Gujarat Orthopaedic Association

An affiliated chapter of INDIAN ORTHOPAEDIC ASSOCIATION | Regd. No. E/13423

GOA e-Bulletin Volume -4

(January - February 2024)

Year 2023 - 2024

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FROM THE PRESIDENT'S DESK

Dear Members of the Gujarat Orthopaedic Association,

As we celebrate the success of the fifth issue of our scientific e-Bulletin, I am delighted to witness the continued excellence in academic content. Our dedicated guest editors and contributors have once again demonstrated their commitment to maintaining a high standard of orthopedic knowledge. Dr Ankit Desai, this issue's guest editor has left no stone unturned to serve us an academic feast which we will savour for a long period of time.

This milestone is a testament to the collaborative spirit within our association, and I extend my heartfelt gratitude to everyone involved. Let's continue to strive for excellence in orthopedic education, ensuring that the Gujarat Orthopaedic Association remains at the forefront of advancements in our field.

Last, but not the least, no words to thank Dr Ketan Shah and Dr Parin Kantesaria who are the sheet anchors of this project and have excelled in their work.

Warm regards,

Dr. Shrinivas Rao
President, Gujarat Orthopaedic Association

FROM THE DESK OF SECRETARY

As the sun sets in on an eventful 2023 and the new glorious dawn of 2024 beckons us, we take privilege in publishing yet another issue of the scientific e-bulletin of Gujarat Orthopaedic Association.

Through this year, it has been a fascinating fiesta of academics, rollicking rollercoaster of orthopaedics and scintillating science of skills and techniques which have been showcased and compiled with impeccable alacrity by the team of dedicated and dexterous regional editors. The chief editors, Dr. Ketan Shah and Dr. Pareen Kantesaria's zest, zeal and zing have been remarkable.

Special gratitude to Dr. Ankit Desai from Vapi who has shown eager and earnest energy in coordinating and collecting the articles for this volume of the e-bulletin from South Gujarat.

We appreciate and salute the unstinted support, cooperation and unbridled enthusiasm displayed by the astute academicians who have shared their contributions for the larger good of their orthopaedic colleagues in our state. We have been able to acquire and accumulate articles from all the various zones of Gujarat Orthopaedic Association with an amazing rainbow of topics.

The e-bulletin was a coveted dream of our President Dr. Shrinivas Rao and it is so gratifying and fulfilling to see the aspirations being metamorphosed into rewarding realities.

We hope to receive feedbacks from our esteemed members regarding the quality of contents and presentations in the e-bulletins all through the year. This will help us in formulating and implementing the changes for the future editions.

2024 will bring in newer challenges, promises and vistas for all of us. We pray for good health and bonhomie for all our members and their families and do wish that our exhilarating journey of education has endless encores.

AMEN!

Dr. K. C. Thakkar
Secretary, Gujarat Orthopaedic Association

SGOA PRESIDENT'S MESSAGE

I congratulate Ankit Desai and team GOA for thinking about and publishing a bulletin of GOA. It is a very tedious job to think, collect and compile a bulletin catering to Orthopaedic community of Gujarat. We have ample of talented people who can contribute to this idea. We all should contribute in one or the other way to make it a grand success. This bulletin should become a mouth piece of our young talent and our seasoned seniors. We can discuss the latest method and techniques, what is successful and what is not. I wish this new idea to be a great success. Once again I thank the team and wish a great success.

Dr. Shammi Patel
President, SGOA

VVOF PRESIDENT'S MESSAGE

Dear members and colleague,

Welcome to our calendar of GOA news bulletin we are delighted to have the opportunity to share with you our exciting academic news bulletin this year.

With our Valsad Vapi orthopaedic forum we are passionate about high quality academy content and program that meet the needs of our members.

We understand that every member is unique and we take pride in our ability to tailor our offering to meet your scientific requirements as defined in our GOA theme "building bones, strengthening bonds".

I hope this bulletin will give you a sense of our value our capability and our commitment to academic excellence.

With Regards,

Dr. Mukesh Maurya
President, VVOF

GUEST EDITOR MESSAGE

Dear readers & team of editors ,

I am delighted to have the opportunity to serve as a guest editor for this publication. It is an honour to be entrusted with curating the content and ensuring that it meets the high standards of this esteemed publication.

