshine hospital, secundarabad, Telangana.

1.2. Aim

To provide clinical evidence for TEAW method for its application in evaluation of joint line in revision TKR patients and functional outcome related to it.

1.3. Objectives

1. To evaluate accurate restoration of joint line in patients who underwent revision total knee replacement and it's functional outcome

Table 1
Analysis of data.

	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
AGE	27	35.00	83.00	64.4444	1.93213	10.03966	100.795
TIME FROM INDEX SURGERY	27	.50	20.00	3.3222	.78804	4.09477	16.767
POLY INSERT THICKNESS	27	10.00	22.00	15.9815	.61236	3.18192	10.125
distal femur augment	27	.00	8.00	2.2222	.61633	3.20256	10.256
TEAW	27	71.80	92.00	83.5630	1.07257	5.57323	31.061
MEJL*0.36	27	25.80	35.60	30.1867	.43107	2.23992	5.017
MEJL POST OP	27	24.80	38.50	32.1778	.67755	3.52064	12.395
DEVIATION FROM EXPECTED MEJL DISTANCE	27	-4.40	6.10	2.0207	.62039	3.22365	10.392
LEJL*0.31	27	22.20	28.52	25.9689	.33602	1.74599	3.048
LEJL POST OP	27	22.80	36.50	29.5148	.72609	3.77285	14.234
DEVIATION FROM EXPECTED LEJL	27	-3.80	8.60	3.3867	.70276	3.65163	13.334
TTJL	27	20.00	20.00	20.0000	.00000	.00000	.000
TTJL (NORMAL)	27	21.40	38.00	27.2741	.75609	3.92875	15.435
DIFFERENCE OF TTJL	27	1.40	18.00	7.2741	.75609	3.92875	15.435
CATON DECAMPS INDEX (NORMAL)	27	1.00	1.00	1.0000	.00000	.00000	.000
CATON DECAMPS INDEX(POST OP)	27	.52	1.10	.8207	.03092	.16067	.026
Knee society score(KSS)	27	60.00	80.00	73.8519	.99958	5.19396	26.977
KSS follow up	27	86.00	94.00	89.6296	.45338	2.35581	5.550
nAGE	3	56.00	70.00	62.6667	4.05518	7.02377	49.333
nTIME FROM INDEX SURGERY	3	1.00	6.00	2.6667	1.66667	2.88675	8.333
nPOLY INSERT THICKNESS	3	12.50	17.50	15.8333	1.66667	2.88675	8.333
ndistal femur augment	3	.00	4.00	1.3333	1.33333	2.30940	5.333
nTEAW	3	72.60	82.20	76.7000	2.85832	4.95076	24.510
nMEJL*0.36	3	26.10	29.50	27.5667	1.00885	1.74738	3.053
nMEJL POST OP	3	20.20	24.30	21.6333	1.33458	2.31157	5.343
nDEVIATION FROM EXPECTED MEJL DISTANCE	3	-6.70	-5.20	-5.9333	.43333	.75056	.563
nLEJL*0.31	3	22.00	25.50	23.6000	1.02144	1.76918	3.130
nLEJL POST OP	3	18.20	22.10	20.8000	1.30000	2.25167	5.070
nDEVIATION FROM EXPECTED LEJL	3	-3.80	-1.20	-2.8000	.80829	1.40000	1.960
nTTJL	3	20.00	20.00	20.0000	.00000	.00000	.000
nTTJL (NORMAL)	3	31.30	36.00	33.8667	1.37396	2.37978	5.663
nDIFFERENCE OF TTJL	3	11.30	16.00	13.8667	1.37396	2.37978	5.663
nCATON DECAMPS INDEX (NORMAL)	3	1.00	1.00	1.0000	.00000	.00000	.000
nCATON DECAMPS INDEX(POST OP)	3	.60	.70	.6633	.03180	.05508	.003
nKnee society score(KSS)	3	70.00	78.00	74.0000	2.30940	4.00000	16.000
nKSS follow up	3	80.00	86.00	83.6667	1.85592	3.21455	10.333
Valid N (listwise)	3						

2. To correlate the indication of revision TKR with joint line alteration
3. To evaluate patella Baja in relation to joint line restoration in post revision TKR patient

1.4. Material

A total of 32 patients were available for our study. This retrospective study was approved by our institutional review board. Our study included 30 consecutive patients who underwent revision TKR between December 2014 to December 2016 for failed primary TKR.Two patients were excluded because they underwent knee arthrodesis. All patients received revision TKR system that address stability in both flexion and extension including Depuy TC3 for 26 knees, walder link for 3 Knee and 1 extratech. Fluted extension rods were used in revision system when required for stability with addition of augment posterior and distal condyles. No offset stems were used in any patients.

1.5. Surgical technique

All the operations were performed by the same group of surgeons using the standard medial Para patellar or extensile approaches under spinal anesthesia. We first removed the antibiotic impregnated spacer if present and then proceed for through debridement .We than evaluated distal femur and proximal tibia bone. Ligament stability was checked. To avoid joint line change we preserved as much bone as possible. We considered the distal femoral augments for bone loss compensation and fluted extension rods for achieving stability. Finally we implanted the revision system with proper ligament tension and sutured the extensor retinaculum.The patients started passive movements 24 hours after surgery with the assistance of a walking frame. The patients usually started full weight bearing after surgery.

1.6. Clinical and radiological evaluation

In all patients the indication for revision septic/aseptic, the time duration from index surgery and one stage or two stage revision, pre-operative knee society score(KSS) were noted from the data retrieved from medical record department of sunshine hospitals. All revision patients' poly insert size was noted. All patients post-operative x-ray was retrieved from PACS system of sunshine hospital and evaluated for joint line evaluation.

We used trans epicondyle axial width(TEAW)method for the evaluation of joint line in AP view described by Romero et al,[8]Griffin et al.[9] and Figgie's method[6] for evaluation of joint line in lateral view.

In all cases, the Trans epicondyle axial width (TEAW) was measured from most prominent part of medial and lateral epicondyle and the distance from lateral and medial femoral epicondyle to described joint line tangent which is most distal point of femoral component was measured with radiant dicom software. In the lateral view the distance from tip of tibial tubercle

to most distal point of femoral condyle tangent was taken in to consideration for joint line level as described by Figgie's method. Patella Baja was diagnosed with Caton deschamps index.[11]

All patients were called back for reevaluation and recording knee society score. The mean duration of follow up was 5.8 months.

Post op X-ray was evaluated for

1. Trans epicondyle axis width(TEAW)
2. Medial epicondyle to joint line distance(MEJL)
3. Lateral epicondyle to joint line distance (LEJL)
4. Tibial tubercle to joint line distance. – Normal 2.0
5. Caton Deschamps index. – Normal 1

1.7. Data analysis

All statistical analyses were performed by using SPSS software for Windows (version 16; SPSS, Chicago, IL, USA).

2. Results

2.1. Clinical outcomes

In review of 30 consecutive patients retrospectively we found joint line position was elevated from the native position after revision TKR compared with preoperative measurement in 10 patients. Out of 10 patients 3 patients have significant elevation of joint line more than 5 mm.

The average age of patients was 64.2 years. We found the average time duration since index surgery for patients with revision TKR was 3.2 years. .The indication of revision was septic in 21 Cases and aseptic in 9 Cases. Out of which joint line evaluation was more in septic indication cases. The average poly insert thickness was 15.9 mm in revision case.

Joint line was elevated more in two stage revision TKR compare to one stage.

The mean Knee society score was 73.8 in preoperative period which increased up to 89 in post-operative period. The 3 patients in whom joint line was elevated more than 5 mm from native joint line shows less improvement in knee society score by 7 points compare to others. The difference of which is statistically significant with p value 0.0004 when measured by unpaired T test.[25]

Patients in whom the joint line was restored within 5 mm from native joint line, knee society score improved significantly compare to patients with $>$5 mm joint line proximalization.

In patients with joint line elevation more than 5 mm there were no Augments used and it was two stage revision TKR with septic indication. Out of 3 patients two patients poly used was 12.5 mm and one is 17.5 mm.

2.2. Imaging results

In our study the mean epicondyle width was 82.8 ± 1.06 mm (range, 71–92 mm),the mean perpendicular distance from the medial epicondyle to the joint-line tangent was 31.12 ± 0.8 mm (range, 2.2–38.5 mm), and the mean perpendicular distance from the lateral epicondyle to the joint-line tangent was 28.64 ± 0.82 mm (range, 18.2–36.5 mm).

After revision TKR, the joint line measured from the TEAW was shifted more than 5 mm in 3 patients in which mean shift of joint line from medial epicondyle to joint line distance was 5.9 mm and from lateral epicondyle to joint line distance it was 2.8 mm. In 27 cases the joint line was at its anatomic position considering more than 5 mm elevation as abnormal.

The mean difference from normal tibial tuberosity to joint line distance was 13.8 mm in joint line elevated patients compare to 7 mm in normal joint line patients.

The mean Caton deschamps index was 0.66 in elevated joint line patients which suggest patella baja compare to 0.82 index level in normal joint line elevated patients.

Inter observer variability was within 2–3 mm difference.

3. Discussion

Elevation or depression of joint line in revision TKR may significantly alter the post-operative outcome. So it is important to evaluate joint line preoperatively and implement that method intraoperatively. Other methods that rely solely on intraoperative determination of the joint-line level have shown severe potential errors. The flexion-extension gap balancing technique to restore the joint line[19] is useful only in hands of experienced surgeon.

In the primary TKA the resection level depends on degenerative bone wear, deformity, and flexion contracture so, the radiographs of the primary TKA cannot be used as a reference for joint line positioning at revision TKA.A large distal femoral cut to compensate for preoperative flexion contracture is a common reason for an elevated joint line in primary TKR and subsequent midflexion instability hence, flexion contractures need to be addressed with alternative methods such as capsular release and osteophyte excision to prevent elevation of joint line. Distal femoral augments can also be used for it. Previously there were many studies of normal joint line however all methods were not reproducible intraoperatively. Determination of the joint line at revision TKA also may become difficult as a result of distal femoral bone loss during extraction of the femoral component or after two-stage revision for infection. Joint line alteration can lead to many consequences like mid flexion instability and reduced ROM in post-operative period. Elevated joint line also leads to other problems such as anterior knee pain and decreased flexion secondary to alteration in patella femoral mechanics, patella strain and alteration in patella position in relation to the joint axis. Partington et al.[22] reported that joint line elevation in their study was average 24 mm in revision TKR patients. They reported worse clinical outcome with excessive elevation of joint line.

Laskin et al.[17] in their study revealed that joint line elevation affect the collateral ligaments, leading to mid-flexion laxity or incapacitating instability. Emodi et al.[18] in their study suggested that joint line elevation leads to alter the contact pressures of the patellofemoral joint[3] and may lead to patella infera and impingement of the patella on the tibial insert.

Martin et al.[23] emphasized that stability in condylar knee replacement depends on joint line restoration. Hofmann et al.[24] reported in their study that clinical outcome was improved if the joint line was accurately restored. Contrast to this, Jackeb et al.[16] in their study suggested that joint line elevation by 4 mm in revision total knee arthroplasty does not cause significant kinematic and kinetic differences during passive flexion/extension movement and squatting in the tibio-femoral joint, nor does it affect the elongation patterns of collateral ligaments.

So if the original radiographs before primary TKA are not available or if the contra lateral knee also has been replaced we can use the TEAW method described by Romero et al.[8], Griffin et al.[9]. The described method is based on the fact a linear correlation between the epicondyle width and the perpendicular distance from the medial and lateral epicondyle of the joint-line tangent.

These measurements proved to be highly reliable and reproducible for preoperative planning on radiographs. The calculated joint-line level may be helpful during revision knee arthroplasty for proper placement of the implants and use of bone graft/metallic augments when required for restoration of joint line.

The result of our study suggests the TEAW is appropriate methodology for preoperative planning and its implementation intraoperatively in revision TKR patients although it has some limitations. Our main purpose was to observe the joint line position and we believe that the joint line position remained constant when the components were stable. One potential limitation of the TEAW method was that we have applied in small number of cases in revision TKR patients so larger number of is required for correlation between radiological and intraoperative measurements. Second the duration of follow-up in our study was moderate (average 4.3 months).

Measurement of joint line by TEAW method also correlate with functional outcome measured with knee society score (KSS) in our study. Finally, our clinical results shows correlation of alteration of joint line in septic cases with two stage revision and thicker poly inserts, so we recommend to preserve as much bone as possible and use distal femoral augments, offset stems for joint line restoration in revision TKR and plan for single stage revision whenever possible such as in aseptic loosening. This method is useful for evaluation of pre-operative and post-operative assessment of revision TKR radiographs and reproducible. However, its intraoperative implications require larger study for better evaluation.

Conflict of interest

None.

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Research paper

Anthropometric assessment of tibial resection surface morphology in total knee arthroplasty for tibial component design in Indian population

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ABSTRACT

Introduction: An anthropometrically well designed knee prosthesis that matches properly to the resected surface of the bone is key for long term survivorship in TKA.
Aim: The aim of the study was to make an anthropometric analysis at resected surfaces of proximal tibia in Indian population and to compare it with the available data of other ethnicities. Methods- CT scans of 50 subjects were used to select the tibial resection surface. The surface selection was virtually done on each tibia at 8 mm off the lateral plateau using Micro Dicom system (reflecting a 10-mm surgical cut assuming a cartilage thickness of 2 mm). We measured the mediolateral, middle anteroposterior, medial and lateral anteroposterior dimensions, the aspect ratio and asymmetry metrics of the resected proximal tibial surface.
Results: The dimensions of the tibial plateau of Indian knees demonstrated significant differences according to gender ($P < 0.05$) in terms of size. The shape parameters are not different significantly. When compared to all other ethnicities the Indian knee differs in size as well as the shape parameters i.e. Aspect ratio.
Conclusion: Clinically relevant differences in proximal tibia morphology at the level of proximal TKA resections across ethnicities can lead to mismatch of sizes of Western TKA implants in Indian patients. Tibial component designs should be done by considering the morphometry of knee in Indian population. Indian females were found to have significant smaller dimension of tibia in terms of size than. But the impact of small sample size and single centre on study warrant a multicentric study with large sample size.

1. Introduction

Total Knee Arthroplasties (TKAs) has been reported to have unsatisfactory results in upto one-third of patients.[1] Beside accurate bone cutting and adequate balancing of the soft tissues, the successful outcome of TKA depends on, maximizing tibial coverage with the correct component size. This is mandatory for minimizing the stress applied to the bone–implant interface and ensuring an appropriate load transmission.[1–2] Several studies assessed knee morphology, focusing on qualitative description of or basic dimensional measurements at the TKA resection level (such as anterior–posterior and medial–lateral dimensions).[3–6]

As compared to western counterparts Asian subpopulations are known to have a smaller build and stature.[7] This results in implant size mismatch with the resected bony surface in the Asian patients. Compared to the femoral side, the tibial component is more prone to complications in TKA.[8] In case tibial component does not match accurately to the resected proximal part of the tibia, the surgeon may have to choose either a larger, overhanging component or a smaller, underhanging one.[9]

To fully characterize the asymmetric and irregular shape at the Tibial resection level, however, morphological quantification beyond qualitative or basic dimensional measurements is needed, with the potential to reveal ethnic- and gender-based morphological differences relevant to TKA design.

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In respect to the above facts and paucity of anthropometric data in the literature on the proximal tibia in the Indian population, we evaluated the anthropometric data on the proximal tibia that was obtained by using computer tomography. Furthermore, the pattern of change of the mediolateral dimensions in relation to the anteroposterior dimensions was compared between the study population and the available data of other ethnicities.

2. Materials and methods

The prospective analysis was done in a tertiary care center in New Delhi in total 50 subjects from Jan 2016 till July 2017. Morphologic data from the proximal tibia of 50 normal knees in 50 subjects were analyzed, wherein one knee of each subject was studied. Subjects with normal lower limb appearance, normal alignment, no prior trauma or congenital deformities were included in the study. Patients with any deformity in the coronal or sagittal plane, lower extremity malalignment (metaphyseal varus/valgus $>10^{\circ}$), knee flexion deformities $>10^{\circ}$, substantial bone loss, history of previous surgery, proximal tibial fracture or knees with any implants were excluded from the study.

CT scans of 50 subjects were used to select the tibial resection surface. The surface selection was virtually done on each tibia at 8 mm off the lateral plateau using *Micro Dicom system* (reflecting a 10-mm surgical cut assuming a cartilage thickness of 2 mm). We measured the mediolateral, middle anteroposterior, medial and lateral anteroposterior dimensions, the aspect ratio and asymmetry metrics of the resected proximal tibial surface. The system of measurements was adopted from the work of Dai and Bischoff published in 2013 (Figs. 1–6).[10]

The neutral rotational axis (Y) was defined as the line connecting the medial third of the tubercle and center of the PCL attachment site, projected onto the resection plane (Fig. 3). The origin of the coordinate system was placed at the midpoint between the anterior and posterior intersecting points of the tibial contour with the Y&HIPHEN;axis (Fig. 4). A bounding box was constructed in this coordinate system (Fig. 5). The medial and lateral compartments of the resection contours were identified as the regions separated by the neutral rotational axis. A series of morphological metrics was then computed for each contour:

3. Dimensions

ML width; medial and lateral AP dimensions (Fig. 1A).

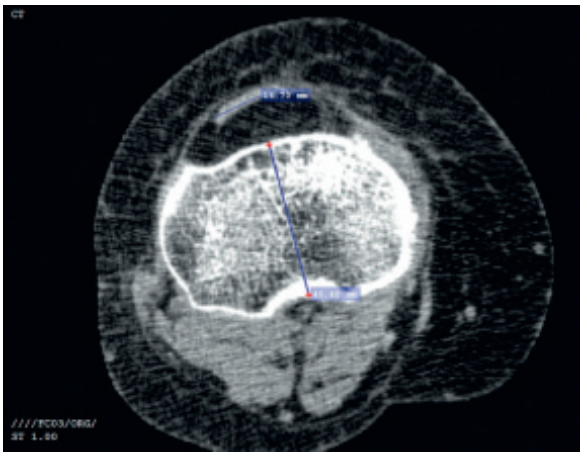

Fig. 2. Measurements performed on resected surface of Proximal tibia showing Y rotational axis.

3.1. Radii

The medial curve was identified as the portion of the resection contour from the medial 25% (0–25%) of the ML dimension; the anterior medial curve was identified as the anterior 50% of this medial curve (Fig. 1B). The medial anterior radius was then defined as the radius of the least squares best-fit circle to the anterior medial curve. The lateral anterior radius was defined similarly (Fig. 1B).

3.2. Areas

Bounding box area (overall).

3.3. Aspect ratios

For overall resected plateau (Plateau aspect ratio), the ratio was defined as the ML/AP ratio of the bounding box. For each individual compartment (compartment aspect ratio), the ratio was defined as the ML/AP ratios for the medial and lateral bounding boxes. This convention was chosen to ensure that aspect ratio values generally ranged from 0 to 1, with closer to unity representing a more square-like geometry.

Fig. 1. Tibail Resection Surface reflecting 10 mm surgical cut.

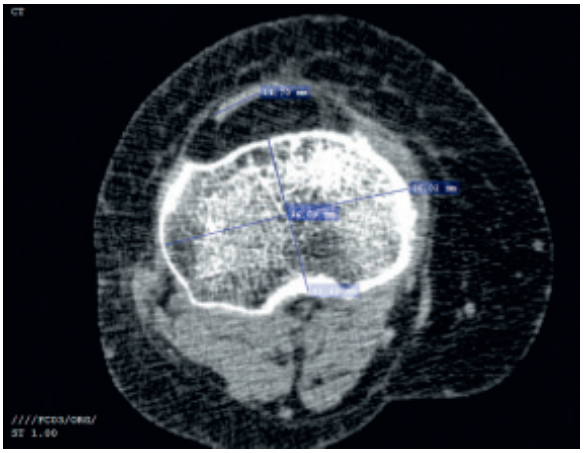

Fig. 3. Measurements performed on resected surface of Proximal tibia showing Mediolateral and Anterio-posterior dimensions.

3.4. Asymmetry

Several asymmetry metrics were incorporated to quantify the shape difference between the medial and lateral compartments (values closer to unity representing more symmetric profiles). AP asymmetry was defined as the ratio between medial and lateral AP dimensions; anterior radius asymmetry was defined as the ratio between medial and lateral anterior radii.

3.5. Statistical analysis

The Normality of quantitative data was checked by measures of Kolmogorov-Smirnov tests of Normality. As our data was normally distributed, so it was written as in the form of its mean and standard deviation. Means of 2 groups (gender) were compared using Independent *t*-test. To study the relationship between different variables Pearson Correlation coefficient was applied. All the statistical tests were two-sided and were performed at a significance level of $\alpha = 0.05$. Analysis was conducted using IBM SPSS STATISTICS.

4. Results

50 patients were evaluated during the study of which 29 were male and 21 were females. The following calculations were made on each knee in term of various dimensions, radii, areas and asymmetry; the values are as mentioned below.

4.1. Dimension and area (Table 1)

Overall AP dimension was 46.04 ± 4.09, with value of 47.80 ± 3.65 in males and 43.53 ± 3.40 in females. The medial AP value was 46.36 ± 5.22 overall while it was 48.58 ± 4.41 in males and 43.19 ± 4.74 in females. The lateral AP value was 44.48 ± 4.08 overall, 48.32 ± 5.45 in males and 42.297 ± 2.92 in females.

Overall ML dimension was 67.30 ± 5.21 while the value in male population was 69.65 ± 7.52 and in female population was 66.13 ± 3.99. Value of medial compartment ML was 33.90 ± 4.03 overall, 34.61 ± 6.91 in male and 33.55 ± 2.56 in females. In lateral compartment, the overall value of ML was 33.55 ± 2.60; in male was 35.04 ± 0.85 and 32.82 ± 2.92 in females .

The area of the bounding box was calculated to be an overall value of 3668.71 ± 474.9 with value of 3765.11 ± 832.34 in males and 3620.51 ± 274.55 in females.

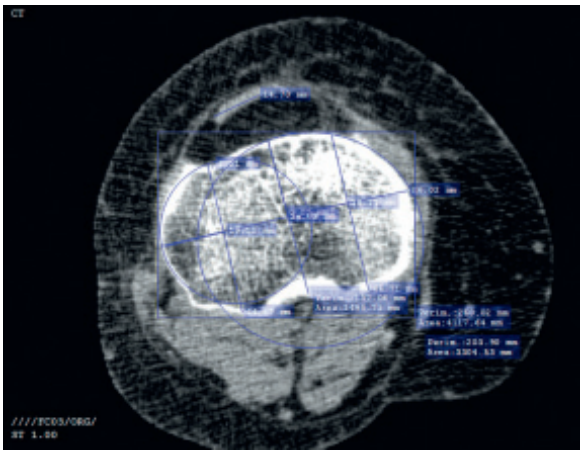

Fig. 5. Measurements performed on resected surface of proximal tibia showing dimensions of anterior radii of medial and lateral compartment.

4.2. Radius

The overall value of medial anterior radius was 25.97 ± 3.13 while the radius in male population was 25.89 ± 3.13 and 26.01 ± 3.04 in female population. The value of lateral anterior radius was 19.26 ± 4.34 overall while was 20.34 ± 5.13 in males and 18.73 ± 4.33 in females.

4.3. Aspect ratio (Table 2)

The aspect ratio was calculated separately for the plateau, medial and lateral compartment. The overall value of plateau aspect ratio was 1.55 ± 0.07, 1.54 ± 0.10 in males and 1.56 ± 0.06 in females.

In medial compartment, the value of aspect ratio was 0.81 ± 0.06 overall, 0.82 ± 0.08 in males and 0.80 ± 0.04 in females. In lateral compartment, the overall value was 0.76 ± 0.07, 0.72 ± 0.07 in males and 0.78 ± 0.07 in females .

4.4. Asymmetry (Table 2)

The asymmetry was considered in terms of AP and anterior radius. The overall AP asymmetry was 0.95 ± 0.17, 0.86 ± 0.01 in males and 0.99 ± 0.19 in females. The overall value in anterior

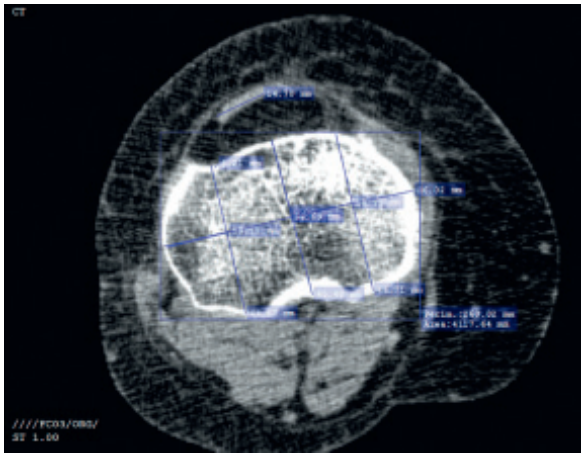

Fig. 4. Measurements performed on resected surface of proximal tibia showing Mediolateral and Anterio-posterior dimensions of medial and lateral compartment and area of bounding box.

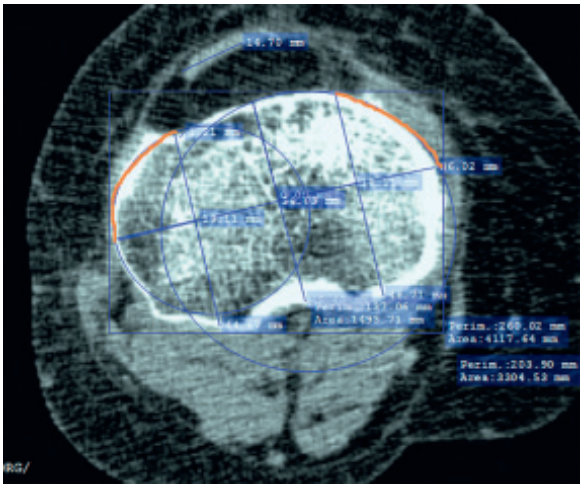

Fig. 6. Figure describing the calculation of all parameters on the resected tibial plateau.

Table 1
Average values of the tibia morphology measurement in terms of size.

Metrics (Mean ± SD	All n = 50	MALE n = 29	FEMALE n = 21	P value
AP	46.04 ± 4.09	47.80 ± 3.65	43.53 ± 3.40	.002
ML	70.19 ± 5.72	72.02 ± 5.13	67.58 ± 5.69	.024
Medial compartment ML	36.30 ± 4.30	37.35 ± 4.30	34.80 ± 3.97	.089
Lateral compartment ML	33.94 ± 2.69	34.67 ± 2.29	32.89 ± 2.95	.056
Medial compartment AP	46.36 ± 5.22	48.58 ± 4.41	43.19 ± 4.74	.002
Lateral compartment AP	44.48 ± 4.08	45.54 ± 1.00	42.97 ± 2.92	.07
Area bounding box	4144.44 ± 585.28	4390.28 ± 566.09	3793.23 ± 418.75	.002
Medial anterior radius	28.63 ± 3.36	29.95 ± 2.87	26.74 ± 3.17	.004
Lateral anterior radius	21.29 ± 3.55	22.21 ± 3.31	19.99 ± 3.57	.072

Table 2
Average values of the tibia morphology measurement in terms of shape.

Aspect ratio	All n = 50	MALE n = 29	FEMALE n = 21	
Plateau	1.52 ± 0.08	1.50 ± 0.09	1.55 ± 0.06	.15
Medial compartment	0.78 ± 0.06	0.76 ± 0.07	0.80 ± 0.05	.14
Lateral compartment	0.76 ± 0.07	0.77 ± 0.08	0.76 ± 0.05	.88
Asymmetry	All n = 50	MALE n = 29	FEMALE n = 21	P value
AP	1.04 ± 0.14	1.07 ± 0.14	1.01 ± 0.13	.18
Anterior radius	1.36 ± 0.17	1.36 ± 0.15	1.36 ± 0.21	.99

radius asymmetry was 1.38 ± 0.25; male value was 1.29 ± 0.18 and was 1.43 ± 0.29 in females.

5. Discussion

Total knee replacement is a precise surgical procedure and its long-term success depends on a good shape match between the prosthesis and the resected surface of the knee. Asian knees have been reported to be smaller than the Western knees. The prostheses must accurately cover the resected surface in order to achieve a successful outcome. Hence, it is essential to know the exact morphology of the resected surface of Asian knees and to design proper prostheses for the Asian-Pacific population. Quantification of differences in the tibia at the level of TKA resection can improve understanding of anatomic variation and potentially provide a basis for understanding differences in clinical outcomes across populations. We pursued a multifaceted approach to quantify morphology: a comprehensive set of metrics related to size and shape that can reveal ethnic and gender differences.

In our study (Table 1), males had larger values of AP (47.80) and ML (72.02) as compared to AP (43.53) and ML(67.58) in females ($p < 0.05$). There is a significant difference in AP and anterior radius of medial tibial condyle in males as compared to female. The area of bounding box also showed a significant difference ($p < 0.05$). This reflects the significant difference in size parameters (dimension, area, radius). But, the shape parameters (aspect ratio, asymmetry) did not show a significant difference. This trend was observed in other ethnic groups too and this study showed a conformation with this general trend.[10–14]

As compared to other studies in Chinese, Korean, American, Japanese and Caucasian the dimension of mediolateral plane in our study was less as compared to these ethnicities (Table 3).[10–14] As far as the AP dimensions were concerned, again the values in our study were lower as compared to the above mentioned studies.[10–14] This difference was more in male population as compared to female population. The major difference in AP dimensions was observed in the medial compartment while in lateral compartment the AP dimensions were nearly equal as compared to the Caucasian population in Dai et al.10 The area of bounding box in our population was also less as compared to the knees of Caucasian and Japenese population evaluated by Dai et al.10

In particular, the anterior radius of the medial compartment is consistently greater depending on the ethnic and gender subgroup than of the lateral compartment. The above comparisons suggest that the Indian knees had overall smaller dimensions in terms of size parameters.

Table 3
Comparison of the measurements of proximal tibia among various ethnic groups.

Author	Ethnicity	ML	AP	Aspect ratio(ML/AP)
Our study	Indian	70.19 ± 5.72(C) 72.02 ± 5.13(M) 67.58 ± 5.69(F)	43.30 ± 3.68 (C) 47.80 ± 3.65 (M) 43.53 ± 3.40(F)	1.52 ± 0.08 (C) 1.50 ± 0.09 (M) 1.55 ± 0.06 (F)
Cheng et al11	Chinese	73.0 ± 4.6(C) 76.4 ± 2.8(M) 68.8 ± 4.6(F)	48.8 ± 3.4(C) 51.3 ± 2.0(M) 45.7 ± 1.9(F)	1.49 ± 0.05(C) 1.49 ± 0.06(M) 1.51 ± 0.06(F)
Kwak et al12	Korean	71.9 ± 5.6(C) 76.1 ± 4.0(M) 67.6 ± 3.1(F)	45.7 ± 3.8(C) 48.2 ± 3.3(M) 43.2 ± 2.3(F)	1.57 (C) 1.58(M) 1.56 (F)
Mensch et al13	American	80.3 ± 3.7(M) 70.1 ± 2.8(F)	48.9 ± 2.3(M) 42.1 ± 1.7(F)	1.64(M) 1.66(F)
Uehara et al14	Japanese	83.0 ± 6.2(M) 71.7 ± 4.0(F)	53.8 ± 6.6(M) 46.6 ± 3.6(F)	1.54 (M) 1.53 (F)
Dai et al10	Caucasian	74.3 ± 6.6(C) 78.1 ± 3.9(M) 69.1 ± 2.8(F)	48.3 ± 5.4(C) Medial AP 54.4 ± 3.0(M) 48.0 ± 2.4(F) Lateral AP 48.6 ± 3.0(M) 42.6 ± 2.3(F)	1.53 (C) 1.31(M) 1.31(F)

The medial anterior radii was more less as compared to lateral anterior radii in our study group suggesting a significant implant overhang in the tibial component from the knees designed for Caucasian population.[10]

It is always undesirable to have overhang of an tibial implant component. Frequent overhang questioned the anatomical suitability of Western implants for the Indian population. Due to overhang the surgeon would have to choose an implant of even smaller size. This will lead to additional resection of the bone causing an undesirable loss of healthy bone. Moreover, decreasing the size of the implant, and hence the radius of curvature, would affect the biomechanics of the replaced knee. This warrants an absolutely different line of design making in Indian knees.

Aspect ratio which is the ratio of ML/AP for overall plateau and each compartment was calculated in this study. In comparison to Caucasian, the ratio was higher in Indian population[10] but the ratio was lower as compared to the Korean and American population.[12] Although the Indian knee is smaller in size as compared to other ethnicities, the shape parameters i.e Aspect ratio also differs from all other ethnicities with higher values from Caucasian and lower from Korean and American.

The comparison in terms of asymmetry in AP and anterior radii suggested that the overall as well as the gender based values were less as compared to the Caucasian and Japenese ethnicities in Dai et al.10

In summary, by leveraging a large set of morphological data, combined with a comprehensive set of shape metrics, we facilitated quantitative understanding of the proximal tibial morphology at the implantation level across Indian population.

6. Conclusion

Distinct difference in size and shape between the Indian knees and Western knees leads to mismatch of sizes of Western TKA implants in Indian patients. While designing total knee prosthesis, morphometry of knee in Indian population must be taken into consideration. Indian females were found to have significant smaller dimension of tibia in terms of size than Indian males although the shape parameters are not different significantly. But the limitation of our study is small sample size and done in single centre of northern India. Hence it is suggested that a multicentric study with large sample size should be conducted.

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Conflict of interest

The authors declare that there are no conflict of interest.

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Research paper

Fat pad excision in total knee arthroplasty does not affect functional outcome or anterior knee pain at 1 year follow-up

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ABSTRACT

Background: In total knee arthroplasty (TKA), excision of infra patellar fat pad (IPFP) is usually done to enhance exposure. But effects of this are not clearly understood. A few studies indicate that it may lead to increased incidence of anterior knee pain (AKP). This study was undertaken to determine the effect of excision of IPFP on incidence of AKP (as indicated by Hospital for Special Surgery (HSS) patella score), Knee society score (KSS) and functional score, change in Patellar Tendon length (as measured by Insall-Salvati ratio (ISR)) and, Range of motion (ROM).

Methods: 135 patients (151 knees) operated by two senior arthroplasty surgeons in the period of January 2014 to December 2015 were followed-up for minimum of 1 year. Group 1 consisted of 106 knees in which complete excision of fat pad was done and group 2 consisted of 45 knees in which fat pad was retained.

Results: There was no significant difference in HSS patella score of two groups during the follow-up of 1 year. KSS and functional score was significantly better for IPFP retention group at 6 week follow-up, but in later follow-ups till 1 year, the difference was not significant. The mean change in patellar tendon length for patients with the fat pad removed (ISR = −0.022) and those with it retained (−0.011) was significantly different ($p = 0.026$). Average range of flexion in both the groups at 1 year follow-up was beyond 110 degrees. There was a significant difference in range of flexion at 1 year of follow-up (117.07 degrees in group 1 versus 118.44 degrees in group 2, $p = 0.04$). There were no fracture or avascular necrosis of patella in either group.

Conclusion: AKP and functional outcome is not significantly affected by excision of IPFP. Fat pad can be sacrificed if exposure is compromised.

1. Introduction

Total Knee Arthroplasty (TKA) has been a revolution in modern orthopaedics for the management of osteoarthritis of knee, with a very high satisfaction rate, upto 90%.[1] There are also certain reasons for dissatisfaction among patients, commonest of which is anterior knee pain (AKP).[2]

In a well-balanced knee, reason of pain can be attributed to patello-femoral over loading, patellar maltracking, or pain from free nerve endings from retinaculum, infrapatellar fat pad or synovial membrane due to stretch or impingement.[2–5] Of these reasons, patella femoral articulation has been extensively studied. Perfect placement of a well-designed TKA can minimize AKP, but cannot omit it completely due to its multifactorial origin.

Among all these factors, the role of infra patellar fat pad (IPFP) is less understood. IPFP or Hoffa's fat pad is intracapsular but extra synovial adipose tissue filling the void between the inferior pole of patella and the tibial articular surface. It has rich vascular supply and numerous nerve endings, and also a part of the vascular supply to the patella is through the IPFP. Generally, it is excised to gain better exposure, but with improved instrumentation and surgical techniques, it has become possible to retain it partially or completely without obstructing the exposure significantly. The exact cause of anterior knee pain due to IPFP has been debatable. Macul'e et al[6] and Tanaka et al[7] found that patients with an intact IPFP experienced the same or higher rates of knee pain, while a few

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other studies concluded that patients with intact IPFP experienced less pain than those with IPFP resection after TKA.[7–9] Pain on IPFP retention is attributed to its dense nerve supply. Whereas advocates of IPFP retention give credit to its cushioning effect on the patellar tendon. Also removal of the fat pad has been postulated to cause patella baja and reduction of flexion due to post-operative scarring of patellar tendon.[10]

Although biomechanical and kinematic evidence comprise both sides of the argument, the clinical and functional significance of excising IPFP during knee arthroplasty surgery has not yet been clearly established. Given that the number of patients undergoing TKA is increasing, it is important to explore strategies which could be used to improve patient satisfaction in these areas. We therefore conducted this study to determine the effect of infrapatellar fat pad excision on (1) Anterior knee pain; (2) Knee Society Score (KSS) and functional score; (3) Patellar tendon shortening (as measured by Insall-Salvati ratio); and (4) Range of Motion (ROM).

2. Material and methods

135 patients (151 knees) operated by 2 senior surgeons, from February 2014 to March 2016 are included in the study. One surgeon (IVR) prefers complete excision of IPFP while the second surgeon (KK) prefers retention of IPFP based on their philosophies. Patients with post traumatic arthritis, history of fractures around knee, inflammatory arthritis, severe medical disability that limits ability to walk, disabling diseases of other joints or extremities, patients who could not be followed up for a minimum of one year were excluded from the study. Demographic data, pre-operative and post-operative evaluation were recorded. Prosthesis of same make was used in all the cases. Radiographs were obtained, ROM, KSS and functional score, Hospital for Special Surgery (HSS) Patella score (as an indication of anterior knee pain) were noted preoperatively, post-operatively after 6 weeks, 3 months, 6 months and one year. Rehabilitation was supervised by the same team of physiotherapists, according to an established program. Radiological measurements for calculating Insall-Salvati ratio were made on a standard lateral view of the knee at 30° flexion on a pre-operative x-ray and x-ray at follow-up of one year (Fig. 1).

3. Results

IPFP was excised in 70.2% (106) and retained in 29.8% (45) of the 151 knees. Demographic data was comparable for both the groups (Table 1).

Pre-operative HSS patella score, KSS and functional score were comparable (Tables 2–4). HSS patella score improved gradually till 6 months in both the groups and there was no significant difference between both the groups at 6 weeks, 3 months, 6 months or 1 year (Table 2). Similar improvement with time was seen in KSS and functional score in both the groups. Significant difference was found in KSS and functional score between the two groups at 6 week follow-up, but at 3 months, 6 months and 1 year follow-up, the difference was not significant. (Tables 3 and 4)

Pre-operatively Insall-Salvati ratio was comparable in both the groups ($p = 0.47$). The mean change in patellar tendon length for patients with the fat pad removed (ISR = −0.022) and those with fat pad retained (ISR = −0.011) was significantly different ($p = 0.026$). (Table 5)

Knee flexion range increased progressively in the two study groups, and average range of flexion in both the groups at 1 year follow-up was beyond 110 degrees. There was a small but statistically significant difference in range of flexion between the two groups with IPFP retention group faring better at 6 weeks, 6 months and 1 year of follow-up. (Table 6)

We observed no complications, fractures of the patella, or avascular necrosis in either group during the study.

Table 1
Demographic data of patients.

	Average age	Female patients	Male patients
Fat pad excised	67.5 years	72 (67.9%)	34 (32.1%)
Fat pad retained	68.1 years	32 (71.1%)	13 (28.9%)

Table 2
HSS Patella score.

HSS Patella score	Pre-op	6 weeks	3 months	6 months	1 year
Fat pad excised	17.22	26.42	27.82	29.2	29.2
Fad pad retained	16.78	26.51	27.29	29.1	29.1
p value	0.16	0.40	0.10	0.4	0.4

Table 3
Knee Society score.

Knee society score	Pre-op	6 weeks	3 months	6 months	1 year
Fat pad excised	43.34	82.02	84.13	87.9	90.79
Fad pad retained	45.49	82.84	84.2	88.34	90.73
p value	0.11	0.04	0.25	0.09	0.4

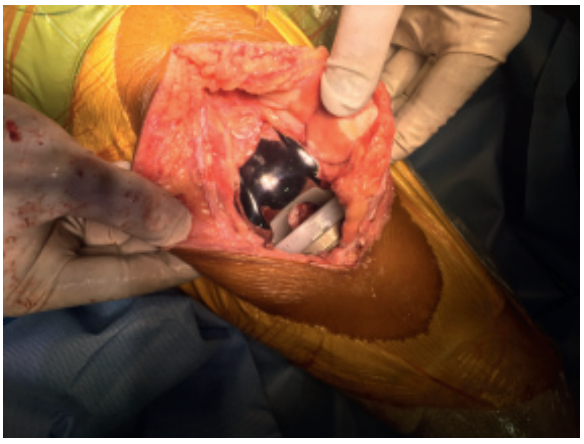

Fig. 1. Intra-operative image showing retained IPFP.

4. Discussion

Around 10% of the patients with a knee prosthesis have residual pain at various locations without any apparent cause. This pain is mostly anterior.[11–13] AKP may be caused by problems with patellar tracking, patella resurfacing and patella innervation.[4,14] Role of IPFP is less understood and its contribution to AKP is debatable. There have been various hypotheses implying or denouncing IPFP of its role in post-operative anterior knee pain. Also various clinical studies have shown conflicting results.

Exposure of the lateral tibial compartment is usually made difficult by the fat pad, and this sometimes requires partial or complete fat pad resection. Most of the surgeons choose to excise IPFP to gain wide exposure of the joint surfaces to facilitate placement of guiding and cutting instruments. Another advantage of resection of IPFP is favourable changes in patella-femoral biomechanics. In an examination of 20 cadaver knees, Bohnsack et al[15] reported that total resection of the IPFP resulted in a significant decrease in patellofemoral force, decreased contact

Table 4
Knee Society- functional score.