As a guest editor from southern part of Gujarat, my aim is to bring a fresh perspective and introduce new ideas to the table. I will strive to select articles and features that are thought-provoking, informative, and engaging. My goal is to provide you, the reader, with a diverse range of content that will captivate your interest and expand your knowledge.

I understand the importance of maintaining the integrity of this publication and upholding its reputation. I will approach my role with the utmost professionalism and attention to detail, ensuring that each piece of content is thoroughly reviewed and meets the publication's guidelines.

I encourage you to share your feedback and suggestions with me. Your input is invaluable in shaping the direction of this publication and ensuring that it continues to meet your expectations. Together, we can create an enriching reading experience that leaves a lasting impact.

Thank you for your continued support and trust. I look forward to embarking on this journey with you and delivering content that inspires, informs, and entertains.

Sincerely,

Dr.Ankit Desai
Consultant Trauma & Spine Surgeon

EC member South Gujarat
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OBITUARY

Prof Dr Sumant Shah

In memory of Prof Sumant Shah, preeminent President of Gujarat Orthopaedic Association (1985-86), a revered teacher, a luminary in orthopedics and the esteemed founder President of Ahmedabad Orthopedic Society (1991-92). With a profound legacy as a professor and head of the Orthopedic Unit at V S General Hospital, he shaped the field with his expertise and unwavering commitment to ethical practice and patient-centric care.

His towering personality earned respect from students, colleagues and contemporaries alike. Prof Shah's impactful teaching, encapsulated in the belief, "when bias prevails in medicine, truth becomes the enemy," will resonate in the hearts of those he touched.

Gujarat Orthopedic Association expresses heartfelt condolences to his family and may his divine soul rest in eternal & divine peace.

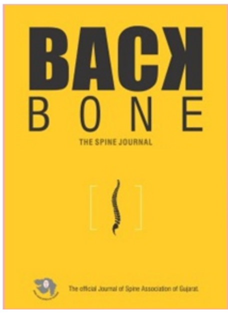
DISCREPANCIES BETWEEN RADIOLOGIST AND SPINE SURGEON INTERPRETATIONS OF CERVICAL AND LUMBAR STENOSIS

Dr. Ankitkumar A. Desai

Henceforth, nowadays demonstrated poor interpreter reliability of imaging interpretation between surgeons of various specialties and radiologists for a variety of pathologic conditions. Particularly in spine surgeons' practice Discrepancies in radiologic interpretations can lead to diagnostic frustration and difficulty in formulating treatment plans. Moreover, the third-party payee (insurance party) only relies on documented radiology reports rather than surgeons' independent interpretation of imaging studies (and never reviews the actual images without clinical findings), which can impact insurance authorization for surgery or reimbursement. Ultimately, conflicting Radiological interpretations may negatively impact patient care. The purpose of my letter to the editor and running research design was to evaluate the rate and degree to which radiologists and spine surgeons differ in interpreting magnetic resonance imaging (MRI) studies in the setting of cervical and lumbar spinal stenosis.

Assessment of the MRI:

Magnetic resonance imaging (MRI) is the standard mode of investigation in spine pathology. Stenosis is a disability triggered by a cord or sac compression because of degenerative spine structure changes with its adjacent structure changes. Compression correlates poorly with Quantifiable language and words used for describing compressive pathology in reports aren't standardized. MRI [1] is the tool for assessing the extent of cord or sac compromise or injury [2] and typical features include cord or sac compression, altered cord or signals or MRI myelogram in the lumbar spine, canal stenosis, and altered spinal balancing. Despite an investigation, no