Knee society- functional score	Pre-op	6 weeks	3 months	6 months	1 year
Fat pad excised	60	77.40	79.24	91.98	91.98
Fad pad retained	60.89	78.44	79.77	91.11	91.11
p value	0.07	0.03	0.1	0.1	0.09

Table 5
Insall- Salvati Ratio.

Insall-Salvati Ratio	Pre-op	1 year
Fat pad excision	1.036	1.013
Fat pad retention	1.041	1.030
p value	0.47	0.027

Table 6
Range of motion.

Range of Motion	Pre-op	6 weeks	3 months	6 months	1 year
Fat pad excised	114.15	102.07	113.49	116.42	117.07
Fad pad retained	113.33	105.33	113.56	117.78	118.44
p value	0.32	2.5×10^{-5}	0.46	0.03	0.04

pressures, a reduction in peak pressures, decreased external rotation of the tibia and significant medialization of the patella. A few studies suggest that IPFP has dense nerve supply[16,17] and so resection of IPFP may decrease pain sensitivity. It has also been hypothesised that fibrosis of IPFP and inflammatory markers released it by may be the actual cause of AKP. Hence, its resection may reduce AKP.

Proponents of IPFP retention credit the cushioning effect of IPFP and preventing impingement of the patellar tendon over the tibial insert. There is also some evidence that its removal may result in complications such as patellar baja,[8] and limited knee ROM[10] due to scarring of the patellar tendon. It is also suggested that excision of IPFP may decrease vascularity of patella and cause avascular necrosis and fracture of the patella.[19] But the evidence is inconclusive.

In our study, HSS patella score was taken as a reflection of AKP, and in sequential follow-up upto 1 year after surgery no significant difference was found between the two groups. In published literature, various authors have reported conflicting results. A few studies claim to have increased AKP in fat pad excision group,[8,9] whereas a few others suggest vice-versa.[6] KSS and functional score followed a trend of similar results, although at 6 weeks post-operative period, group with fat pad retained had significantly better knee score. At later follow-ups no significant difference was present and at last follow-up of 1 year KSS was almost same. Most of the studies have reported equivalent KSS in both the groups.[8,9]

A few studies suggest that intraarticular fibrosis and scarring after IPFP excision caused patellar tendon shortening.[10] Our results reiterate the same. In the group with IPFP excision, patellar tendon shortening, as reflected by Insall-Salvati ratio, and ROM of knee were slightly decreased. But this did not reflect in the Knee score as this decrease was minimal.

Very rarely complications like avascular necrosis and patellar fracture have been reported in literature after excision of IPFP.[14] In our studies there were no such complications, similar to most of the published literature.

We recognize the limitations of this study. First, the operating surgeons for both the groups were different which could lead to difference in post-operative results. Though, both the surgeons used similar operative techniques and same prosthesis design, a randomised trial by a single surgeon operating on both the groups; or a large sample size with multiple surgeons in both the groups, could be more reliable evidence. Second, anterior knee pain is a subjective measurement. We used HSS patella score as a reflection of knee pain as it forms the most important component of the scoring system. But perception of pain and causing difficulty in routine activities is a very subjective felling and is largely affected by the personality of the patient. Thirdly, we used the Insall-Salvati ratio as a surrogate measure for patellar tendon shortening, which may not be a reliable parameter for postoperative TKA because osteophyte removal around the patellar bone can affect the patellar bone length.

5. Conclusion

Based on the results of our study, we believe that surgeons should retain the fat pad if excellent exposure can be achieved, but resect it if needed to improve exposure during TKA. Difference in outcome is minimal and functionally insignificant.

A randomised controlled trial (RCT) by multiple surgeons would have provided much more robust and clinically applicable results. An RCT would have also allowed for a higher level comparison of the impact of an intact versus resected IPFP. In future, larger studies, directed specifically at the question of anterior knee pain after TKA, may shed further light on this important topic.

Conflict of Interest

None.

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Further reading

Grelsamer RP. Patella baja after total knee arthroplasty: is it really patella baja? *J Arthroplasty*. 2002;17:66–69.

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Research paper

Osteoarthrosis knee: Need for a simplified prognostic knee score

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ABSTRACT

Osteoarthrosis is the commonest joint disorder. There may be variations depending upon the type of joint involved and amount of loading of joint. Weight bearing joints appears to have a higher predisposition as compared to other joints. The treatment modalities for symptom relief vary from nonpharmacological to pharmacological and surgical interventions. The type of intervention required depends mainly on the amount of joint destruction which can be quantified clinically and radiologically. Knee joint is one of most common joints affected in destructive pathology and taken for the most invasive procedure i.e joint replacement. Treatment choice is based on clinical evaluation,radiological changes and patient specific scores. Osteoarthritis of knee can be primary or secondary and symptoms complex can be quantified using various scales like WOMAC, HSS, KOOS, OKS and KSS. The radiological criteria of Kellgren and Lawrence can be applied to assess the extent of destruction. The two extremes of all criteria explains the normal and worst conditions. No criteria explains the amount or the type of intervention needed for a particular stage of disease. All criteria being nonuniform and diverse. The other most important thing being difficult utility and tredious scoring system. The present need is a single, easy,clinically validated scoring system which combines clinical,radiological and patient reported variables which can guide treatment interventions and has the ability to prognosticate the disease. New score (KALIA AND RAINA Score) can be recognised as a new assessment tool in evaluating a patient for osteoarthrosis knee in future.

1. Introduction

Osteoarthrosis of knee is the result of physiological change occuring in the joint and causing unwanted symptom complex that corerelate poorly with the disease. About 13% of women and 10% of men aged 60 years and older have symptomatic knee OA.[1] The proportions of people affected with symptomatic knee OA is likely to increase due to the aging of the population and the rate of obesity/overweight in the general population.[1] Females, particularly those ≥55 years, tended to have more severe OA in the knee.[2] The structural determinants of pain and mechanical dysfunction is explained by multiple interactive pathways.[3–6]

The pathological cascade involves decrease in water content of joint cartilage, fibrillations of joint cartilage and destructive changes in cartilage architecture, abnormal bony osteophytes and bony spurs. The symptoms worsen with increasing age and cause a chronic morbid condition. The predisposition is higher in cases with previous joint inflammatory or infective pathology, trauma, chronic abnormal stress and irregular loading of joint. African Americans had slightly higher prevalence of knee symptoms, and symptomatic knee OA, and significantly higher prevalence of severe radiographic knee OA compared to Caucasians.[7] The pathological changes can be quantified in terms of clinical and radiological criteria. Radiographic criteria were proposed by Kellgren and Lawrence in 1957[8] and those criteria were later accepted by the World Health Organization at a symposium held in Milan in 1961.[9] Lequesne has proposed sets of clinical criteria for OA in several specific joints.[10,11].

Numerous classifications are available to quantify the disease in terms of either symptoms and signs or radiological aspect of disease. The literature shows some scales being practiced to grade knee osteoarthritis includes WOMAC, KOOS, OKS, HSS, KSS and K-L system. Review of scores shows difficult in utility, less practical applicability, difficult to remember, uneven group and subgroup score and unspecified treatment guidence.

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The present study aims at designing and assessing the utility analysis of a new scoring system for osteoarthrosis knee which includes the criteria of a ideal scoring system.

- Complete assessment of pathology which includes patient specific complains or parameters, Physician specific assessment or examination findings, radiological grading of pathological process and type of modality needed to treat a particular stage of disease.
- It should be easy to remember and use. It must have easiest possible practical utility in assessment of the disease and can be applied in a minimum possible time.
- It should be widely applicable to all group of populations.
- It must have minimum possible interobserver variability.
- It must have both internal and external validity.

New score (KALIA AND RAINA score) can be recognised as a new assessment tool in evaluating a patient for osteoarthrosis knee in future.

1.1. WOMAC score

Western Ontario and MacMaster Universities Arthritis Index (WOMAC),[12–14] is a widely used set of questionnaire used to evaluate the condition of patient with knee arthritis, chiefly a patient rated scale. Its drawbacks include lack of physician rating, radiological and treatment component involved. The parameters being assessed are pain, stiffness and physical function. Involved parameters are further divided into multiple subgroups. Although the scale has classified many aspects of knee arthritis it lacks uniformity in grading of parameters and is difficult to remember and most important no radiological component involved and no treatment modality is taken into consideration.

1.2. KOOS score

Knee Injury and Osteoarthritis Outcome Score (KOOS),[14] is a patient based knee score to quantify the arthritic pathology. Lack of physician assessment, radiological aspect and treatment modality involved is one of important deficient factor. The components studied involves symptom complex, pain, function of daily living, functions of sports and recreational activities and quality of life involved. The score is being further complicated by dividing each parameter into non-uniform dimensions like symptom complex into five dimensions, stiffness into two dimensions,pain into nine dimensions, function of daily living into 17 dimensions, function of sports and recreational activities into 5 dimensions and quality of life into 4 dimensions. The score is very difficult to be utilizeb even in professional hands.

1.3. OKS score

Oxford Knee Score (OKS),[12,15,16,17] another knee is used to grade the knee function and is patient reported score with no physician specific, radiological and treatment specific modality involved, thus lacks the qualities of an ideal scale. The twelve parameters being assessed are all patient specific questions. The scale shows some uniformity but lacks the quality of assessing the disease load completely by omitting physician and radiological assessment and treatment modality to be needed for cure.

1.4. HSS score

Hospital for Special Surgery Rating System (HSS),[18] devised a knee arthritis scoring system which is chiefly a patient and physician specific criteria. The scale involves total five parameters with two patient specific parameters- pain, functional limitation and three physician specific parameters- tenderness, impingement and range of motion. No component of radiological assessment and ideal intervention needed is explained, thus lacking the criteria of an ideal scoring system. The score also appears to be non-uniform as there is uneven distribution of each parameter included in score.

1.5. KSS score

Knee Society Score (KSS),[12] a widely prevalent and commonly used scoring system is a patient and physician based system. Parameters being assessed are pain, range of motion, stability. Each being further divided with 50 points for pain, 25 points for range of motion and 25 points for stability. As like other scales it lacks the radiological assessment and does not guide the modality of treatment appropriate for the stage of the disease.

1.6. K–L system

Kellgren and Lawrence Grading System,[8] is a radiology based assessment system adopted in 1957 to quantify the pathological burden. The severity grades ranges from 0 to 4 with increasing severity of radiological changes. Grade zero is normal joint with no pathological involvement. Grade 1 and grade 2 involves findings of joint space narrowing and osteophyte formation with "Probable or Possible" and "Definite" terminology used for grade1 and 2 respectively. Grade 3 and 4 are further aggravation of disease

Table 1
Knee scores with Assessment Parameters and possible limitations.[12–18]

Parameters	WOMAC	KOOS	OKS	HSS	KSS	K—L
Patient specific	Pain, Stiffness, Physical Function	Symptoms, Pain, Function, Quality of life	Pain, Physical activity	Pain, Function	Pain	–
Physician specific	–	–	–	Tenderness, Impingement, ROM	Stability, ROM	–
Radiological, Parameters	–	–	–	–	–	Osteophytes, Joint space narrowing, Bony deformity
Suggested Treatment, Modality	–	–	–	–	–	–
Limitations	No physician assessment, No radiology assessment, No treatment guidence	No physician assessment, No radiology assessment, No treatment guidence	No physician assessment, No radiology assessment, No treatment guidence	No radiology assessment, No treatment guidence	No radiology assessment, No treatment guidence	No patient assessment, No physician assessment, No treatment guidence

process with multiple osteophytes, significant joint space narrowing and "probable and definite" bony deformity respectively. The classification system appears to be uniform, widely applicable, easily remembrable and usable in majority of patients. As illustrated in Table 1, the distribution of components in all subgroups for various scores available for knee osteoarthrosis and possible limitations seen by authors (PR and RBK).

Western Ontario and MacMaster Universities Arthritis Index (WOMAC), Knee Injury and Osteoarthritis Outcome Score (KOOS), Oxford Knee Score (OKS), Hospital for Special Surgery Rating System (HSS), Knee Society Score (KSS), Kellgren and Lawrence Grading System(K-L).

The other important scores like Lysholm,International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC), Activity Rating Scale (ARS) and Tegner activity scale are chiefly used to grade early age post traumatic knee pathology. Osteoarthritis being age related physiopathological process is associated with both bony and soft changes. So grading system should have both components involved in it.

1.7. Osteoarthrosis–associations and implications

Osteoarthrosis is a age related degenerative process which vary with differences in age group, race, sex, physical loading and pathologic affections of joint. Inflammatory pathologies like rheumatoid arthritis, ankylosing spondylitis, psoriatic arthritis, villonodular synovitis and infections like tuberculosis alter the normal physiologic process and has residual sequelae ending with degenerative changes in joint. To design a scale, it must have all components like patient specific complains, physician assessment factors, radiological assessment and most important being treatment modalities to treat the disease complex.

1.8. Development of new knee score (KALIA and RAINA score)

The aim of present study is to design the simplest possible scoring system for osteoarthritic knee. The study conducted in a tertiary care hospital with a hospital based cohort analysed for knee complains. The patients of both sexes with age group more than 30 years with isolated knee complains were analysed for their complains. Analysis by all authors were considered to design a simple rationale. A total of about 430 knees over period of ten months were assessed and examined to reach a final grading based scoring system.

Step 1: Assessment of Patient complains (Patient Score)

On analysis of hospital cohort with knee complaint, three complaint were considered finally to constitute the total patient score. The three complains are pain knee, swelling knee and stiffness of the knee. The chief complain associated with osteoarthritis knee is pain. It is also a common criteria in all scales like WOMAC,KOOS,OKS,HSS and KSS. It is seen that pain is not continuous and is usually activity related and varies with each individual. It can be simplified as resting pain, household pain and exertional pain. Other associated complaint in a osteoarthritis patient are swelling and stiffness which can be occassional or persistant. The value of total score is kept at maximum of five scores and minimum value being zero. So patient specific complains can be simplified in the form of scale as shown in Table 2 reflecting all possible symptom complex in patients with knee osteoarthrosis. All parameters included was evaluated by authors PR and RBK in study cohort.

Step 2: Assessment by Treating Physician (Physician Score)

Outpatient assessment protocol was followed for the same patient group. A comprehensive assessment tool was formulated keeping the spectrum of all findings seen in all stages. Total score is kept to a maximum of five points and minimum being zero.

Analysis shows that pathologic signs involving the joint which needs specification by physician includes local tenderness over joint, mediolateral instability, mediolateral deformity and range of motion. It can be simplified in terms of scale as shown in Table 3 involving all possible clinical assessment parameters need to be assessed by examiner in a osteoarthritic knee patient. The score not quantifies the each component and relies on presence/absence of sign as evaluated by authors.

Step 3: Radiographic assessment of patient (Radiological Score)

The present study involves assessment of knee radiographs taken as weight bearing involving anteroposterior and lateral views only. No special views were included. The assessment was done by the treating authors. No expert radiologist was involved for the radiological assesssment. The total score is kept to maximum of five points and minimum score zero.

Assessment shows the commonest pathological changes occuring in an osteoarthritic knee joint with Kellgrence Lawrence reviewed includes joint space narrowing and osteophytes. Associated changes seen can be subchondral osteopenia or sclerotic changes and osteochondral fractures. It can be quantified in a scale as illustrated in Table 4. Table 4 shows the visible findings to be assessed in a knee radiograph in patients with knee osteoarthritis as reflected by study cohort and evaluated by authors PR and RBK. The parameters relates to findings as mentioned by Kellgren-Lawrence except knee subluxation as seen in advance stage arthritic knees. Figure 1 (AP view)taken from study cohort reflecting isolated medial articular space narrowing

Table 2
Patient Specific complains assessed in study cohort.

Symptom	Score
Pain	
Exertional Pain/Household Pain/Resting Pain	3/2/1
Swelling	1
Stiffness	1

Total Score (Patient Specific)–5, Maximum score is 5. If specific symptom is absent it can be graded as zero.

Table 3
Physician Specific Factors assessed in study group population.

Sign	Score
Tenderness	
Medial or lateral joint line	1
Patellar grind	1
Mediolateral	
Instability (valgus/varus laxity)	1
Deformity (varus/valgus)	1
Range of motion	
Nonfunctional ($<120^{\circ}$)	1

Total Score (Physician specific assessment)–5, Maximum score is 5. If specific sign is absent it can be graded as zero.

Table 4
Radiological assessment parameters evaluated in study group population.

Radiological Finding	Score
Joint space narrowing	
Medial	1
Lateral	1
Osteophytes	
None	0
Minimal	1
Diffuse	2
Subluxation	1

Total Score–5, Maximum score is 5. If specific finding is absent it can be graded as zero.

Fig. 1. Shows early isolated medial compartment joint space narrowing (score 1).

when compared with lateral articular space in same knee radiograph. Figure 2 (AP view)taken from same study cohort illustrating the distribution of osteophytes in medial and lateral knee compartments as reflected in patient radiograph. Figure 3 (Lateral view) taken from study cohort illustrates the distribution of parapatellar osteophytes in a arthritic knee. Figure 4 (AP view)

Fig. 3. Shows distribution of osteophytes in Lateral radiograph.

shows the articular subluxation causing varus angulation and isolated medial joint space narrowing in a osteoarthritic knee as visible in study patient radiograph.

Fig. 2. Shows distribution of osteophytes in AP radiograph.

Fig. 4. Shows subluxation of knee in advance stage arthritis.

Step 4: Assessment of Treatment modalities (Staging of Treatment)

A wide range of modalities are available for treatment of knee osteoarthritis. The type of modality needed depends on stage of disease. Review of literature and classification systems shows no mentioning of any stage specific treatment system.

The chief modalities available for patients affected with osteoarthritis involving knee joint can be broadly classified in three stages. It can be nonoperative group, intervention group and surgical group. Modalities involved in nonoperative group includes braces, physiotherapy, muscle strengthening, physical therapy and oral pharmacological drugs. It can be considered as first stage and usually applied in every patient. The second stage includes borderline group between nonoperative and joint replacement group. It involves modalities like local intraarticular steroid injections, collagen building preparations, joint preserving procedures like arthroscopic debridement, high tibial osteotomy and unicompartment knee replacement. The third stage or final stage involves joint with widespread destructive changes with limited joint preserving procedures available. The treatment modalities usually involves bicompartment or tricompartment knee replacement. On analysing the patients with stage two treatment modality needed,a subset of patients between stage 2 and 3 shows isolated medial compartment arthritis. The same group shows the minimum score of 9 and maximum reaching upto 10 points. The type of modality needed includes high tibial osteotomy or unicompartment knee replacement. The subgroup was categorised as a special part of total score and needs B2 treatment modality. The proposed classification in the form of a scoring system is shown in Table 5, involving mainly three stages of treatment modalities needed for patients with osteoarthrosis knees. As listed in Table 5 the treatment modalities ranges from noninvasive to semi-invasive and radical in extreme cases. The subgroup score for each stage being evaluated on analysing the patient cohort involved in study by authors PR and RBK.

1.9. Practical utility and statistical analysis

The study involves hospital based cohort of 430 knees analysed over a period of 10 months to design the simplest possible practically applicable, treatment based knee score for osteoarthritic knee.

The score was applied on a subgroup of patients with age group more than 30 years and no defined upper limit. A total of 100 cases with 70 patients were included for statistical analysis. The mean age was 56.4 years. A random selection of patients was done who presented to orthopedic out patient department, the primary complain being isolated unilateral or bilateral knee pains. Sex distribution involved 30 males and 40 females. Age distribution was assessed and included 24 patients (30 cases) with age less than 50 years,36 patients (46 cases) with age between 50 to 70 years and 10 (24 cases) patients with age more than 70 years. A total of 30 patients have bilateral knee pains. Fourty patients presented with unilateral knee pain only which included 30 patients with age group less than 60 years and ten patients with age group more than 60 years. VAS for pain was assessed and involve less than 4 in 32 patients (40 cases),4–8 in 30 patients (45 cases) and more than 8 in 8 patients (15 cases). The patients were assessed by two different well skilled orthopedic surgeons independently. The first surgeon evaluated the patient and assessed the new knee score with documentation (Evaluation—A). The second examiner/skilled orthopaedic surgeon independently assessed the patient the decided his own treatment modality with documentation preserved (Evaluation—B). Table 6 enumerates the demographic variables studied in study comprising mainly sex distribution,age distribution and side affected. The outpatient based assessment of visual analogue scale (VAS) was performed and recorded in all cases by involved authors.

Table 5
Treatment modality followed as per New knee score.

Stage	Modality
Stage 1	
Score 0–5	Nonoperative group Includes braces, physiotherapy, muscle strengthening, physical therapy and oral pharmacological drugs
Stage 2	
Score 6–10	Intervention group Local intraarticular steroid injections, collagen building preparations, joint preserving procedures like arthroscopic debridement and high tibial osteotomy, unicompartment knee replacement
Stage 3	
Score 11–15	Bicompartment or Tricompartment knee replacement

Table 6
Demographic Variables involved in the present study group population.