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standard MRI characteristics consistently representing disease severity in canal stenosis have been found [4], cord or sac compression is considered a stamp of authority, and its extent correlates poorly with severity. This may be due to the dynamic component of injury mechanics being untraceable by MRI protocol [5] or Mechanical stress is the cause of biological differences. Asymptomatic individuals can have a significant cord or sac compression [4, 5]. At present, quantitative measurements such as 'Spinal Cord Occupation Ratio', "Maximum spinal cord compression", 'Transverse Area', 'Compression Ratio', and 'Maximum Canal Compromise' have been used regularly with description. Although their opinions and use of such words, to quantify or qualify the compression are just to provide an objective to the measurements of the cord or sac compression. Standardized terminology exists to describe disc pathology which is a good verse by us, for radiologists aren't! The nomenclature used by radiologists to report cord or sac compromise impact on clinical management gives the surgeon a drive to extend the surgical plan. I think I will plan to do research with aims to 1) identify terminology used for cord or sac compression 2) compare it 3) From asymptomatic cord compression to symptomatic stenotic features are they able to distinguish between them and 4) Rule out either a language or qualifiers influences spine surgeons opinions.

Do qualitative or quantitative features identify spinal compression levels?

Maximum Spinal Cord Compression' (MSCC) [7]; 'Spinal Cord Occupation Ratio '(SCOR) (3), and 'Compression Ratio' (CR) this four are measurements used to calculate compression based on MRI records I found. These represent the visible compromise and good clinical significance [3]. Greater cord compromise is indicated by a larger MCC, MSCC or SCOR, or smaller CR. Quantitative vocabulary used to understand spinal cord or sac compression are: 'Compress', and 'Indent'. 'Abut', 'Flatten', 'Touch', 'Mould', 'Compromise', 'Contact', 'Displace' 'Distort'

'Encroach' Qualifier Term Greater, Just, Lesser Degree,

Mild, Mild-Moderate, Minimal, Minor maximum numbers of MRI shows the canal diameter as a sign of canal stenosis. Which are non-compared to Slandered deviation and which vary from patient to patient according to their age, sex, height, weight from which demographic region they belong, etc Many variable terms are used in MRI reporting of spinal cord involvement, with the overlap in their quantitative features. For example, the term 'Compressed' = greater quantifiable compromise meaning is inconsistent. Neither qualitative nor quantitative measures of cord or sac involvement correlated with clinical symptoms, despite it generating referral to spinal surgeons. Some relationships are present between radiological reporting of spinal MRI; findings of the clinician by examination clinicians which generate the requirement for MRI to diagnose canal stenosis although the stage of disease and severity can not be specified. Qualitative versus quantitative descriptors are debatable for a longer period for various conditions [8-9]. However, terms chosen by radiologist has no clear guideline or individual meaning. Clinical decision-making depends on radiological reports & their finds. Research shows Radiologist and their reports are better judges that the majority of clinicians [10]. All to gather, research shows suggests that radiologists' choice of language may have unintended effects on patient care. This is consistent with our findings suggesting that language choice may influence non-expert clinicians' decisions about whether to refer patients with canal stenosis. The degree of radiological compromise correlates poorly with disease severity. Patients with cord or sac compression may not suffer from UMN or LMN disease respectively [11] and some patients suffer UMN or LMN diseases without visualized compression due to dynamic injury [5]. Henceforth As the ratio of GP (general physician) to spine specialist is very high in India .They are reliable enough to treat basic family diseases but due to this large gap patients has been already undergone an expensive investigation in the form of an MRI and also informed about the report which was made by radiologist .Hence for the very first consultation the spine surgeon force to see the MRI and not to be evaluated as per the standard protocol and go forward accordingly for the patient profile, this also creates misunderstanding between the GP and Spine Specialist in Indian Scenario. Treating any canal stenosis patient is the work of "BHIM" from "MAHABHARATA" rather than "ARJUNA" who sees a tunnel vision rather than a broad spectrum view.

As Matter of fact, MR imaging cannot currently replace the clinical assessment and vice versa but, notably, interpretation of MRI reports by non-expert clinicians may contribute to false reassurances and variable care. To prevent confusion for non- expert clinicians, descriptive terminology could be removed from reporting and replaced by statements of consistency (or non-consistency) with canal stenosis but further investigation is needed to confirm the value of such an approach. There are, of course, limitations to the conclusions with a lack of data from various centers, and patterns of language likely differ across individual centers, different cities, and countries. Nowadays endoscopy spine is the new sunrise in the world of spine surgery which gives different stories and different tale in a different part of the world, some research article shows that patient underwent endoscopy spine surgery goes for a follow- up MRI after a year shows no signs of surgery, I don't know how things are going to turn in the future.