Parameter			
Sex distribution	Males	Females	
	30	40	
Age distribution	<50	51–70	70 and above
	30 cases	46 cases	24 cases
Side involved	Unilateral	Bilateral	
	40	30	
VAS score	<4	4–8	>8
	40 cases	45 cases	15 cases

1.10. Evaluation A

Table 7 shows the results of new score application on study cohort with result values reflected as three subgroups. The total score for each subgroup ranges from minimum of one to maximum of five as shown in Table 7. Table 8 illustrates the total score and

Table 7
Assessment of parameters of New knee score.

Score	Number of Patients		
	(Patient score)	(Physician score)	(Radiology score)
1	18	9	9
2	14	34	17
3	24	28	33
4	17	16	26
5	27	3	5

Table 8
Assessment of total score in present study group patients.

Total Score	Number of Patients	Treatment modality
0–5	18	A
6–8	33	B 1
9–10	18	B 2
11–15	31	C

Table 9
Table showing application of available scores and clinical criterias by second examiner and results.

Treatment modality selected	Number of patients
A	22
B 1	23
B 2	21
C	34

treatment modality needed in patients as guided by KALIA and RAINA score. The treatment modalities was divided in three main groups ranging from noninvasive to semi-invasive and finally replacement group. Subgroup B involved patients with variable overlap with need of semi-invasive to invasive modalities as evaluated in study cohort by authors.

1.11. Evaluation B

Table 9 illustrates the results of assessment of knee complains for same study group by independent senior surgeon with more than ten year orthopaedic experience. The patients were evaluated using clinical assessment and application of old knee scores for severity assessment and concluding the treatment modality needed. The data was collected for evaluation by author PR, recorded in microsoft excel software and statistical analysis done. Data was analysed statistically using Chi Square method and calculating inter-observer aggrement (Cohen's kappa coefficient).

Chi square test is used to find the significance of difference in number of patients requiring various treatment modalities. The null hypothesis was assumed that the difference between data from Examiner A and Examiner B is not significant.

2. Results

A total of 100 knee cases with 70 patients were included to analyse the new score results. Evaluation A by first examiner shows 18 knees needing treatment modality A, 33 knees needing B 1 treatment modality, 18 knees needing B 2 treatment modality and 31 knees needs modality C for treatment. An independent evaluation by examiner B with no score applied and treatment modality selected on basis of clinical and radiological evaluation shows results with 22 knees needing treatment modality A, 23 knees as modality B 1, 21 knees as modality B 2 and 34 knees needs treatment modality C. Analysis shows comparing Chi square value (0.469) with the reference value for a degree of freedom of 3, the null hypothesis turned out to be true i.e difference in number of patients as suggested by the evaluation A and evaluation B for specific treatment modality is not significant.

Inter-observer aggrement (kappa) was calculated using the same data (Table 10), results shows a unweighted kappa value of 0.88 (Standard Error = 0.0289,95% CI = 0-0.056). Landis and Koch guidelines applied to assess the strength of kappa coefficient shows almost perfect agreement. (0.01–0.20 slight,0.021–0.40 fair,0.41–0.6 moderate,0.61–0.80 substantial,0.81–1.00 perfect).

Analytic process involving the study cohort concluded with generation of new knee score (KALIA and RAINA score) as shown in Table 11. The score comprises cheifly of four main groups with three groups analysing the disease burden and fourth being treatment guiding group. The score reflects the analytic results drawn over a group of study cohort in a tertiary care hospital by authors PR and RBK. Table 12 illustrates the comparative analysis of new new score verses tedious versions of other scores available in literature.

Table 10
Data for Chi Square Analysis in present study group population.

Treatment modality	Number of Patients	
	(Evaluation A)	(Evaluation B)
A	18	22
B 1	33	23
B 2	18	21
C	31	34

Table 11
Osteoarthritis New Knee Score (KALIA and RAINA Score).

Symptom (Patient Score)	Score
Pain	
Resting Pain/Household Pain/Exertional Pain	3/2/1
Swelling	1
Stiffness	1
Sign (Physician Score)	Score
Tenderness	
Medial or lateral joint line	1
Patellar grind	1
Mediolateral	
Instability (>5 mm)	1
Deformity (>10°)	1
Range of motion	
Nonfunctional (<120°)	1
Radiologic Finding (Radiology Score)	Score
Joint space narrowing	
Medial	1
Lateral	1
Osteophytes	
Minimal/Diffuse	1/2
Subluxation	1
Stage	Modality
Stage 1	
Score 0–5	(A) Nonoperative Group Includes braces, physiotherapy, muscle strengthening, physical therapy and oral pharmacological drugs
Stage 2	
Score 6–10	(B) Intervention Group B1–Local intraarticular steroid injections, collagen building preparations, joint preserving procedures like arthroscopic debridement and B2–high tibial osteotomy, unicompartmental knee replacement
Stage 3	
Score 11–15	(C) Bicompartment or Tricompartment knee replacement
Type of Arthritis	D- Degenerative T- Traumatic R- Rheumatoid P- Psoriatic O- Others

Total score can be written as 2 parts; Score + Type. Eg 7R–score 7 with rheumatoid knee with stage 2 intervention needed.

Table 12
Number of parameters involved in all scales with comparison to number of primary groups and subgroups involved in old scores and New knee score.

Score	Number of Parameters/Items
KOOS	42 items across 5 subscales
OKS	12
WOMAC	24
HSS	4 primary 1 secondary and numerous subgroups
KSS	3 primary 8 subgroup
New score (KALIA and RAINA Score)	4 primary groups

3. Discussion

Osteoarthrosis of knee joint is an inevitable pathological change occuring in joint complex involving patellofemoral joint and femorotibial joint. Numerous variations in symptom complex and treatment modalities are seen depending upon the geographical area. The predisposition appears to be higher in advance age group, increased body weight, high loading of joint and traumatic events.

Patients with OA are at a higher risk of death compared with the general population.[12] History of diabetes, cancer, or cardiovascular disease and the presence of walking disability are major risk factor.[19] The economic costs of OA are high, including those related

to treatment, for those individuals and their families who must adapt their lives and homes to the disease, and those due to lost work productivity.[20] Previous knee trauma increases the risk of knee OA 3.86 times.[21]

The pathological changes in osteoarthritis knee occur over a long duration of time and causes gradually worsening of symptoms and functions.The radiological findings follow the same sequence with worsening trend with time. The treatment modalities vary from one patient to other depending on stage of osteoarthritis. The commonly used modalities include Nonoperative including braces, physiotherapy, muscle strengthening, physical therapy[22,23] and oral pharmacological drugs,[24,25] local intraarticular steroid injections, collagen building preparations,[26,27,28] joint preserving procedures like arthroscopic debridement[29–34] and high tibial osteotomy[35] and in final stages partial or total knee replacement.[36,37]

Literature review shows numerous criteria used to grade the intensity of pathological process. It includes criteria like Western Ontario and MacMaster Universities Arthritis Index (WOMAC), Knee Injury and Osteoarthritis Outcome Score (KOOS), Oxford Knee Score (OKS), Hospital for Special Surgery Rating System (HSS), Knee Society Score (KSS), Kellgren and Lawrence Grading System(K-L). WOMAC is 96 point based score with 3 components-pain 0–20 points, stiffness 0-8 points, physical function 0-68 points. The ideal scoring system must be simple enough to be easily applied. It must include all components of pathological process including symptom complex, signs elicited by physician and if possible imaging component. The goal of every grading system is to decide the type of intervention needed. It is seen that no score critically mentions the types of procedures needed for a particular stage of disease. This new scoring system aims at classifying the osteoarthritis in a simplified process and grading the pathological process in all respects including patient specific factors, surgeon specific findings and radiological assessment of disease. The score also suggests the intervention to be needed at a particular stage of disease.

First component of score includes patient specific factors or patient's aspect of disease. The primary complain seen in patient with osteoarthritis knee is pain found to be universal and seen in 100% of patients. It can be graded in a simplified version as of three main types firstly, exertional pain which occurs on activities like prolonged walking,jogging,after attending social activities or in a simple manner can be called as pain during outside home activities. Second type of pain include household pain occuring during routine household work like sitting,squatting, posture change,walking stairs etc. Third type is the resting pain, which is the worst type, with persistant pain through out the day with no relation to routine activities. Present scale grades maximum points for resting pain. Other complain in a patient with osteoarthritis knee include swelling which can be occassional or persistant. Occassional swelling usually presents as swelling following prolong rest and usually persists less than a hour and decrease with activity. Knee stiffness can be perceived as heaviness or increased resistance to movement usually accompanied with swelling or can be a isolated complain in a patient with osteoarthritis knee. Table 13 illustrates the authors method of eliciting history and prevalance of specific symptom complex in study cohort.

Table 14
Physician specific score assessment (Author criteria).

Physician specific score measured with patient lying supine in bed	
Joint line tenderness	it can medial/lateral joint line
Patellar grind	It can be taken positive if • Patellar tenderness on grinding test • Cracking/roughening sensation due to degeneration of cartilage felt on patellar grind • Patellar facet tenderness present
Mediolateral instability	It is measured with knee in 30 degree flexion and seen for opening of joint and taken positive if joint opening more than 5 mm
Mediolateral deformity	It is measured with knee in extension and goniometer used to see for variation in femur and tibia axis
Range of motion	It can be taken positive if • Knee range of motion less than 0 to 120 degree • Any grade of knee flexion deformity

Second component involved in scale includes physician assessment of pathological process. It includes joint line tenderness. It shows the initiation of pathological process. Medial side being more weight bearing appears to be usually affected early. Some cases show the early or gradual involvement of lateral joint line with appearance of tenderness. Patellar grind tenderness asseses the condition of patellofemoral joint with tenderness either appearing on grinding manouver or eliciting the patellar facet tenderness can be a diagnostic tool. Second factor which needs to be assessed include mediolateral instability or deformity. Arthritic process gradually erodes the medial/lateral supporting structures leading to either instability or deformity. Both conditions coexist in a single patient. Mediolateral instability due to collateral insufficiency is specifically examined in 30 degree knee flexion. Joint opening more than 5 mm or 1+ is graded as abnormal. Abnormal mediolateral abnormality includes varus or valgus alignment of knee more than 10 degrees. Third factor to be assessed in patient is the range of motion which includes 0–140 degree for normal knee joint. It can decreased either in form of loss of terminal range of motion to be compared with opposite knee or in form of loss of terminal extension. Both conditions may be coexistant in a single patient. To perform activities of daily living like squatting and sitting,minimum of 120 degree range of motion is needed. Knee range of motion less than 0 to 120 degrees is graded as abnormal as per present scale. Table 14 shows the author specific clinical parameters used and their method of assessment as done in present study group by involved authors (PR and RBK).

The third component include visible or radiological aspect of pathological process. The changes mainly include the gradual

Table 13
Patient specific score assessment (Author criteria).

No attempt should be made to examine knees	
Pain	Resting pain–patient asked about the perception even on lying down position/needs analgesics for rest or not Household pain–pain perceived on routine essential activities of daily living Exertional pain–pain even on mild outdoor walking activities or prolong exertional activities
Swelling	Patient is asked whether he/she perceives any swelling in knee joints whether during early morning hours or during prolonged activities which may be short duration (less than half hour usually seen) or may be persistent
Stiffness	Patient asked about whether he/she perceives any stiffness or heaviness in knee joints during routine movements or postural change activities

Table 15
Radiographic assessment of score.

Standing radiographs of both knees should be taken for assessment	
Joint space narrowing	• Medial compartment joint space should be compared with lateral compartment • Both knees x-rays should be compared for joint space
Osteophytes	It includes the visual inspection of following areas: • Medial tibia articular surface • Lateral tibia articular surface • Medial femur articular surface • Lateral femur articular surface • Suprapatellar articular region • Infrapatellar articular region • Posterior osteophytes should not be included for assessment
Subluxation	Marginal Femoral-Tibial medial and lateral axis should be drawn to look for any incongruity of articular surface in AP x-ray view

degeneration of articular cartilage leading to visible joint space narrowing on radiograph. The usual trend is narrowing of medial joint space followed by involvement of lateral joint space in age related osteoarthritis knees. Rheumatoid knee usually presents with early lateral compartment joint space narrowing. Pathologies like tuberculosis and villonodular synovitis affects the both compartments simultaneously. Abnormal bone formation in form of osteophytes appearing near the articular area occur as a sequelae of degenerative process. Increasing number and size proportionate the progress of degenerative process. Common locations being tibia bony margins,femoral bony margins and supra and infrapatellar articular margins. Visible osteophytes upto three or less than three are graded as score 1. Visible osteophytes more than three in both views are graded as score 2. Arthritic subluxation of joint usually apparent in late stages is graded as score 1being an important parameter and not included in Kellgren-Lawrence classification system. Table 15 illustrates the author specific criteria for observing radiological findings in study group patients. Kellgren-Lawrence classification in literature acts as a guide for assessment of the radiological parameters.

The fourth component or the treatment group includes the modality of intervention needed depending on the stage of pathological process. The modalities varies from simple muscle strengthening exercises to invasive procedure of joint replacement. Intervening joint preservation modalities like high tibial osteotomy and arthroscopic joint debridement may be needed in mid stage disease to prolong the need of joint replacement surgery. The choice of procedure varies from one patient to other and can be patient specific, physician specific or disease specific. It can be pharmaceutical drugs in form of analgesics in age related osteotrthritic knee or can be DMARDS in rheumatoid knee. Treatments methods can vary among the surgeons with same grade of knee complains and with same knee score like literature supports both high tibial osteotomy and unilateral knee replacement for early stage unicompartmental knee arthritis. Table 16 illustrates the total score specific assessment of treatment modality needed for osteoarthritic knees as evaluated in study group using criterias involved in New knee score.

Table 16
Assessment of treatment modality (New knee score).

Assessment of treatment modality	
A (Score—0–5)	Physiotherapy, Drugs
B 1 (Score—6–8)	Injection steroids or collagen building preparations locally Arthroscopic joint debridement
B 2 (Score—9–10)	Surgical intervention needed High tibial osteotomy Unicompartment knee replacement
C (Score11–15)	Bicompartment or Tricompartment knee replacement

Another parameter to be included in new score involves the cause of arthrosis. Primary arthritis simply called as osteoarthritis is age related, others being rheumatoid joint disease,psoriatic joint disease and traumatic arthritis. The new simplified score can be written in a summerised form to indicate the type of pathology, example 7R indicates score seven with rheumatoid knee involvement with stage two intervention needed.

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC),[13] a 100 point scale, chiefly a patient reported scoring system is most commonly used for assessing changes in patient reported outcomes related to post traumatic osteoarthritis in older population. The score has been shown to be valid,reliable and sensitive to change over time. The limitations of score being no physician assessment component and no radiology survey included. The score has no guide for treatment intervention needed. Althrough the score is available in several languages but has been shown to take as average of 10 to 15 minutes to complete.

Knee Injury and Osteoarthritis Outcome Score (KOOS)[14] first published in 1998, a 100 point score shows same limitations being only a patient reported outcome, no guide for treatment modality and needs a relatively longer time (10 to 15 minutes) to apply.

New knee score (KALIA and RAINA score) when applied to the patient cohort under study needs no extra time to quantify the disease process. The score is part of routine patient asessment process and aids in quantifying the pathological burden.

Chi square analysis shows value 0.469 compared with the reference value for a degree of freedom of 3, the null hypothesis turned out to be true i.e difference in number of patients as suggested by the evaluation A and evaluation B for specific treatment modality is not significant.

Inter-observer aggrement (kappa) was calculated and shows a unweighted kappa value of 0.88 (Standard Error = 0.0289,95% CI = 0–0.056). Landis and Koch guidelines applied to assess the strength of kappa coefficient shows almost perfect agreement.

The analysis of score shows a significant group of cases 18 (18%) in evaluation A group and 21 (21%) in evaluation B group were graded to need B 2 modality of treatment. The reason being the medial compartment involved early in degenerative process and needs for isolated intervention in the form of axis correcting high tibial osteotomy or may be unicompartment knee replacement.

The limitations of score are 1) No standard similar scoring system to compare treatment prognosis 2) Needs a large number of patients to evaluate the results 3) External validity needs to be evaluated in future.

New score explains the role of patient complains,physician assessment and radiology in evaluating a patient with knee osteoarthritis. It has a role in guiding the type of intervention needed for a particular stage of disease. It can be considered for osteoarthritic evaluation in future.

4. Conclusion

Osteoarthrosis knee assessment involves a number of parameters which can be isolated patient based as involved in WOMAC, KOOS,OKS scale,combined patient and physician based as included in HSS,KSS scale,isolated radiological as explained by Kellgren and Lawrence criteria. No criteria combines the all parameters and explains the intervention needed. New simplified knee score hes combined all the parameters in a simplified way including patient complains,physician assessment factors and visible radiographic appearence. Based on all assessment parameters new score guides

the intervention method needed as well. New score (KALIA AND RAINA Score) can be recognised as a new assessment tool in evaluating a patient for osteoarthrosis knee in future.

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Research paper

Comparison of psychometric properties of subjective structured assessment instruments of technical performance during knee arthroscopy

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ABSTRACT

Objectives: Various subjective assessment global rating scales to assess proficiency of surgeons while performing knee arthroscopy have been described but it is still unclear as to which of the assessment scale is the most optimal and "gold standard". The aim of the present study was to compare and contrast psychometric properties like validity and reliability of objective assessment global rating scales for knee arthroscopy.

Methods: A systematic review was performed of articles published in Pubmed, Embase, AMED, ERIC, Proquest and CINAHL. Ten assessment scales (Arthroscopic surgery skill evaluation tool [ASSET]; Arthroscopy skills score; global ratings of arthroscopic performance; basic arthroscopic knee scoring system [BAKSS]; modified basic arthroscopic knee scoring system [modified BAKSS]; modified objective structured assessment of technical skill [modified OSATS]; modified objective assessment of arthroscopic skills [modified OAAS]); modified orthopaedic competency assessment project [modified OCAP; Imperial global arthroscopy rating scale [IGARS] and Injury grading index [IGI] fulfilled the inclusion criteria. A predefined checklist was used to compare content validity, construct - convergent validity, construct - discriminant validity, criterion validity, predictive validity, internal consistency, inter-rater reliability, intra-rater reliability and test-retest reliability of all the included assessment global rating scales.

Results: The ASSET demonstrated optimal number of satisfactory psychometric properties of content validity, construct-convergent validity, construct - discriminant validity, criterion validity, internal consistency, inter-rater reliability, intra-rater reliability and test-retest reliability. The IGI demonstrated the least number of satisfactory psychometric properties.

Conclusion: We recommend the use of Arthroscopic surgery skill evaluation tool [ASSET] as it demonstrates optimal psychometric properties. The ASSET can be used as gold standard to compare existing outcome assessment tools.

1. Introduction

Knee arthroscopy is a specialized surgical procedure which entails a learning curve. Various methods have been devised to enhance training of the trainee surgeons like human cadaver knees, bench top simulator models and virtual reality knee simulator models with haptic force feedback capabilities.

Assessment of competency to perform knee arthroscopy can be done using subjective methods and objective methods. Subjective methods include using a global rating scale with predetermined criteria and task specific checklist having predetermined criteria. Objective methods include 3D Motion analysis metrics or 3D Motion analysis parameters and time taken to complete the surgical procedure or particular task. Evaluation using 3D Motion analysis metrics or 3D Motion analysis parameters needs external camera and other additional devices for performing the motion analysis and these devices are costly. Subjective methods of assessment are cheaper, practical and feasible to administer in the

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clinical and laboratory setting. Though subjective assessments entail risk of bias, efforts have been made to reduce the element of subjectivity by introducing a global rating scale (GRS) wherein various domains and attributes are marked on a predetermined rating assessment sheet with the aim to make the subjective assessment more objective and reduce the element of subjectivity. Of the two commonly used subjective assessment methods, the GRS is better than the task specific checklist because the GRS is able to discriminate between trainees of varying expertise level whereas the checklist is unable to discriminate between them[1].

Validity and reliability are crucial psychometric properties for any assessment tool[2].

There have been systematic reviews evaluating psychometric properties of competency assessment tool in microsurgery[3], laparoscopic surgical skills[4], laparoscopic cholecystectomy[5] and vascular surgical skills[6]. A systematic review had identified deficiency of validated outcome instruments to assess competency of arthroscopic surgery skills[7]. This was probably due to lack of having a standardized check list for evaluation of various psychometric properties like validity and reliability. Moreover, lot of literature has been available recently pertaining to assessment of competency of knee arthroscopy. Hence, the objective of the present study was to find out the objective global rating scale assessment of performance of knee arthroscopy having the most optimal psychometric properties.

2. Methods

2.1. Institutional HREC approval

The study proposal was reviewed by the hospital research ethics committee and granted exemption as it was a systematic review of published literature that was already available in the public domain.

2.2. Literature search

Literature search was performed of electronic databases comprising Pubmed, Ovid (Embase/AMED [Allied and complementary medicine]/ERIC [Education resources information centre]), Proquest and CINAHL using the following keywords: "knee arthroscopy competency"; "knee arthroscopy competence"; "knee arthroscopy skills"; "knee arthroscopy global rating scale"; "knee arthroscopy proficiency" and "objective structured assessment of technical skill". The electronic search consisted of screening of all articles published from 1990 to December 2016. The last date for performing the literature search was 20th of December 2016.