Conclusion

That disagreements in MRI interpretation between orthopedic spine surgeons and radiologists occur often. The discrepancies were often with some fold, with spine surgeons rating pathology as more severe. why do I hypothesize that? This is due to the spine surgeons also having clinical data, physical examination, and its interpretation and differentials in their mind while interpreting imaging studies. Insurance companies should not only rely on MR imaging and radiologist interpretation but should also be given equal importance to clinicians and clinical findings. I do agree and pushing a thought that doing better research for this problem by doing collaboration of spine surgeon and radiologist, so we can have better reporting of MRI and radiologist can also took in some clinical inputs from surgeons respectively with their expertise.

References

1]. Suleiman LI, Bhatt SA, Parrish TB, Patel AA. Imaging modalities and tests for cervical myelopathy. Semin Spine Surg. 2014. June;26(2):68–72.

[2]. Batzdorf U, Flannigan BD. Surgical decompressive procedures for cervical spondylotic myelopathy. A study using magnetic resonance imaging. Spine (Phila Pa 1976). 1991. February;16(2):123–7.

[3]. Nouri A, Martin AR, Mikulis D, Fehlings MG. Magnetic resonance imaging assessment of degenerative cervical myelopathy: a review of structural changes and measurement techniques. Neurosurg Focus. 2016. June 1;40(6):E5 10.3171/2016.3.

[4]. Wilson JR, Tetreault LA, Kim J, Shamji MF, Harrop JS, Mroz T, et al. State of the Art in Degenerative Cervical Myelopathy: An Update on Current Clinical Evidence. Neurosurgery. 2017. March 1;80(3S):S33–45.

[5]. Xu N, Wang S, Yuan H, Liu X, Liu Z. Does Dynamic Supine Magnetic Resonance Imaging Improve the Diagnostic Accuracy of Cervical Spondylotic Myelopathy? A Review of the Current Evidence. World Neurosurg. 2017. April;100:474–9.

[6]. Kovalova I, Kerkovsky M, Kadanka Z, Kadanka Z, Nemec M, Jurova B, et al. Prevalence and Imaging Characteristics of Nonmyelopathic and Myelopathic Spondylotic Cervical Cord Compression. Spine (Phila Pa 1976). 2016. December 15;41(24):1908–16.

[7]. Nakashima H, Yukawa Y, Suda K, Yamagata M, Ueta T, Kato F. Abnormal Findings on Magnetic Resonance Images of the Cervical Spines in 1211 Asymptomatic Subjects. Spine (Phila Pa 1976). 2015. March 15;40(6):392–8.

[8]. Kang Y, Lee JW, Koh YH, Hur S, Kim SJ, Chai JW, et al. New MRI Grading System for the Cervical Canal Stenosis. Am J Roentgenol. 2011. July;197(1):W134–40.

[9]. Fehlings MG, Rao SC, Tator CH, Skaf G, Arnold P, Benzel E, et al. The optimal radiologic method for assessing spinal canal compromise and cord compression in patients with cervical spinal cord injury. Part II: Results of a multicenter study. Spine (Phila Pa 1976). 1999. March 15;24(6):605–13.

[10]. Bosmans JML, Weyler JJ, De Schepper AM, Parizel PM. The Radiology Report as Seen by Radiologists and Referring Clinicians: Results of the COVER and ROVER Surveys. Radiology. 2011. April 1;259(1):184–95.

[11]. Witiw CD, Mathieu F, Nouri A, Fehlings MG. Clinico- Radiographic Discordance: An Evidence-Based Commentary on the Management of Degenerative Cervical Spinal Cord Compression in the Absence of Symptoms or With Only Mild Symptoms of Myelopathy. Glob Spine J. 2017. December 18;219256821774551.