2.3. Inclusion and exclusion criteria

The studies that used a structured assessment tool (global rating scale) to evaluate performance of technical skills of novice and/or expert orthopaedic surgeons during knee arthroscopy and described validity or reliability or both of the assessment tools were included in the systematic review. Non-English language studies, studies that did not report validity or reliability of the global rating scale assessment method or used irrelevant statistical method, studies focussing on non-technical skills like communication skills, studies dealing with proficiency assessment of arthroscopy of joints other than knee joint, conference proceedings and literature reviews or expert opinions were excluded from the systematic review.

Table 1
Checklist to evaluate psychometric properties of GRS in individual studies.

Psychometric property	Positive rating (+) Adequate	Doubtful rating (?)	Negative rating (−) Inadequate	Nil rating (0)
Content validity	Explicit mentioning of the process of choosing domains relevant to knee arthroscopy surgical skils [Literature review/textbook review/expert knee arthroscopy surgeons/sports medicine fellowship trained surgeons opinion obtained using either Delphi method or focus group discussion] [9]	No involvement of experts in the development process [13]	Experts consider items in the final version of GRS to be irrelevant OR consider the GRS to be incomplete	No information on content validity
	Experts consider all items in the GRS to be relevant and consider the final version of the GRS to be complete	Doubtful method. Modification of pre-existing GRS by addition/ deletion		Process of selection of various domains in assessment of knee arthroscopy not mentioned
Construct − convergent validity	Correlation with related constructs/instruments measuring the same construct >/= 0.50 [11–13]	Correlations determined with unrelated construct	Correlation with instruments measuring the same construct/ related construct < 0.50[11–13]	No information on construct − convergent validity
	Statistical significant (p </= 0.05) result and there was prespecified hypothesis	Statistical significant result but no pre-specified hypothesis	Statistically insignificant result	
Construct - discriminant validity	Able to discriminate various groups. Able to show significant difference between groups	Doubtful design or method	Unable to discriminate various groups statistically despite adequate design and method.	No information on construct − discriminant validity
Criterion validity	Correlation coefficient >/= 0.70 [(11)]	No convincing argument that gold standard is indeed gold std/Doubtful design and method	Correlation with "gold standard" < 0.70 despite adequate design and method [11]	No information on criterion validity
Internal consistency	Cronbach's alpha between 0.70 and 0.95 [11]	Doubtful design or method	Cronbach's alpha < 0.70 or > 0.95 despite adequate design and method [11]	No information on internal consistency
Reliability (Inter-rater reliability/Intra-rater reliability/Test retest reliability)	ICC or Weighted kappa >/= 0.70 [11]OR Pearson's correlation coefficient >/= 0.80 [12,13]	Doubtful design or method (e.g time interval between readings not mentioned)	ICC or Weighted kappa < 0.70 [11]OR Pearson's correlation coefficient < 0.80 despite adequate design and method [12,13]	No information on reliability

2.4. Data extraction and tabulation

For studies that were included in the systematic review, following data was collected pertaining to the study (name of the journal, authors, year of publication, type of model on which the structured assessment tool (global rating scale) was studied [cadaver/bench top simulator/virtual reality simulator], type of setting [operating theatre {OT}/bioskills laboratory {Lab}], type of procedure assessed using the global rating scale [diagnostic knee arthroscopy/partial menisectomy/loose body retrieval/ACL reconstruction/meniscal repair], sample size) and the global rating scale (original version or any modification of the original version, domains (psychomotor/knowledge/affective) and proportion contribution of various domains, number of items, ease of scoring [easy method/complex calculation], mode of assessment [direct observation/video recording of intra-articular arthroscopic view/external video recording of hand movements], number of assessors, type of assessors [medical student/trainee doctors/trainers/unspecified], training given to assessors [yes/no], validity and reliability). Domains were subdivided into psychomotor technical skills domain, knowledge domain and non-technical skills domain like communication skills and ability to remain calm while performing knee arthroscopy.

2.5. Definition of psychometric terms

Content validity refers to the ability of the structured global rating scale to assess all relevant skill domains required by surgeons for successfully performing knee arthroscopic procedure. Validity can be broadly subdivided into three main categories: content validity, construct validity and criterion validity. Content validity refers to the ability of the structured GRS assessment to assess all relevant skill domains required for competency in knee arthroscopy[8]. Construct validity refers to the ability of the structured GRS assessment to assess the level of knee arthroscopic surgical expertise. Convergent validity[8] and discriminant validity[4] are variants of construct validity. Convergent validity assesses the strength of correlation between the points scored on the GRS and other similar and related constructs[8]. Discriminant validity pertains to the ability of an assessment score to discriminate between different levels of expertise of surgeons either based on designation, years of experience or training on different modalities like cadaver knee, bench top simulator or virtual reality simulator[4]. Criterion (concurrent) validity refers to the extent of correlation between points scored on the GRS and another related construct or assessment method or assessment parameter that could be considered as "gold" standard[8].

Internal consistency refers to the extent of correlation between various items of the GRS to each other[9]. Inter-rater reliability is the extent to which two or more assessors tend to agree on performance of a candidate (multiple assessors view performance of the same candidate for a single time)[9]. Intra-rater reliability is the extent to which the same assessor agrees with own assessment on the same candidate on viewing performance of the same candidate after a specified duration of time (the same assessor views single performance of the same candidate two times, usually using a recorded DVD)[10]. Test retest reliability refers to the agreement of GRS score when the same test is taken twice by the same candidate within a short time interval and when the performance of the candidate is not expected to have changed much (the same candidate performs the knee arthroscopy twice between short duration of time wherein the surgical skill of the candidate is not expected to have changed much)[9,10].

2.6. Criteria for assessment of psychometric properties

The evaluation of psychometric properties of the subjective structured GRS was done using a checklist. No standard checklist exists to evaluate psychometric properties of assessment tools to evaluate psychomotor skills and technical skills while performing surgical procedures. Hence a checklist (Table 1) was devised trying to amalgamate optimal features from various previously reported studies[9,11–13]. Finally, the evidence for psychometric properties from individual studies were summarised into a rating criteria and interpretation of the data of various GRS was done as per the following rating criteria (Table 2).

3. Results

3.1. Electronic search and study selection

Fig. 1 shows the flow diagram of electronic search, study selection, exclusion of irrelevant titles and data extraction process. Twenty one full text articles comprising of ten structure assessment GRS satisfied the inclusion criteria (Arthroscopic surgery skill evaluation tool [ASSET]; Arthroscopy skills score; global ratings of arthroscopic performance; basic arthroscopic knee scoring system [BAKSS]; modified basic arthroscopic knee scoring system [modified BAKSS]; modified objective structured assessment of technical skill [modified OSATS]; modified objective assessment of arthroscopic skills [modified OAAS]); modified orthopaedic competency assessment project [modified OCAP; Imperial global arthroscopy rating scale [IGARS] and Injury grading index [IGI] fulfilled the inclusion criteria and were compared for various types of validity and reliability.

The ASSET was the most commonly used GRS for assessment (8 studies)[14–21] followed by modified BAKSS (5 studies)[19,26–29], BAKSS (2 studies)[24,25] and modified OAAS (2 studies).[30,31] Arthroscopy

Table 2
Rating criteria to compare and summarize evidence for psychometric property of various GRS.

Rating	Criteria
A (Satisfactory evidence)	One study (if only one study evaluated the GRS)/Majority of the studies (if more than one study evaluated the GRS) consistently gave positive rating for the particular psychometric property
B (Unsatisfactory evidence)	One study (if only one study evaluated the GRS)/Majority of the studies (if more than one study evaluated the GRS) consistently gave negative rating for the particular psychometric property
C (Conflicting evidence)	Conflicting evidence. One study gave positive rating whereas another study gave negative rating.
D (Doubtful evidence)	Doubtful evidence due to doubtful methodology (statistical measure not described completely)
O (No evidence)	The particular psychometric property has not been reported in any study

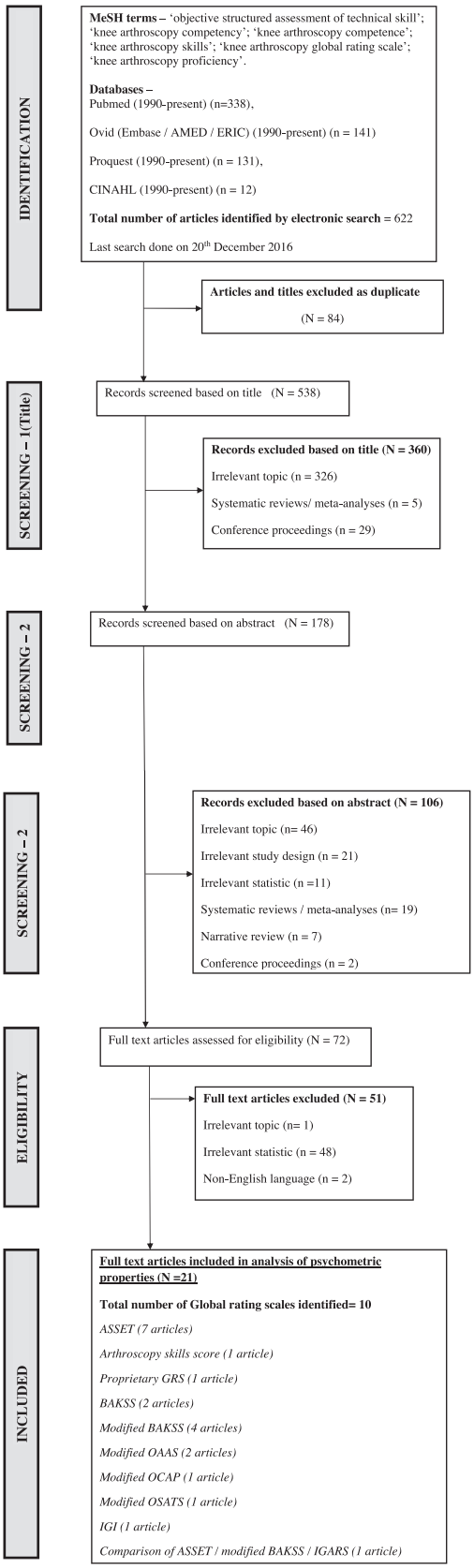

Fig. 1. shows the process of literature search and identification of various GRS.

skills score,[22] Proprietary GRS[23], modified OCAP[32], modified OSATS[33], IGARS[19] and IGI[34] were used in only one study each.

3.2. Characteristics of structured GRS

Fig. 2 shows proportional contribution of various domains to the overall GRS score in the ten GRS that are included in the present study.

Modified OCAP was the only GRS to have nontechnical skills domain items like acting calmly, appropriately using surgical assistants and effectively communicating with the scrub nurse. BAKSS, modified BAKSS, modified OCAP, modified OSATS and IGARS had items from the knowledge domain as well. The percentage composition of the knowledge domain items to the overall score ranged from as low as 11% (modified OCAP) to as high as 25% (modified OSATS). The percentage composition of knowledge domain items in BAKSS and IGARS was 20% and in modified BAKSS the percentage contribution was 22%. Psychomotor technical skills were least assessed by modified OCAP as the percentage composition for technical skills domain was only 56% followed by modified OSATS wherein the contribution was 75% and modified BAKSS wherein the contribution was 78%. BAKSS and IGARS had a modest contribution of 80% from items belonging to psychomotor technical skills domain.

3.3. Evaluation of psychometric properties of the structured GRS

3.3.1. Content validity

Content validity was assessed in nine assessment tools. The ASSET, Proprietary GRS, BAKSS, modified OAAS and IGARS[35] were given positive rating because of their robust methodology to establish content validity (Table 3).

Arthroscopy skills score, modified BAKSS, modified OCAP and modified OSATS were given doubtful rating due to inferior methodological quality or doubtful methodology in the study. The modified BAKSS was devised by excluding one item pertaining to soft tissue dissection from the BAKSS tool because the authors of modified BAKSS felt that the item of soft tissue dissection was not relevant for knee simulators as the portals were already made prior to the study and it was common to all participants[26]. However, the modified BAKSS was subsequently revised in two studies[19],29 wherein various domains were excluded and these modifications and revisions were done by the authors (institutional experts) of the study and there is no mention of the method to gain consensus amongst the institutional experts. The OSATS global rating scale has been validated in laparoscopic surgeries and other surgical procedures. The authors modified the OSATS to suit the 9 items of orthopaedic competency assessment project (OCAP)[32]. There is no mention of how consensus was obtained from all the experts for the creation of modified OCAP tool. The OSATS global rating scale described by Reznick et al[36] had 7 items. 1 item (use of assistants) was removed and 2 items (overall performance and quality of final product) were added by the authors to form the modified OSATS tool[33]. There is no mention of how consensus was obtained from all the institutional experts for the creation of modified OSATS.

The IGI was given nil rating because there was no mention of validation of content of the assessment tool[34].

3.3.2. Construct (convergent) validity

ASSET [14,15,17], Proprietary GRS[23], BAKSS[24,25], modified BAKSS[29], modified OAAS[30,31] and modified OSATS[33] had positive rating for construct convergent validity (Table 3). There were no information on convergent construct validity of Arthroscopy skills score, modified OCAP, IGARS and IGI and hence nil rating was given to them.

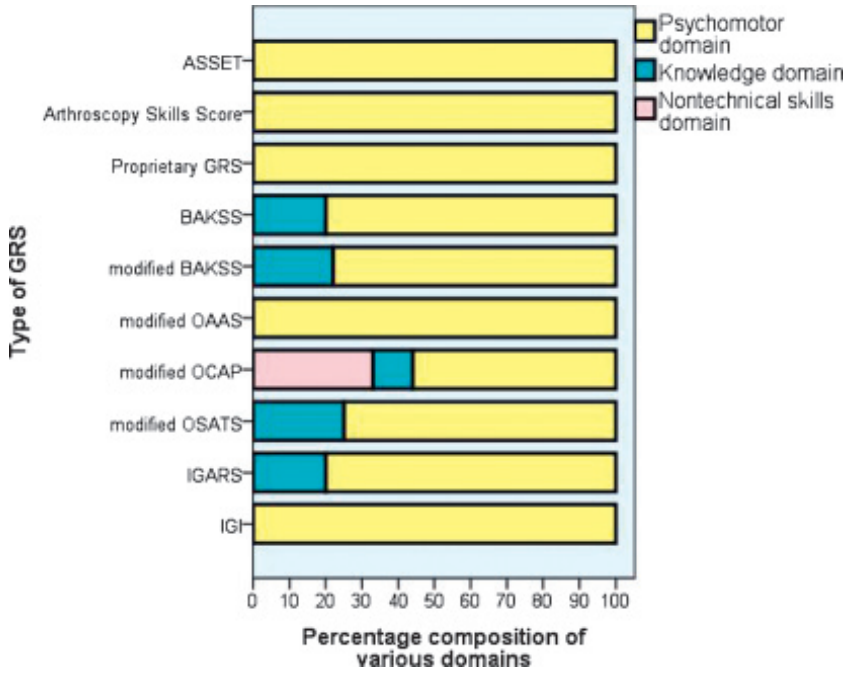

Fig. 2. shows percentage composition of various domains of the included GRS.

3.3.3. Discriminant (construct) validity

Discriminant validity was reported for all assessment tools except the IGI (Table 3). ASSET, Arthroscopy skills score, BAKSS, modified BAKSS, modified OAAS, modified OCAP and modified OSATS had positive rating for having adequate discriminant validity. The Proprietary GRS was unable to discriminate between simulator trained and non-simulator trained surgeons and hence given negative rating due to inaedquate discriminant validity[23]. For modified OAAS, one study[30] revealed adequate discriminant validity whereas another study[31] showed inadequate discriminant validity. For assessment of discriminant validity of modified BAKSS, results of four studies[19,26,28,29] suggested adequate discriminant validity whereas discriminant validity reported in one study[27] appeared to be indeterminate due to doubtful methodology and result reporting.

3.3.4. Criterion validity

Motion analysis has been found to have validity as an objective assessment tool of surgical skill of surgeons[19,32]. Hetaimish et al defined criterion validity as the correlation between simulator generated results and other assessment tools[37]. Another recent systematic review concluded that the most common objective assessment instruments were time to complete the task followed by path length traversed by the surgeon's hand and the number of collisions[38].

Criterion validity was evaluated in five assessment tools (Table 3) and four tools –ASSET, modified BAKSS, modified OSATS and IGARS were found to have adequate criterion validity and were given positive rating. Criterion validity of BAKSS was evaluated in one study[25] however analysis of criterion validity in that study was found to be lacking as per our checklist and hence, it was given negative rating. As there was no study evaluating criterion validity of arthroscopy skills score, proprietary GRS, modified OAAS and modified OCAP, they were all given nil rating.

The criterion validity of Modified BAKSS was evaluated in two studies[19,26]. Alvand et al.[26] demonstrated adequate criterion validity by demonstrating statistically significant strong correlation between the GRS and prevalence of instrument loss, triangulation time and prevalence of look downs. The virtual reality simulator used in the study by Middleton et al.[19] had capability to measure dexterity metrics like total time/camera path length/instrument path length. There was significant correlation between modified BAKSS score and time taken for various tasks and total path length. Though the authors did not claim this as criterion validity, we can infer the presence of criterion validity based on the above adequate evidence.

One study[19] demonstrated adequate criterion validity of ASSET. Two studies claimed that ASSET had adequate criterion validity however as per our checklist both studies had doubtful methodology and were given doubtful rating. The authors of one study[14] claimed concurrent validity by showing ability of the total ASSET score to differentiate performance of surgeons with different levels of experience. This, we think, is a measure of discriminant validity and not criterion validity. Dwyer et al[17] mentioned that concurrent validity was established by showing positive correlation between total ASSET score and the number of previous sports rotation, previous knee arthroscopy experience and previous ACL reconstruction experience. The above parameters as per our checklist constitute evidence for construct convergent validity and not criterion validity. One study[33] demonstrated adequate criterion validity of modified OSATS and demonstrated that higher score correlated with shorter procedure time and higher score correlated with shorter equipment movement distance. One study[19] demonstrated adequate criterion validity of IGARS by describing significant correlation between IGARS score and time taken for various tasks and total path length.

Objective motion analysis is considered the gold standard and motion analysis data was obtained using an electromagnetic motion tracking system in the study by Alvand et al[25]. There was significant moderate correlation between GRS and three motion analysis parameters (time taken to complete the procedure, total path length travelled by the trainee's hands, total number of hand movements during arthroscopy) but the values of correlation coefficients ranged from 0.51 to 0.58. This study evaluated criterion validity of BAKSS however the value of the correlation coefficient was found to be lower than the threshold value of 0.70 as per our

Table 3
shows comparison of different types of validity of various GRS.

Name of GRS	Author, Reference	Content validity	Construct–convergent validity	Discriminant validity	Criterion validity
ASSET	Koehler et al, Am J Sports Med 2013 [14]	+	+ {r = 0.76 and 0.83}.	+ 3 groups [PGY1 2/PGY3 4/PGY5 & Consultant]	?
	Koehler et al, JBJS Am 2013 [15]	+	+ ROC showed > 35 scopies to attain pass mark in ASSET.	+ 2 groups [Pass/fail]	0
	Koehler et al, Arthroscopy 2015 [16]	+	0	+ 4 groups [PGY3/PGY4/PGY5/Consultant]	0
	Dwyer et al, Am J Sports Med 2015 [17]	+	+ {r = 0.58, 0.65, 0.71, 0.73}.	+ 4 groups [PGY1 2 3/PGY4 5/fellow/ Consultant]	?
	Camp et al, JBJS Am 2016[18]	+	0	+ (p = 0.002). Cadaver group	0
	Middleton et al, JBJS Am 2016 [19]	–	0	+ 3 groups [novice{no scopy exp}/trainee{<100 scopy}/expert{>100 scopy}]	+ {r = 0.757 to −0.949} {r = −0.641 to −0.936}
	Roberts et al, KSSTA 2016 [20]	-	0	+ 3 groups [novice{no scopy exp}/trainee{<100 scopy}/expert{>100 scopy}]	0
	Dwyer et al, Arthroscopy 2016 [21]	+	0	+ 4 groups [PGY 1 2 3/PGY 4 5/fellow/ Consultant]	0
Arthroscopy skills score (ASC)	Elliot et al, Arthroscopy 2012 [22]	?	0	+ 3 groups [PGY 1 2/PGY 3 4 5/Staff]	0
Proprietary GRS	Cannon et al, JBJS Am 2014 [23]	+	+ {r = 0.59,0.65,0.72}	– 2 groups [simulator trained/non-simulator trained]	0
BAKSS	Insel et al, JBJS Am 2009 [24]	+	+ {r = 0.88, 0.93}.	+ 6 groups [PGY1/PGY2/PGY3/PGY4/PGY5/ fellow or consultant]	0
	Alvand et al, Arthroscopy 2013 [25]	+	+ (P< 0.0001). Prespecified hypothesis present	0	– {r = 0.51, 0.58, 0.58}
Modified BAKSS	Alvand et al, JBJS Am 2012 [26]	-	0	+ 3 groups [novice{no scopy exp}/resident{50-150 scopy}/expert {> 700 scopy}]	+ {r = 0.829, 0.830, 0.834}
	Butler et al, JBJS Am 2013 [27]	-	0	? no mention of p value	0
	Olson et al, CORR 2013 [28]	-	0	+ 2 groups [PGY1 2/PGY 3 4 5}	0
	Price, Bone Joint J 2015 [29]	(Revised modified BAKSS)	+ r = 0.92	+ 5 groups [novice/junior trainee/registrar/ fellow/consultant]	0
	Middleton et al, JBJS Am 2016 [19]	(Revised modified BAKSS)	0	+ 3 groups [novice{no scopy exp}/trainee{<100 scopy}/expert{>100 scopy}]	+ {r: 0.66 to 0.94} {r: 0.81 to 0.95}
Modified OAAS	S Shantz et al, Arthroscopy 2013 [30]	+	+ {r = 0.64, 0.97}.	+ 4 groups [novice/experienced resident/ fellows/faculty].	0
	Martin et al, CORR 2016 [31]	+	+ {r = 0.78; 0.80; 0.84}	- 3 groups [PGY1 2/PGY 3 4 5/fellow + faculty]	0
Modified OCAP	Howells et al, JBJS Br 2008 [32]	?	0	+ (p = 0.001) Simulator group	0
Modified OSATS	Chang et al, CORR 2016 [33]	?	+ {r = 0.80, 0.87}	+ 2 groups [med student yr 3 PGY 1 2 3/PGY 4 5 consultant]	+ {r = 0.57 to 0.92}
IGARS	Middleton et al, JBJS Am 2016 [19]	+	0	+ 3 groups [novice{no scopy exp}/trainee{<100 scopy}/expert{>100 scopy}]	+ {r = 0.673 to 0.943} {r = 0.796 to 0.951}
IGI	Rebolledo et al, AJSM 2015 [34]	0	0	0	0

checklist and hence, despite satisfactory methodology, the evidence for criterion validity was found to be lacking and hence it was given a negative rating.

3.3.5. Internal consistency

ASSET had the best evidence for internal consistency (Table 4). There was conflicting evidence for internal consistency of modified OAAS with one study[31] reporting adequate Cronbach's alpha value of 0.92 and 0.95 whereas another study[30] reported high Cronbach alpha value of 0.97. Due to the conflicting evidence, modified OAAS was given conflicting evidence rating for internal consistency. Doubtful rating was given for internal consistency of proprietary GRS as one study[23] mentioned that the value for internal

Table 4
showing comparison of different types of reliability of GRS.

Name of GRS	Author, Reference	Internal consistency	Inter-rater reliability	Intra-rater reliability	Test retest reliability
ASSET	Koehler et al, Am J Sports Med 2013 [14]	+ Cronbach's $\alpha = 0.94$	+ ICC = 0.79	0	+ r = 0.79
	Koehler et al, JBJS Am 2013 [15]	0	+ ICC = 0.83 {Agreement was on pass-fail status}	0	0
	Koehler et al, Arthroscopy 2015 [16]	0	+ ICC = 0.81 Kappa = 0.72 for pass/fail	0	? Inappropriate statistic
	Dwyer et al, Am J Sports Med 2015 [17]	? $\alpha > 0.90$. Value unspecified	+ ICC = 0.85	0	0
	Camp et al, JBJS Am 2016 [18]	0	− ICC = 0.68	0	0
	Middleton et al, JBJS Am 2016 [19]	0	+ Cronbach's $\alpha = 0.95$	+ Cronbach's $\alpha = 0.82$	0
	Roberts et al, KSSTA 2016 [20]	0	+ Weighted Kappa = 0.85	0	0
	Dwyer et al, Arthroscopy 2016 [21]	0	+ ICC = 0.9.	0	0
Arthroscopy skills score (ASC)	Elliot et al, Arthroscopy 2012 [22]	0	0	0	0
Proprietary GRS	Cannon et al, JBJS Am 2014 [23]	? Statistic = 0.89 (Statistic used unspecified)	+ Correlation between 2 raters: 0.71 to 0.97.	0	0
BAKSS	Insel et al, JBJS Am 2009 [24]	0	0	0	0
	Alvand et al, Arthroscopy 2013 [25]	0	+ Cronbach's $\alpha = 0.88$	0	0
Modified BAKSS	Alvand et al, JBJS Am 2012 [26]	0	+ Cronbach's $\alpha = 0.90$	0	0
	Butler et al, JBJS Am 2013 [27]	0	0	0	0
	Olson et al, Clin Orthop Relat Res 2013 [28]	0	+ Weighted Kappa ranged from 0.69 to 0.85.	0	0
	Price, Bone Joint J 2015 [29]	0	+ Cronbach's $\alpha = 0.81$	0	0
	Middleton et al, JBJS Am 2016 [19]	0	+ Cronbach's $\alpha = 0.93$	+ Cronbach's $\alpha = 0.87$	0
Modified OAAS	S Shantz et al, Arthroscopy 2013 [30]	− Cronbach's $\alpha = 0.97$	+ ICC = 0.78	0	− r = 0.52.
	Martin et al, Clin Orthop Relat Res 2016 [31]	+ Cronbach's $\alpha = 0.92,0.95$	0	0	0
Modified OCAP	Howells et al, JBJS Br 2008 [32]	0	0	0	0
Modified OSATS	Chang et al, Clin Orthop Relat Res 2016 [33]	0	0	0	0
IGARS	Middleton et al, JBJS Am 2016 [19]	0	+ Cronbach's $\alpha = 0.88$	+ Cronbach's $\alpha = 0.84$	0
IGI	Rebolledo et al, Am J Sports Med 2015 [34]	0	0	0	0

ICC: Intraclass correlation coefficient.

Table 5
shows comparison of overall evidence of psychometric properties of various GRS.

GRS	Content validity	Construct validity	Discriminant validity	Criterion validity	Internal consistency	Inter-rater reliability	Intra-rater reliability	Test retest reliability
ASSET	A	A	A	A	A	A	A	A
mBAKSS	D	A	A	A	O	A	A	O
IGARS	A	O	A	A	O	A	A	O
mOAAS	A	A	C	O	C	A	O	B
BAKSS	A	A	A	B	O	A	O	O
mOSATS	D	A	A	A	O	O	O	O
P-GRS	A	A	B	O	D	A	O	O
ASC	D	O	A	O	O	O	O	O
mOCAP	D	O	A	O	O	O	O	O
IGI	O	O	O	O	O	O	O	O

A = Satisfactory evidence; B = Unsatisfactory evidence; C = Conflicting evidence.
D = doubtful evidence; O = no evidence.

consistency was 0.89 but did not explicitly mention the name of the statistical measure used to evaluate internal consistency.

3.3.6. Inter-rater reliability

ASSET, proprietary GRS, BAKSS, modified BAKSS, modified OAAS and IGARS had a positive rating for inter-rater reliability (Table 4). Majority of the evidence for inter-rater reliability was available for ASSET with seven studies[14–17,19–21] demonstrating adequate inter-rater reliability and one study showed inadequate inter-rater reliability as ICC value was lower than the threshold value of 0.70[18]. It is worth noting that two studies on inter-rater reliability of ASSET demonstrated excellent inter-rater reliability between blinded and unblinded assessors [17,21]. Second highest evidence for inter-rater reliability was available for modified BAKSS with four studies[19,26,28,29] demonstrating adequate inter-rater reliability.

3.3.7. Intra-rater reliability

ASSET, modified BAKSS and IGARS had positive rating for intra-rater reliability (Table 4). Arthroscopy skills score, proprietary GRS, BAKSS, modified OAAS, modified OCAP, modified OSATS and IGI were given nil rating due to the lack of evidence of intra-rater reliability.

3.3.8. Test-retest reliability

ASSET was the only assessment tool to have positive rating for test retest reliability (Table 4). Two studies investigated the test retest reliability of ASSET and one study[14] demonstrated adequate test retest reliability whereas another study[16] had doubtful methodology for description of result and was given doubtful rating as assessment was done using repeated measures analysis of variance using Bonferroni correction (neither intraclass correlation coefficient nor correlation coefficient were used).

3.3.9. Current evidence (Table 5)

The ASSET demonstrated optimal number of satisfactory psychometric properties (8 out of 8 points) of content validity, construct-convergent validity, construct–discriminant validity, criterion validity, internal consistency, inter-rater reliability, intra-rater reliability and test-retest reliability. Next to ASSET, modified BAKSS and IGARS demonstrated the higher number of satisfactory psychometric properties. Modified BAKSS has been evaluated in many studies compared to IGARS. The IGI demonstrated the least number of satisfactory psychometric properties (0 out of 8 points).

4. Discussion

The present study critically appraised psychometric properties of objective global rating scales used to evaluate competency in knee arthroscopy. The aim of the present study was to help the reader to make decision regarding the selection of the most appropriate objective global rating scale to evaluate competency in knee arthroscopy. Another strong reason to recommend the use of ASSET is that all the items (100%) of the ASSET measure psychomotor domain whereas in modified BAKSS and IGARS only 78% and 80% items respectively evaluate the psychomotor domain.

The initial systematic review[7] published in 2013 included BAKSS, mOCAP, mOAAS and Arthroscopy skills score. There was only one article for each of the above GRS. The review did not mention use of checklist/criteria to evaluate adequacy of various psychometric properties of validity and reliability. It is probably due to the combination of the above factors that the review identified the deficiency of validated assessment tools for knee arthroscopy. In contrast, our present updated systematic review includes ten knee arthroscopic assessment tools which have been reported in literature. Our study tried to critically appraise the literature to evaluate psychometric properties of various GRS using an independent checklist which was prepared by incorporating criteria from previously published work[9,11–13]. A predetermined checklist was used for critical appraisal of various psychometric properties from individual studies and also to summarise the evidence compiled from various studies. Our study has been successful in terms of highlighting the benefits and deficiencies of various assessment tools and also has identified the best validated knee arthroscopic assessment tool.

Contrary to popular belief that deleting domains from assessment instruments could potentially lead to reduced validity and reliability, revised and modified versions of ASSET and modified BAKSS showed contrary results. Middleton et al showed that modified version of ASSET showed satisfactory discriminant validity, criterion validity, inter-rater reliability and intra-rater reliability despite exclusion of two out of eight domains[19]. Roberts et al showed that modified version of ASSET showed satisfactory discriminant validity and inter-rater reliability despite exclusion of one out of eight domains[20]. Price et al demonstrated that the revised version of modified BAKSS showed satisfactory construct validity, discriminant validity and inter-rater reliability despite excluding four out of ten domains[29]. Middleton et al demonstrated that the revised version of modified BAKSS showed satisfactory discriminant validity, criterion validity, inter-rater reliability and intra-rater reliability despite excluding four to five out of ten domains[19]. GRS have been modified by various authors arguing that arthroscopic surgery skill is a pure motor skill and must not include knowledge base. Knowledge of anatomy and knowledge of procedure can be assessed using other methods of evaluation like theoretical examination or viva voce examination. Other possible solution to reliably assess knowledge of anatomy and procedure include just like the driving test, the trainees can vocalize name of the structures seen during diagnostic knee arthroscopy. In the lab setting, they can ask an assistant who can simulate a theatre assistant to give instruments like probe, punch, knife etc. These can be recorded along with the video recording of intra-articular view.

Presently, there is no gold standard method for evaluation of psychometric properties like validity and reliability of assessment tool of surgical skill. The interpretation of values of various psychometric properties were based on the work by Terwee et al[11] which was mainly for clinical outcome instruments (patient reported outcome instruments, clinician reported outcome instruments and combined patient and clinician completed instruments). COSMIN checklist[39] is used to critically evaluate methodological rigour of studies reporting psychometric properties of health measurement tools and there is a need to develop similar evaluation checklist for assessment tools of surgical competency and proficiency. We rated the evidence as "satisfactory", "unsatisfactory", "doubtful" or "no" evidence. Satisfactory evidence could also be further graded as weak, moderate or strong evidence. Lack of guidelines to evaluate methodological quality of studies evaluating psychometric properties of assessment tools of surgical competency poses challenge in a systematic review of this nature.

There are no studies reporting predictive validity of GRS. Predictive validity pertains to the ability of a GRS to predict future performance of the trainee. The GRS should be administered prior to training and also administered at the end of training to see whether the GRS is able to capture any improvement in the psychomotor skills of knee arthroscopy.

5. Conclusion

We recommend the use of Arthroscopic surgery skill evaluation tool [ASSET] as it demonstrates maximal psychometric properties

of different types of validity and reliability. It solely measures the relevant psychomotor domain that pertains to surgical and technical skills relevant to knee arthroscopy. The ASSET can be used as gold standard to compare existing competence assessment tools.

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Conflict of interest

None.

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Research paper

Our experience in first 100 cases of endoscopic carpal tunnel release: An Indian perspective

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ABSTRACT

Purpose: This study was done to determine the role of endoscopic carpal tunnel release in the treatment of carpal tunnel syndrome and also to note the conversion rates of endoscopic to open release, causes for conversion and to analyse the learning curve of the operating surgeon for endoscopic procedure.
Methods: A total of 100 consecutive idiopathic carpal tunnel cases were included who had undergone preoperative ultrasonography (USG) for assessment of carpal tunnel morphology. All patients were primarily scheduled for a standard single portal endoscopic release after excluding the contraindications for endoscopic carpal tunnel release (ECTR). The conversion rate of endoscopic to open carpal tunnel release (OCTR) was analysed and reasons for conversion were established by an independent observer.
Results: Out of 100 patients, 74 (74%) underwent endoscopic release and 26(26%) underwent mini-open release. The conversion rates from endoscopy to open was noted to be 26%. Distal edge not being visualized in 14 cases (53%) was the most common cause for conversion followed by tight canal hindering the insertion of the scope in four cases (15.3%). In the first fifty cases in our study, 20 cases were converted to open release which amounted to 40% conversion rate, but in the next 50 subset of patients the conversion rates had dropped to 13.3%.
Conclusion: Endoscopic carpal tunnel release can be accepted as the treatment of choice for the surgical decompression of carpal tunnel owing to decreased postoperative complications. One of the major limitations of the ECTR is the slow learning curve of a surgeon. Difficulty to visualise the distal edge of TCL was most common cause for conversion. With increasing experience of a surgeon in endoscopic release, the conversion rates would decrease.
Level of study: level 4, decision analysis

1. Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of the upper limb with a reported prevalence of 6% in the general population.[1]

The treatment of carpal tunnel syndrome is either conservative or surgical. Conservative treatment is generally offered to patients suffering from mild to moderate symptoms and ranges from oral medication, splinting and steroid injection.[2] surgical treatment includes open or endoscopic release of transverse carpal ligament. Open carpal tunnel release has been considered the operative procedure of choice for decompression of the median nerve in CTS. There has been an increasing trend in treating CTS patients with endoscopic carpal tunnel release (ECTR) as it is claimed to be associated with minimal pain and scarring due to small incision with rapid recovery and early return to work .[3] Steep learning curve and possibility of damaging the surrounding neurovascular structure are few complications of ECTR.[4]

This study was done with an aim to determine the role of endoscopic carpal tunnel release in the treatment of carpal tunnel syndrome. The objective of the study was to note the conversion rates of endoscopic to open release, causes for conversion and to analyse the learning curve of the operating surgeon for endoscopic procedure. We hypothesised that the learning curve of the surgeon would improve as more cases were performed and subsequently, the conversion rates would reduce.

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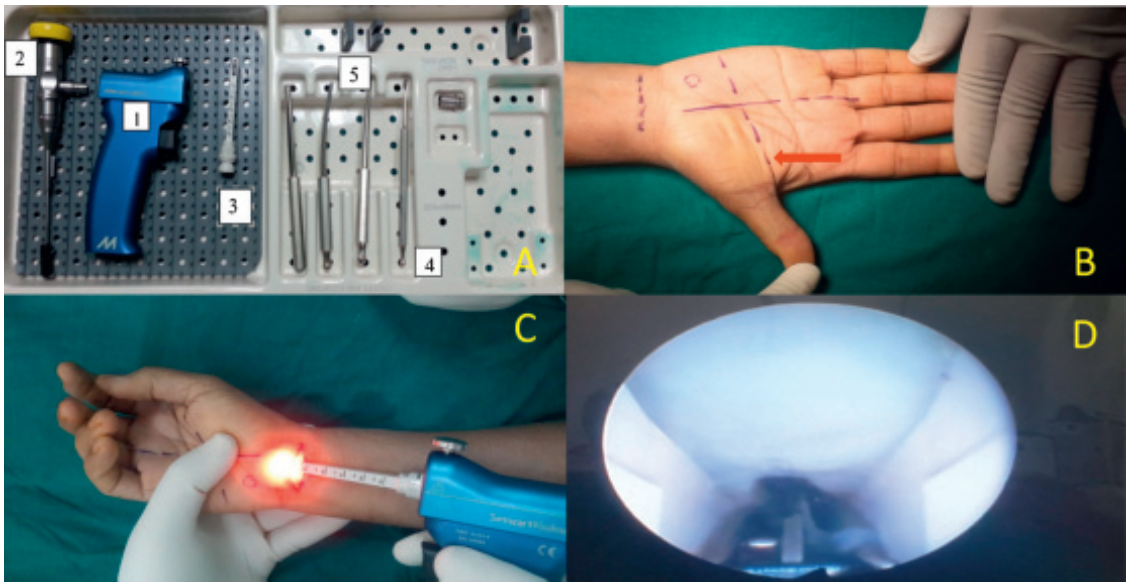

Fig. 1. Standard single portal endoscopic release. A- endoscopic carpal tunnel set {1: hand piece with trigger, 2: 3 mm eye piece endoscope, 3: disposable endoscopic knife, 4: synovial elevator, 5: hamate finder and serial canal dilators}. B- Kaplan's line {red arrow}. C- insertion of scope into the carpal tunnel. D- endoscopic view of distal edge of transverse carpal ligament being divided].

2. Materials and methods

This was a prospective study done in which we analysed 100 consecutive patients with idiopathic carpal tunnel syndrome. Patients who did not improve after a trial of conservative management with splinting and analgesia for a minimum period of six weeks and those patients who consented for undergoing either open or endoscopic release surgery were included. The study was conducted after obtaining approval from the institutional ethics committee.

Previously operated case of carpal tunnel syndrome, patients who required tenosynovectomy and those with space-occupying lesions, patients with localized infection and inflammatory joint disease, trauma to the affected hand and those with anatomical variations identified by preoperative ultrasound imaging were all excluded from the study.

All patients were assessed for clinical findings like thenar atrophy, tinel's sign, altered sensations and provocative tests like Phalen's test, reverse Phalen's test, Durkan's test and Gilliat's test for diagnosis of carpal tunnel syndrome followed by nerve conduction velocity studies.

Patients then underwent preoperative ultrasonography for the assessment of carpal tunnel anatomy and morphology. Ultrasonography (USG) was done by a single senior radiologist specialised in musculoskeletal radiology. The purpose of performing an USG was to assess the carpal tunnel anatomy prior to performing endoscopy. The operating surgeon trained in hand surgery remained blinded for the results of ultrasound of the carpal tunnel. All patients were taken up primarily for standard single portal endoscopic carpal tunnel release (Fig. 1). The conversion rate of the endoscopic to open carpal tunnel release (OCTR) was analysed and the reasons for the conversion were established by an independent observer.

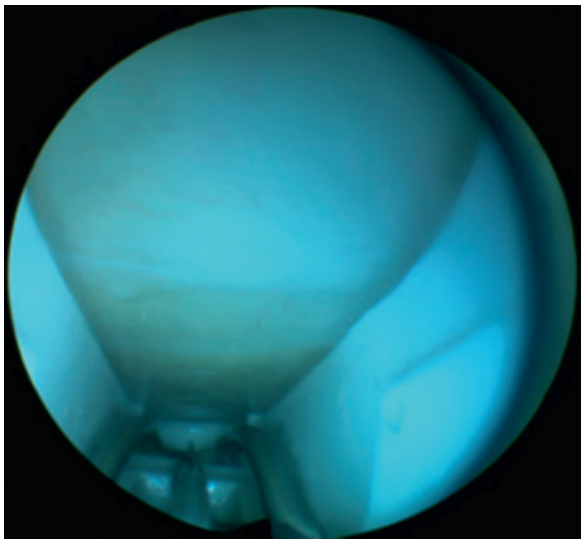

Fig. 2. Distal edge of TCL not visualized.

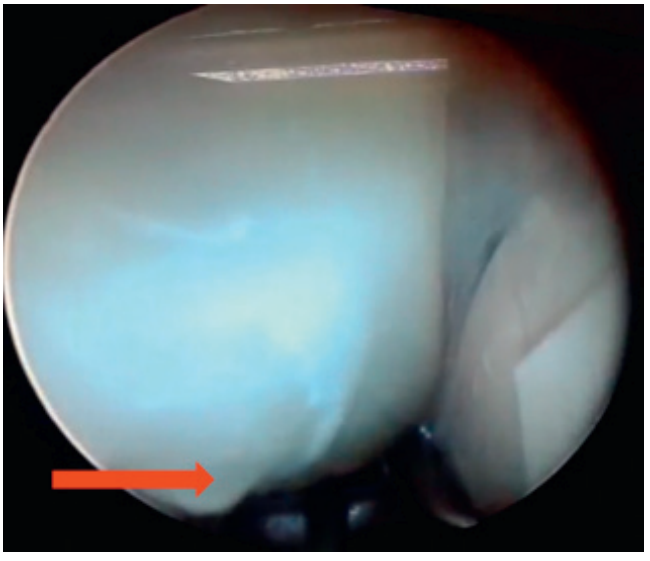

Fig. 3. Fat pad prolapse [red arrow].