Declaration of patient consent:

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

RECENT ADVANCES AND FUTURE TRENDS IN KNEE ARTHROSCOPY

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ABSTRACT

Knee arthroscopic surgery continues to advance in leaps and bounds. The anterior cruciate ligament (ACL) remains the most controversial structure to be operated on in the knee, and although the enthusiasm for double- bundle reconstruction has waned, there is a definite preference for anatomic reconstruction using an individualized approach. Despite early failed attempts at ACL primary repair, there is a renewed interest in this preservative approach with the application of technologically advanced instruments and implants. The thrust toward meniscal preservation too continues as better understanding of meniscal healing, improved repair techniques, and novel methods to enhance healing have encouraged surgeons to repair tears previously deemed irreparable. Similarly, articular cartilage surgery has advanced with better understanding of cellular mechanisms and the development of newer techniques of cartilage regeneration. Although the focus in the present era has been to restore anatomy with optimal biomechanical constructs, upcoming technology will address biological concerns in healing, especially with degenerate tissues. Future trends in knee arthroscopy include application of scaffolds, orthobiologics, stem cells, and bioreactors to generate personalized, and patient specific autogenous tissue engineered implants. This review article summarizes the latest developments in knee arthroscopy and predicts future trends in this rapidly advancing subspecialty.

Keywords: Knee ligament repair, Knee arthroscopy, Knee cartilage repair, Knee meniscus repair, Recent advances

ABSTRACT

Knee arthroscopic surgery continues to advance in leaps and bounds. The anterior cruciate ligament (ACL) remains the most controversial structure to be operated on in the knee, and although the enthusiasm for double- bundle reconstruction has waned, there is a definite preference for anatomic reconstruction using an individualized approach. Despite early failed attempts at ACL primary repair, there is a renewed interest in this preservative approach with the application of technologically advanced instruments and implants. The thrust toward meniscal preservation too continues as better understanding of meniscal healing, improved repair techniques, and novel methods to enhance healing have encouraged surgeons to repair tears previously deemed irreparable. Similarly, articular cartilage surgery has advanced with better understanding of cellular mechanisms and the development of newer techniques of cartilage regeneration. Although the focus in the present era has been to restore anatomy with optimal biomechanical constructs, upcoming technology will address biological concerns in healing, especially with degenerate tissues. Future trends in knee arthroscopy include application of scaffolds, orthobiologics, stem cells, and bioreactors to generate personalized, and patient specific autogenous tissue engineered implants. This review article summarizes the latest

developments in knee arthroscopy and predicts future trends in this rapidly advancing subspecialty.
Keywords: Knee ligament repair, Knee arthroscopy, Knee cartilage repair, Knee meniscus repair, Recent advances**INTRODUCTION**

In recent years, there have been many advances in all orthopedic disciplines, and knee arthroscopy is no exception. These developments in knee arthroscopic surgery have been due to our better understanding of knee anatomy and biomechanics, and in turn, better management of ligament, meniscus, and articular cartilage injuries of the knee. These have been coupled with advances in optical technology, instrumentation, and implants which now enable precise, preservative, reconstructive, and regenerative surgery of the knee. As the science and application of arthroscopic knee surgery grows, we have noted a marked shift toward repairing intra-articular structures such as the menisci and anterior cruciate ligament (ACL) as a means to preserve knee anatomy. Ligaments and menisci not amenable to repair and healing are reconstructed, or transplanted, to restore anatomy. A host of innovative regenerative techniques and cell based technology is also now applied to treat articular cartilage lesions of the knee. This brief narrative describes the recent advances and future trends in knee arthroscopic surgery.

LIGAMENTS

ACL

ACL tears continue to be the most common, and controversial injury in orthopedic sports medicine. The latest trends in ACL surgery include ACL repair, individualized ACL

Rao and Pardiwala: Recent advances and future trends in knee arthroscopyreconstruction, remnant-sparing ACL reconstruction, the use of regenerative adjuncts to improve the biology of ACL graft ligamentization, and early stabilization in skeletally immature ACL deficient patients. There is also an increased recognition in the past few years of the roles of bone morphology, and hormones in the predisposition for ACL tears, with introduction of ACL prevention programs.

ACL repair

Anatomic ACL reconstruction has been able to give excellent results with a high rate of return to sports. However, there are lacunae in this reconstructive approach such as loss of proprioception, graft site morbidity, surgeon errors in tunnel placement, residual instability, and a prolonged process of graft revascularization and incorporation.[1] Hence, despite initial failure in this approach, there has been a resurgence of interest in ACL repair. Healing of the torn ACL following repair, provides an exciting opportunity of restoring knee stability with tissue which retains not only its native anatomy but also neurovascular supply.