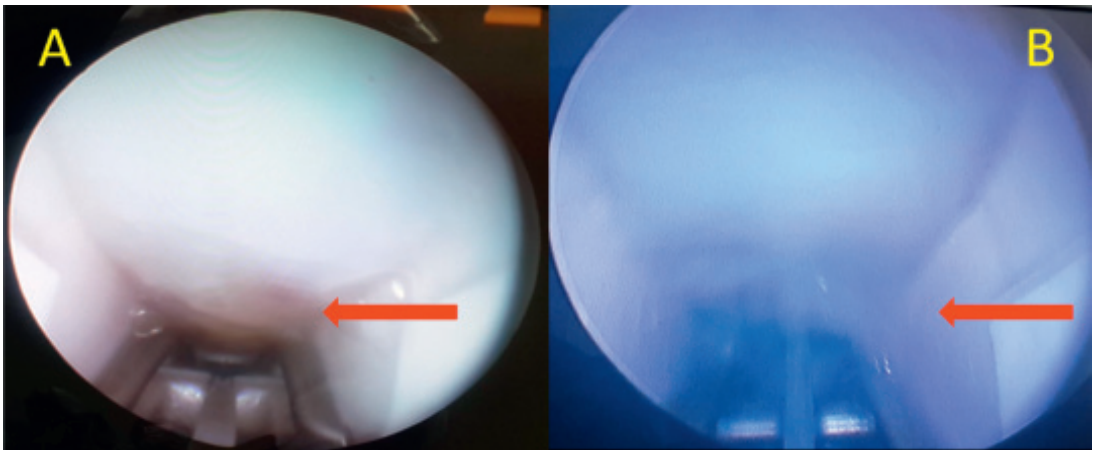

Fig. 4. A- Excess fluid in the carpal tunnel [red arrow]. B- Excess fogging in the carpal tunnel [red arrow].

3. Results

The mean antero-posterior diameter of the tunnel in our patients was 9.6 mm, the mean thickness of the transverse carpal ligament was 1.09 mm and the mean cross sectional area of the median nerve at the level of hamate was 9 mm.[2]

The ultrasonography showed 52 cases with distinctly visible distal edge of the transverse carpal ligament whereas the operating surgeon could distinctly see the distal edge of TCL in 66 cases. We had 46 cases with tight carpal tunnel which was perceived by the operating surgeon while inserting the scope.

Out of 100 patients, 74 (74%) patients underwent standard single portal endoscopic release and 26(26%) patients underwent mini-open carpal tunnel release. The conversion rates from endoscopy to open was noted to be 26%.

The distal edge not being visualised in 14 cases (53%) (Fig. 2 was the most common cause for conversion followed by tight canal hindering the insertion of the scope in four cases (15.3%). Fat pad prolapse (Fig. 3) was seen in two cases (7.6%). Excess fogging and fluid hindering visualisation (Fig. 4) was seen in two cases (7.6%). Tight tunnel along with tenosynovitis (Fig. 5) was seen in one case (3.8%). Muscle tissue prolapse (Fig. 6) was seen in one case (3.8%) and incomplete release (Fig. 7) was noted in one case (3.8%). Table 1 summarises the list of causes for conversion from endoscopic to open release.

Excess fogging is mainly due to the temperature difference between the carpal tunnel which is warmer and the operation theatre temperature. We overcome excess fogging by spraying warm saline to the scope end and wiping it dry before inserting the scope into the tunnel.

We divided our cases into subgroups of 10 patients each and noted the pattern of cases being converted as shown in Fig. 8. The subgroups of 11–20 and 21–30 had the highest conversion rate of 60 percent. However it was noted that there was a small increase in the conversion rates in 71–80 subgroup and 91–100 subgroup. This increase in number of open release was mainly due to difficulty in visualizing the TCL, few cases with tight carpal tunnel and tenosynovitis. Subgroup 81–90 had 100% endoscopic carpal tunnel release.

In the first fifty cases in our study, 20 cases were converted to open release which amounted to 40% conversion rate, but in the next 50 subset of patients the conversion rates had dropped to 13.3%. As the surgeons experienced to the technique increased, less number of cases were being converted to open release.

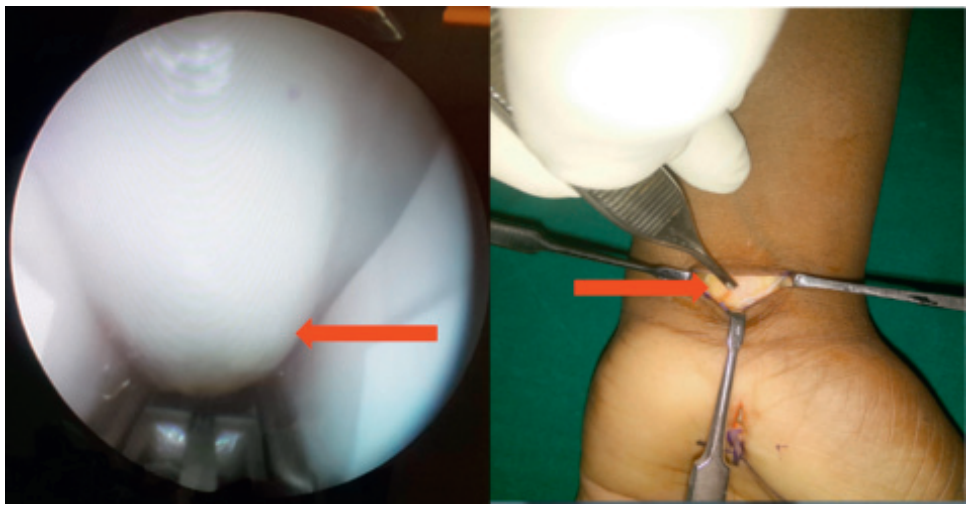

Fig. 5. Tenosynovitis [red arrow].

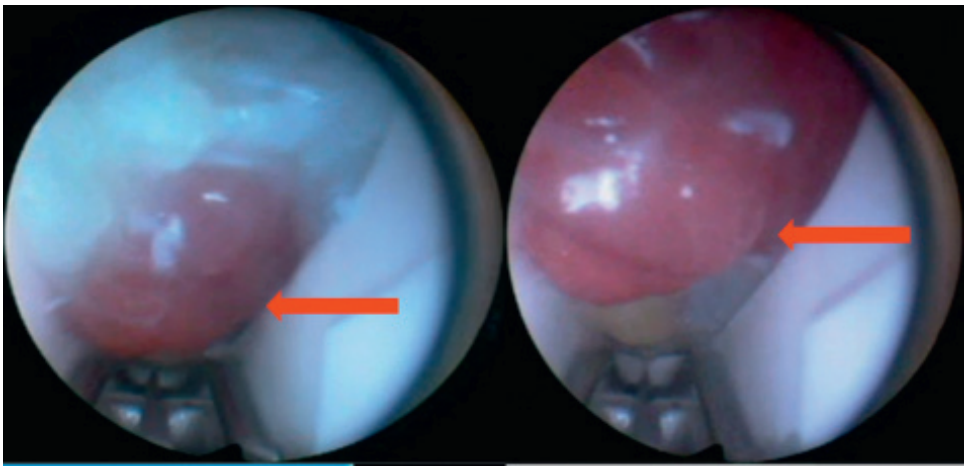

Fig. 6. Muscle tissue prolapse [red arrow].

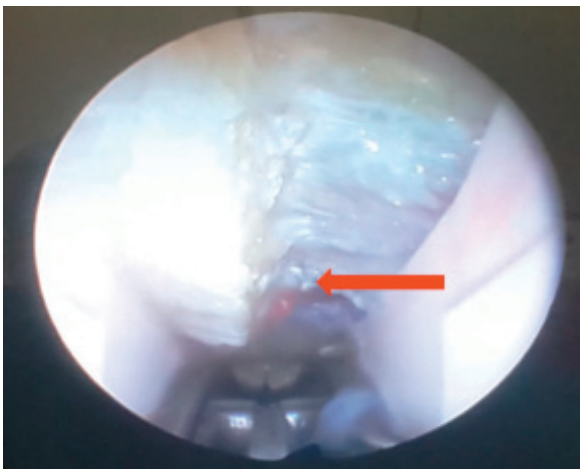

Fig. 7. Incomplete release [red arrow].

4. DISCUSSION

The surgical management of carpal tunnel syndrome includes conventional open release or endoscopic carpal tunnel release. However, there are limitations and debates regarding the efficacy of open versus endoscopic release.

This study is an attempt to find conversion rates of endoscopic to open carpal tunnel release, the causes for the conversion and also to study the learning curve of an operating surgeon with respect to endoscopic carpal tunnel release.

Difficulty in visualising the distal edge of TCL was the commonest cause of conversion in our series. The width of the transverse carpal ligament ranges from 0.8 to 2.5 mm with a mean of 1.52 mm as reported by Cobb et al in their cadaveric study. The thickness of the TCL in our study ranged from 0.6 mm to 2.5 mm with a mean of 1.09 mm. However the anatomy of the flexor retinaculum is such that the distal aspect of the TCL is continuous with palmar fascia and is difficult to delineate precisely.[5] The TCL also has laminar configuration which plays an important role in the endoscopic carpal tunnel release.[6] Hence the distal edge visibility of the TCL does not completely depend upon on the thickness of the TCL but also on distal edge merging with the palmar fascia and different laminar configuration of the fibres. These morphological changes can cause difficulty in the visualization of TCL and as a result, they are the major cause for conversion of ECTR to OCTR.

The mean antero-posterior diameter of the carpal tunnel in 150 wrists in 75 asymptomatic adults was 10.4 mm as reported by Betty Mani et al.[7] The mean AP diameter of the tunnel measured at the level of hook of hamate in our study by USG was 9.6 mm. As per Pajardi G et al and Uchiyama et al, tight carpal tunnel is a common cause for conversion of the ECTR to OCTR.[8,9] Kamolz LP et al opined that antero-posterior diameter of carpal tunnel should be measured before ECTR and a value of less than eight mm was contraindication for ECTR in their clinical practice.[10] In our study we came across six cases with tight carpal tunnel which did not allow the insertion of the scope into the tunnel resulting in conversion to open release. The mean antero-posterior diameter in these six cases was 8.3 mm.

Tenosynovitis is very common finding in carpal tunnel syndrome and is one of the common cause of median nerve compression. It is also one of the important cause for conversion of endoscopic carpal tunnel release to open release.[8,11] It can either cause difficulty in visualization of the distal edge of TCL or cause difficulty in scope insertion .With adequate knowledge regarding

Table 1
causes for conversion in our study.

Causes for conversion	Number of cases (%)
Distal edge not visualised[Fig. 2]	14(53%)
Tight tunnel	4(15.3)
Fat pad prolapse[Fig. 3]	2(7.6%)
Excess fogging and fluid hindering visualisation[Fig. 4]	2(7.6%)
Difficulty in visualisation of distal edge of TCL associated with tenosynovitis	1(3.8%)
Tight tunnel along with tenosynovitis[Fig. 5]	1(3.8%)
Muscle tissue prolapse[Fig. 6]	1(3.8%)
Incomplete release[Fig. 7]	1(3.8%)

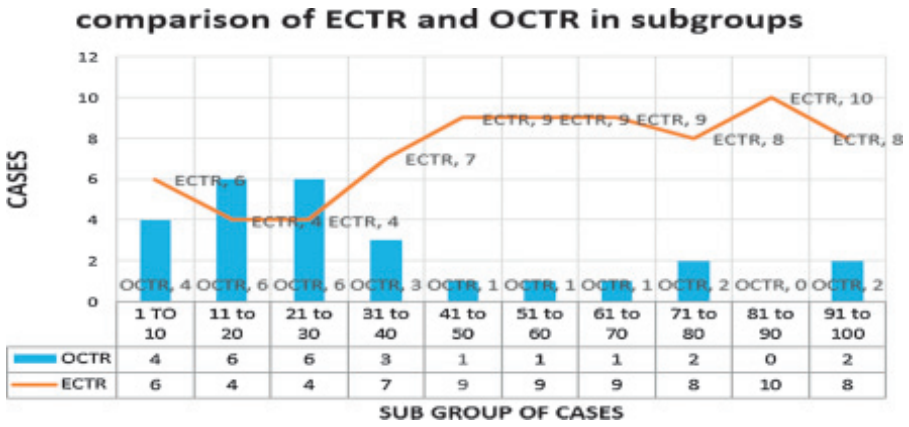

Fig. 8. showing the comparison of ECTR and OCTR in subgroups.

Table 2
Most common cause for conversion of endoscopic release to open release in different studies.

Study group	Sample size	No of cases converted (%)	Most common cause for conversion (no of cases)
Pajardi et al [9]	12702	60(0.46%)	Difficulty to visualise TCL(31)
Beck JD et al [11]	358	12(3.4%)	Difficulty to visualise TCL (5)
Uchiyama et al [6]	311	40(13.5%)	Tight carpal tunnel(11)
Saw et al [12]	74	9(12%)	Difficulty to visualise TCL(5)
Our study	100	26(26%)	Difficulty to visualise TCL (14)

presence of amount of tenosynovitis pre-operatively, a surgeon can decide on the type operative intervention appropriate for surgical decompression and thus reduce the conversion rates. If tenosynovectomy is needed to decompress the tunnel or for biopsy, open release of the tunnel can be planned preoperatively.

As shown in Table 2, Pajardi et al, performed 12,702 cases of endoscopic carpal tunnel of which, only 60 cases (0.46%) were converted to open release. In 31 cases, they had difficulty in viewing the TCl, 21 cases had muscular interpositions, four cases had lipomas and three cases had difficulty in inserting the blade into the tunnel.[9]

Saw et al randomised 74 cases to endoscopic release of which nine cases (12%) underwent open release. Four cases were converted due excessive fogging of camera and in five cases these had difficulty in visualising the TCL.[12] In the study by Uchiyama et al, out of 311 cases, 40 cases (13.5%) underwent open release. One case of anomalous muscle at the entry point of the tunnel, three cases of difficulty in visualising the distal aspect of TCL, 11 cases of tight carpal tunnel, 10 cases having hypertrophied synovial tissue caught at the tip of cannula, steep angle of cannula assembly with difficulty in withdrawal from the exit portal in eight cases and seven cases had median nerve or synovial tissue interposition in the slot were the reasons for conversion.[8] Beck DJ et al converted 12 cases out of 358 cases to open release. Five cases had hypertrophy of the synovial tissue leading to poor visibility of the TCL, six cases were converted due to inadequate anaesthesia and one case had excessive fogging preventing the visualization.[11]

The conversion rates in our first 50 cases was 40% but dropped to 13.3% in the next 50 cases. The commonest cause for the conversion was difficulty in visualising the TCL. This decrease in conversion rates from 40% to 13.3% represents the learning curve and as a surgeon gains more experience in endoscopic release, the lesser would be the incidence of cases being converted to open release. As the surgeon becomes more familiar with the ECTR procedure and the anatomy of the transverse carpal ligament, an inability to obtain clear visualization of TCL becomes a less likely cause of conversion to OCTR.[8] However the learning curve of the surgeon for endoscopic carpal tunnel release doesn't solely depend on the experience of a surgeon but also depends on various anatomical and morphological features of the carpal tunnel which play an important role in successful endoscopic release.

Conflict of interest

None.

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Case report

A unique case of capito-hamate fractures with simultaneous dislocation of third, fourth and fifth carpometacarpal joints in a young adult

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ABSTRACT

Carpometacarpal fracture dislocations are rare and infrequent injuries, which are usually missed at the first presentation. The gross swelling of the wrist and hand conceals the deformity and the radiographs may not reveal much findings. It is important to make an early diagnosis for an appropriate treatment to prevent future morbidity. Therefore, a high index of suspicion, good quality imaging and a prompt surgical intervention in select cases results in a good functional recovery and optimal function of the hand. Simultaneous capitohamate fractures and soft tissue disruption with these injuries are a unique entity and has rarely been reported. We had such an interesting case of third, fourth and fifth carpometacarpal dislocations with fractures of capitate, hamate and metacarpal bases that was diagnosed early and managed successfully with surgical repair of both bone and soft tissue injuries resulting in an excellent outcome and early return to pre-injury activity levels.

1. Introduction

Nonthumb carpometacarpal dislocations are a very rare occurrence and generally missed. They account for less than 1% of all hand injuries.[1] These injuries often result from a high-energy trauma and seen in boxers and motorcyclists.[2] Ulnar side carpometacarpal joints are more commonly involved probably due to their high mobility. Dorsal dislocations are more common than volar and usually involve associated fractures. Carpometacarpal dislocations are difficult to diagnose on x-rays due to overlapping of bones.[3] So, one needs to have a high index of clinical suspicion and proper imaging to pick up these rare injuries for appropriate management to achieve a good functional outcome. Here, we report such an interesting case with unique injury pattern and management, which resulted in early recovery and excellent functional outcome.

2. Case report

A 38-year-old male soldier reported a day after an alleged history of accidental fall on a flexed wrist. Individual complained of pain and swelling of the left wrist and hand. He had difficulty in movements of the fingers. Examination revealed diffuse swelling and tenderness around on the dorsum of wrist, predominantly over distal row of carpal bones and carpometacarpal joints from second to fifth. The deformity was very subtle and could not be appreciated in the presence of swelling. Wrist and hand movements were extremely painful without any neurovascular deficits. Plain anteroposterior, lateral and oblique radiographs of wrist and hand (Fig. 1) were virtually normal except for the suspicion of some abnormality around carpometacarpal area. Hence, a CT scan of the wrist and hand (Fig. 2) done to delineate the exact pattern of injury. It revealed multiple displaced fractures of hamate with dislocation of fourth and fifth hamatometacarpal joints and an 8 mm displaced coronal fracture of capitate bone with capito-metacarpal subluxation. Fractures of base of second and fourth metatarsal were also present.

Individual planned for open reduction and internal fixation in view of his injury pattern. Under general anesthesia in supine position, the left upper limb was prepared for an extended dorsal

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Fig. 1. Preoperative radiographs of wrist and hand. **A**. Anteroposterior view. **B & C**. Oblique views. **D**. Lateral view.

approach. A tourniquet applied and inflated 100 mg above systolic blood pressure before the incision. A 08 cm longitudinal incision given on the dorsum of wrist and hand centered over fourth metacarpal. Anatomical landmarks and neurovascular structures carefully isolated during the approach to explore the distal carpal row and the third, fourth and fifth metacarpal bases. We found coronal fracture of capitate, a comminuted fracture of hamate body with posterior dislocation of third, fourth, and fifth metacarpal. Using small fragment bone holding forceps and k wires, reduction of capitate and hamate fractures performed under fluoroscopic guidance. Capitate fracture fixed using two cortical screws (2 mm × 18 mm) inserted in the postero-anterior axis perpendicular to the fracture line. Fixation of comminuted hamate body fractures was done using two cortical screws (1.3 mm × 18 mm) inserted perpendicular to the fracture lines of bigger fragments. The third, fourth and fifth carpometacarpal joint dislocations reduced under direct vision. The torn dorsal carpal capsule sutured and repaired using one micro anchor inserted in the mid dorsal aspect of the capitate body. There was a complete rupture of intermetarapal ligament between the fourth and fifth metacarpal bases. Its repair done using one micro anchor inserted in the dorsal aspect of the fourth metacarpal base. Reduction, stability and alignment of the third, fourth and fifth carpometacarpal joints checked under fluoroscopic guidance (Fig. 3A & B) and found satisfactory. To hold the construct stability, two k-wires (2 mm diameter) inserted through the third and fifth metacarpal base traversing the carpo-metacarpal joints. Later on, the tourniquet released and hemostasis achieved. After lavage, the wound closed in layers with absorbable sutures and skin with staplers. Sterile dressing and compression bandage applied. Total duration of surgery was 90 min. There were no neurovascular deficits. Volar splint applied for 03 weeks.

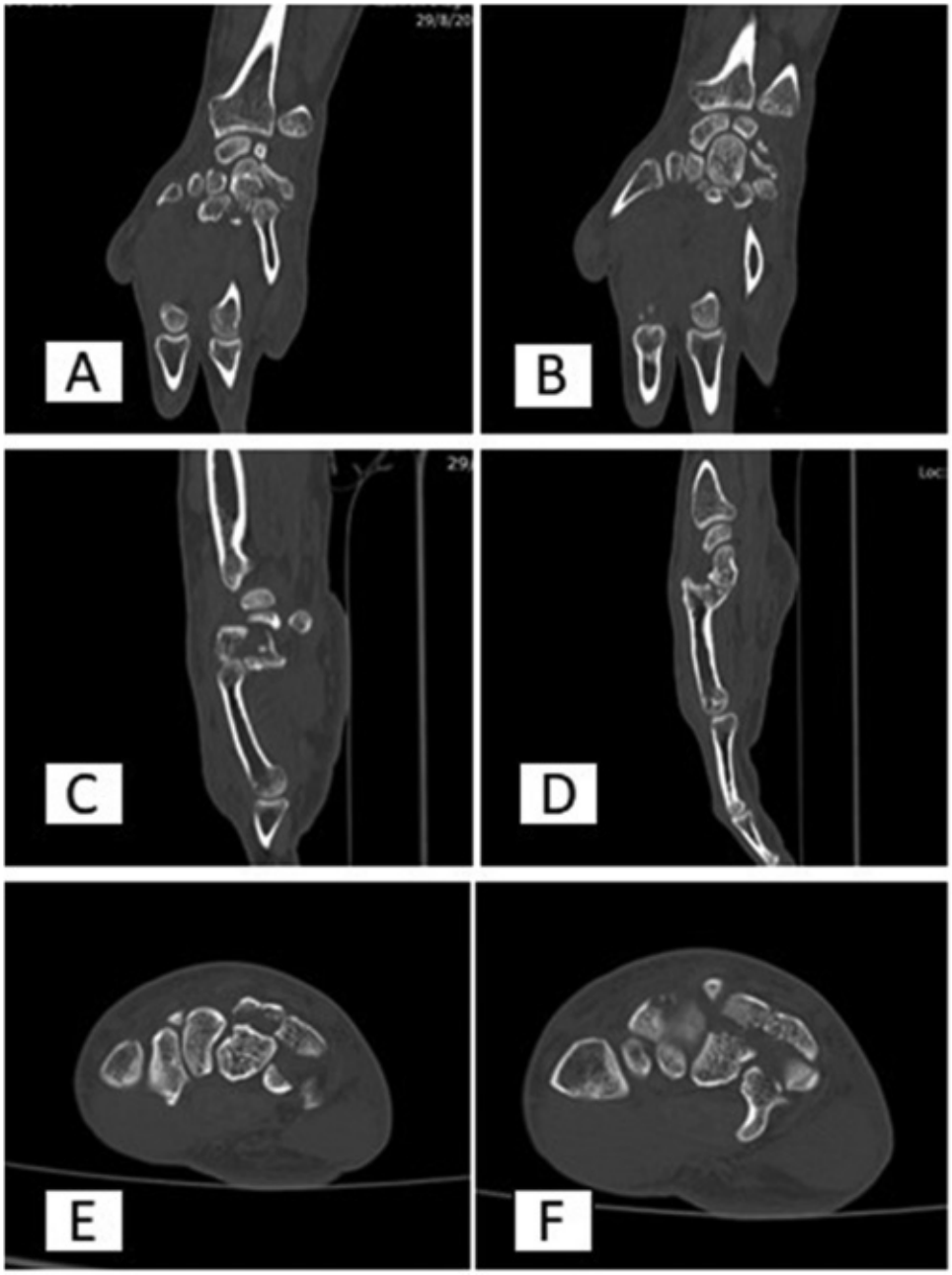

Fig. 2. Preoperative CT scan images of wrist and hand. **A & B**. Coronal images. **C & D**. Sagittal images. **E & F**. Axial images.

Post-operative x-ray (Fig. 3C & D) showed acceptable alignment of the fractures and congruent CMC joints. K-wires and the splint removed at 03 weeks follow-up and ROM exercises of wrist and hand started. At 06 weeks follow-up, Individual was better symptomatically with well-healed Pin tracks and surgical scar. The movements of hand and wrist improving satisfactorily. At 03 months follow-up, individual was asymptomatic and regained his full wrist and hand range of motion. Grip strength was 80% as compared to his right hand and radiographs showed union of fractures with congruent carpometacarpal joints (Fig. 4).

3. Discussion

Carpometacarpal dislocation is a relatively uncommon injury with very little information available in the literature. Many of the cases reported are either in isolation or with only a few cases showing predominant ulnar carpometacarpal dislocations. These injuries are generally caused by a high-energy trauma and hence are associated with significant soft tissue damage.[4] Axial loading of the hand in flexion seems to be the probable mechanism of injury, which was evident in this case. The carpometacarpal joints are inherently stable joints with both static and dynamic restraints. The bony architecture with the increase in degree of concavity toward the radial side of each joint and their capsule ligamentous attachments provides static stability whereas the wrist flexors and extensors account for dynamic stability.[5] The third carpometacarpal joint is the keystone of these joints as the metacarpal joins the capitate more proximally than others do.[6] The ulnar-sided joints have more intrinsic mobility compared to other carpometacarpal joints, which makes them more prone for dislocations in

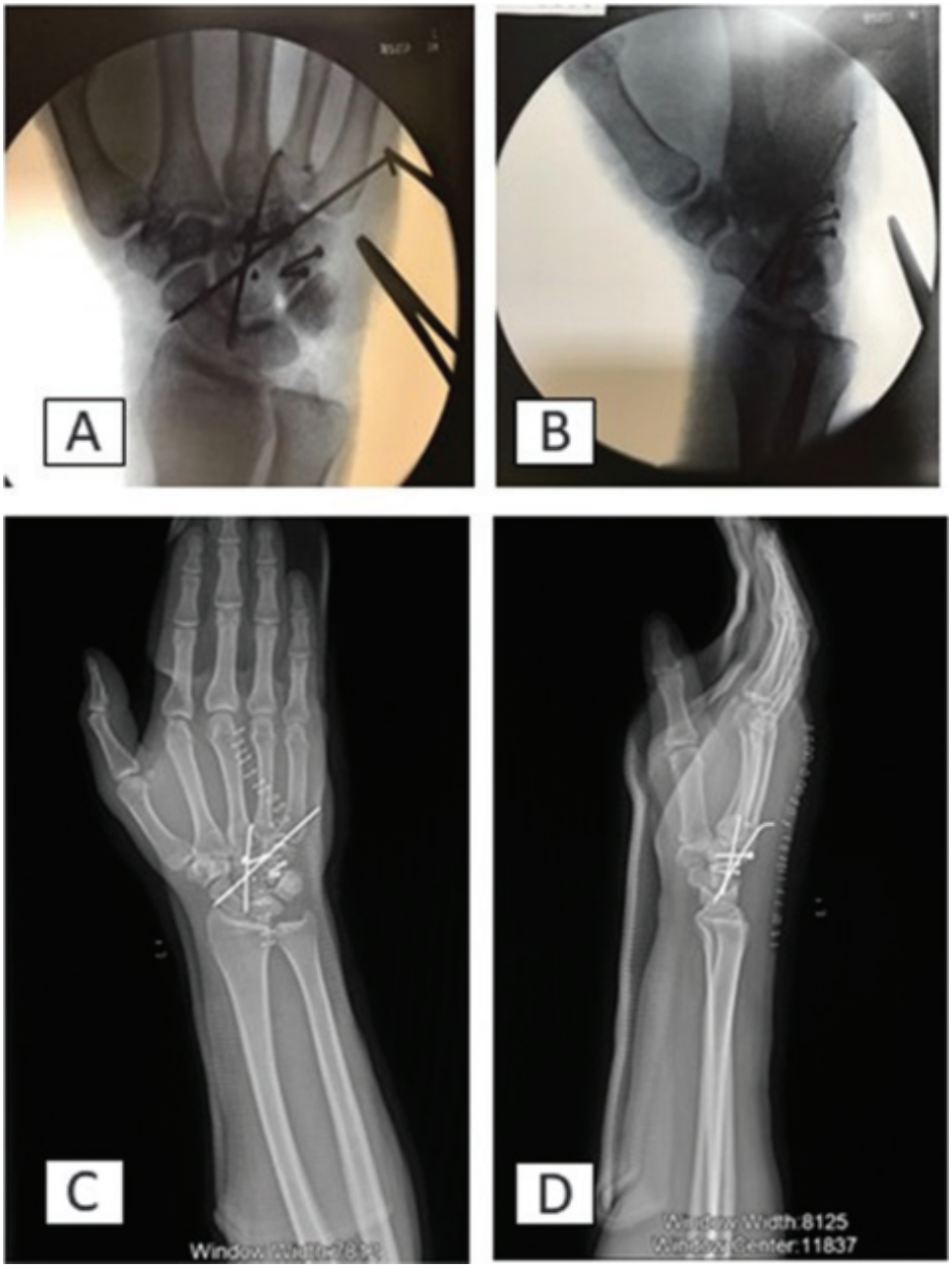

Fig. 3. A & B. Intraoperative fluoroscopy images. **C & D**. Immediate post-operative radiographs (AP and Lateral).

comparison to their counterparts. Hence, the fourth and fifth carpometacarpal dislocations are more common.[7] Whereas, the second and third finger carpometacarpal joints are inherently stable due to their bony articulations and soft tissue attachments.[8] Our case had third, fourth and fifth carpometacarpal dislocation with capitate, hamate and metacarpal base fractures which is unique and rarely been reported in the literature yet.

Carpometacarpal fracture dislocations are generally missed or overlooked[9] on the first presentation due to gross swelling which obscures the deformity. M-line parallelism and metacarpal cascade lines on posteroanterior views can be of some help to diagnose these injuries. Some authors recommend true lateral view but there is a significant metacarpal overlap sometimes, which masks the findings. Henderson et al.[3] reported that, true lateral view revealed dislocations in his case series when anteroposterior and oblique views were virtually normal. However, some authors recommend an oblique view for making diagnosis of carpometacarpal dislocations.[10] When radiographs fail, computed tomography can give us a better delineation of the injury pattern as happened in our case. No radiographs in our case showed any obvious deformity or fracture except for some suspicion on clinical correlation. Carpometacarpal dislocations, if missed can lead to decreased grip strength and inferior functional outcomes. Therefore, a high index of suspicion with clinicoradiological correlation is of paramount importance for early diagnosis and management of these injuries.

Most of these injuries can be managed by closed methods but when these dislocations are associated with fractures, internal fixation may yield superior results. Immediate reduction and fixation wherever required, is necessary to achieve optimal

Fig. 4. 03-Month Post-operative radiographs of wrist and hand. **A**. Anteroposterior view. **B**. Lateral view. **C**. Oblique view.

function of the hand.[7] There are various methods of treatment ranging from closed reduction and immobilization to open reduction and internal fixation. Some authors recommend open reduction and internal fixation for such injuries.[1] We chose open reduction and internal fixation in view of associated fractures of capitate, hamate and base of metacarpals. After exposure, capitate and hamate fractures stabilized with interfragmentary screws and the dislocations reduced. The associated soft tissue injuries in such cases are generally missed or ignored which may decline a result of a good fixation. We had rupture of a dorsal carpal capsule and intermatacrapal ligament between fourth and fifth finger, which was repaired and fixed with a help of micro suture anchors. These soft tissue repairs augment the stability of the construct and result in more anatomical healing with better functional recovery. Secondary dislocation after closed reduction is reported in literature and instantaneous k wire stabilization after reduction has been suggested.[7] Keeping this in view, an additional stabilization with k-wires was done in our case to prevent redislocation. As per Cain et al.[9] classification system, our case was grade III lesion. Grade II and grade III lesions are unstable and open reduction and internal fixation is recommended to prevent redislocation in post-operative period and late carpometacarpal arthritis. With carefull post-operative rehabilitation, we achieved almost full functional recovery with 80% grip strength at 12 weeks follow-up. He returned to preinjury activity levels and had normal function at 04 months.

The unique features of our case are the peculiar injury pattern, diagnostic challenges faced, appropriate management of both bone and soft tissue injuries and early rehabilitation. This case report gives an insight into varied presentation of injuries around carpometacarpal area, which requires a high degree of clinical suspicion coupled with adequate imaging techniques. Computed tomography in select cases and proper management of bone and soft tissues injury plays an important role in early recovery and a successful functional outcome.

Conflict of interest

None.

Acknowledgement

Nil.

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Technical note

A simple method for wrist ganglion staining with diluted surgical marking pen ink in arthroscopic resection and avoiding dye leakage-related subcutaneous discoloration

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ABSTRACT

Arthroscopic resection of the wrist ganglion is commonly performed nowadays, and has a recurrence rate comparable to open excision. It is preferred by some surgeons due to the smaller and more cosmetic operative scar. When using the arthroscopic procedure, identification of the stalk of the ganglion can facilitate accurate resection. In order to achieve this, staining and enhancement of the ganglion through the use of surgical dye injection has been proposed by some surgeons. However, sterile surgical dye is sometimes not easily available, and leakage-related subcutaneous discoloration is sometimes a problem. We propose an easy method by using diluted surgical marking pen ink for wrist ganglion staining. Also, any subcutaneous leakage of the diluted dye, if it occurs, can be easily cleaned up during the arthroscopic ganglion resection.

1. Introduction

Arthroscopic resection of the wrist ganglion is commonly performed nowadays, and has a recurrence rate comparable to open excision.[1] Arthroscopic resection is preferred by some surgeons due to the smaller and more cosmetic operative scar. Also, when performing arthroscopic surgery, the treatment of any intraarticular pathogens can be addressed at the same time.

Identification of the stalk of the ganglion can facilitate the procedure and give the surgeon more confidence and accuracy in the arthroscopic resection of the ganglion. Some surgical dyes, e.g., methylene blue dye and indigo carmine dye, have been proposed for injection into the ganglion for staining of the capsule and stalk.[2] The stained stalk of the ganglion is easy to identify from an intraarticular view. However, the amount of dye injected should be small or there will be leakage of the dye outside the ganglion. The leaked dye will spread to the subcutaneous layer and stain the tissue near the ganglion. For some patients, the leaked dye is visible as a dark discoloration of the skin, mimicking a subcutaneous tattoo. In order to clean the subcutaneous stain, an extension of the incision from the injection hole is required, and ultimate resection of a thin layer of the stained tissue is a solution. Subcutaneous discoloration and an enlarged incision both have a poor cosmetic appearance. We therefore propose a method of using diluted surgical marking pen ink for injection and staining of the ganglion to facilitate arthroscopic stalk resection. This type of ink is easily available, and this is a useful way to enhance the ganglion stalk and capsule. In addition, any subcutaneous leakage can be easily cleaned up.

2. Surgical technique

To prepare the ink solution, a container is filled with about 50cc normal saline (NS). The ink cartridge of the sterile surgical marking pen is retracted by clasping the tip with a needle holder (Fig. 1). Then, the cartridge is put into the prepared NS. The ink in the cartridge will diffuse out and stain the NS, also it is diluted. Then, the NS gradually turns blue in color (Fig. 2). Since the blue-colored NS is a diluted form of the sterile marking pen ink, it is much lighter in color than other available surgical dyes.

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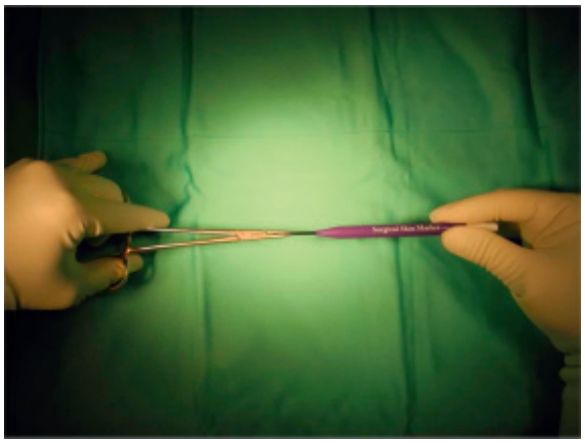

Fig. 1. Pull the cartridge out of the surgical marking pen.

Fig. 2. Soak the cartridge in normal saline, and stir it to dilute the ink into the solution.

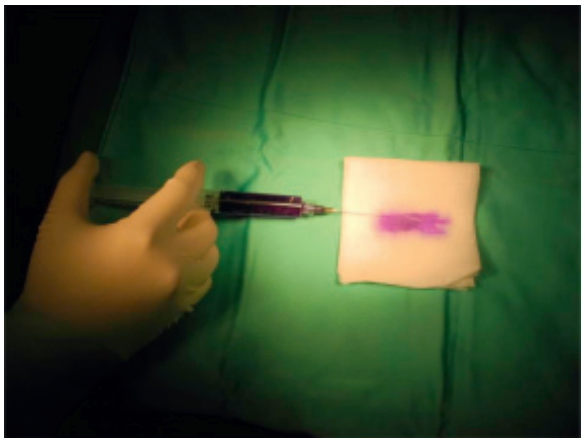

Fig. 3. Prepare the diluted ink solution in the syringe for injection into the ganglion.

The diluted ink solution is drawn in a syringe and then injected into the ganglion cyst (Fig. 3). Aspiration of some mucus from the cyst would be helpful in identifying the correct placement of the needle tip inside the cyst. Also, the reduced amount of mucus will minimize the intracystic pressure, which will make injection of the diluted ink solution (about 0.5cc) into the cyst easier and also prevent any leakage caused by the intracystic high pressure. The viewing scope then can then be inserted into the radiocarpal or midcarpal joint to identify the stalk of the ganglion. It would be helpful to have external digital pressure on the ganglion cyst to cause the stained mucus to flow back into the joint from the stalk, which would facilitate identification. The diluted ink solution is not as dark as methylene blue or other surgical dyes, but in the scope view of the joint, it is still enough for identification (Fig. 4).

As to the problem of subcutaneous discoloration, staining with surgical marking pen ink that is diluted is easier to clean up by irrigation. If any subcutaneous leakage occurs during injection of the ink solution and subcutaneous blue discoloration is obviously visible, an intrafocal cystic portal can be used for both ganglion excision and irrigation.[3] It is not necessary to perform quick and purposeful irrigation to clean the leaked ink solution, because the flowing water used for tissue shaving and debriding during the arthroscopic resection procedure can wash out the leaked color at the same time. After the arthroscopic resection of the ganglion is finished, the subcutaneous discoloration will also be cleaned up.

Gentian violet is the most commonly used dye in surgical marking pens, and it is the same with the marking pen we used.

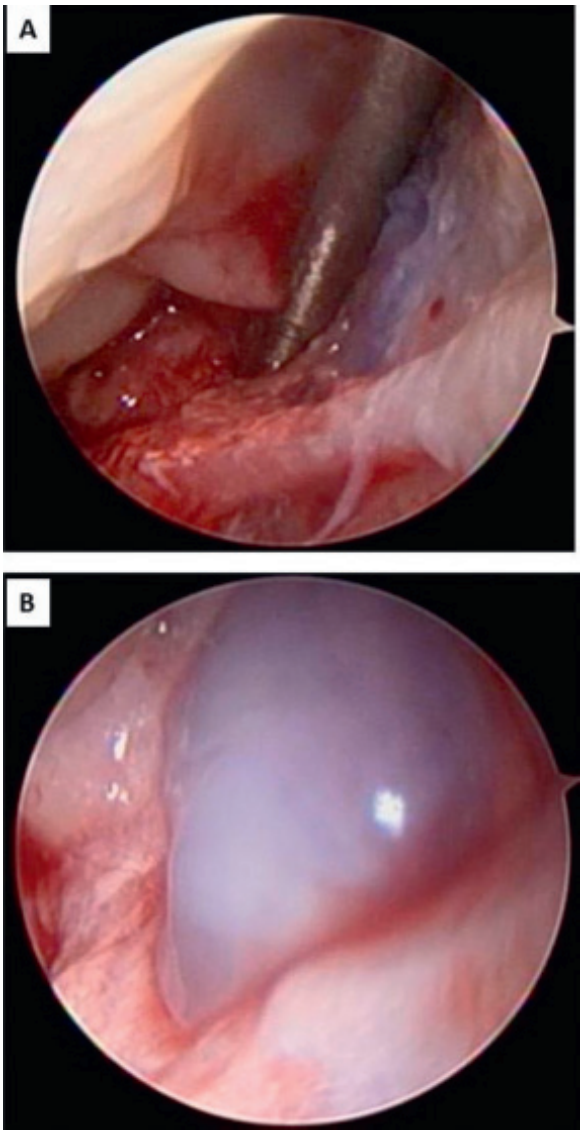

Fig. 4. (A) Identification of the ganglion stalk; (B) After removal of the dorsal wrist capsule, the stained ganglion cyst will be visible under external digital pressure.

Damage to the tissues by gentian violet, including chondrocyte, endothelium, and tendon cells, has been reported, but it is still very commonly used in every kind of surgery and for marking on tissue directly.[4] To our knowledge, no poor clinical results related to the use of the surgical marking pen in bone, tendon, and joint surgery have ever been reported. The dye solution we used was already diluted, and irrigation and suction were included throughout the arthroscopic procedure. Also, the dye was used to target the ganglion capsule, so no other intraarticular tissue would be stained. Furthermore, we did perform and do recommend to have the stained ganglion capsule be resected either by arthroscopic shaving or directly resection by pulling out the capsule from the arthroscopic portals. Therefore, we believe that any possible cytotoxic effect of the surgical dye on the intraarticular joint would be extremely minimized.

We still cannot quantify the volume needed for dilution of the ink in different surgical marking pens, and this is the limitation of our method. But in our experience, about 50cc of NS for dilution of one cartridge is clear for identification in arthroscopic surgery. Also, shaving with dry scope technique will help the identification of the stained spot in the joint (Fig. 4).

Surgical marking pens are in everyday use and are already sterile for intraoperative use. For the commonly used marking pen ink, gentian violet, we had used it for tissue temporary marking intraoperatively for a long time. This method of using the diluted surgical marking pen ink for wrist ganglion staining is easy if the surgeons wish to stain the ganglion capsule and no any other sterile dye is available. Also, any subcutaneous leakage of the diluted dye, if it occurs, can be easily washed out during the arthroscopic ganglion resection.

Conflict of interest

All authors have none to declare.

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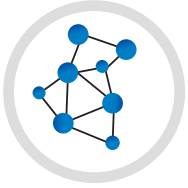

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