The indications for ACL repair are acute femoral avulsions (Sherman Types I and II tears) of <3 weeks duration, with good quality tissue to be approximated, in young patients with lower activity levels and pre-injury Tegner activity scores
<5. Isolated studies have documented good results in athletes and high activity groups too. However, the biggest hurdle to wide acceptability of ACL repair is the lack of convincing clinical data to support its regular use in clinical practice. This may change with time. At present, there are four different techniques of ACL repair described. These include refixation with suture anchors, internal brace

ligament stabilization, dynamic intra-ligamentary stabilization (DIS), and bridge enhanced ACL repair (BEAR).

Refixation with suture anchors

Refixation with two suture anchors in the femoral footprint with alternate interlocking Bunnell type stitches in the two bundles of ACL has been described with varying success. Failure rates ranging from 15% to 25% have been reported.[2,3] Early results, especially in adolescent patients, have so far been encouraging.[4]

Internal brace ligament stabilization

Satisfactory 2-year patient outcomes and failure rates as low as 4.8% have been reported with internal brace ligament stabilization.[5] In this technique, the proximal ACL rupture is reattached to the lateral femoral condyle with a looped suture tied over a cortical button on the lateral femoral condyle. The same cortical button is also used to fix a non-absorbable braided suture passed through the femoral condyle, through the substance of the ACL and tibial footprint and fixed on

the tibia with an anchor. The central non-absorbable suture tape gives mechanical protection to the healing ligament. The addition of the internal brace has been shown to reduce the failure rates from 13.8% (without internal brace) to 7.4% (with internal brace).[6] This technique has also been reported in three children aged 5–7 years, where the internal brace was removed at 3 months after healing. In all patients, the ACL healed on second look arthroscopy, and they returned to routine activities with results sustained at 2 years.[7]

DIS

This technique builds on the internal brace technique with the belief that traditional ACL repair fails due to cyclical loading of the repair. A polyethylene wire is fixed on the tibial side with a spring screw mechanism which holds the tibia in posterior translation during all degrees of movements of the knee. Thus, the repair is protected leading to enhanced healing. A systematic review of 15 studies with Levels 1–5 evidence suggests that ACL repair using this technique is a safe and effective procedure in a select group of patients. The failure rates vary from 4% to 13.6%, and the revision rates varied from 2.1% to 15% at 1 year, and 7.9–11% at 2 years. The study noted that the long-term failure rates are comparable to ACL reconstruction in properly selected patients.[8]

BEAR

The BEAR technique utilizes a bovine origin extracellular matrix scaffold augmentation in addition to the ACL repair to enhance healing of the torn ACL. The drawback is this technique requires a 5 cm arthrotomy. Only one human study has been done and reported good to excellent results at 2 years.[9]

Individualized ACL reconstruction

Although ACL repair shows some promise, the gold standard for ACL tears remains reconstructive surgery. What is increasingly recognized is that "one size does not fit all." Anatomical variations in size and shape of the bones and ligaments, along with varied patient factors and functional demands may not allow the same standardized reconstruction in every knee. Hence, the concept of individualized ACL reconstruction has been proposed.[10] The principles of this include: Appreciate the native anatomy, individualize surgery according to patient needs, place the graft in the center of footprint, attempt to fill in about 80% of the footprint surface, and tension the grafts individually if performing a double-bundle construct. Routine notchplasty is discouraged as it may lead to bone overgrowth and impingement at a later date. Although the ideal graft, technique, fixation, and need for augmentation will continue to be debated, the following information, determined based on recent meta-analyses, may be applied to individualize ACL Reconstruction.

Single-bundle versus double-bundle reconstruction

A Cochrane database review found no difference in pain, complications, graft failure, and subjective knee scores at short- and long-term follow-up in patients with single- and double-bundle ACL reconstruction. However, patients with double-bundle reconstruction were better in terms of IKDC knee examination, knee stability with KT-1000, rotational knee stability, with better prevention of meniscus injury.[11] A recent meta-analysis of randomized controlled trials with at least 5 year follow-up found no difference in the objective stability, subjective IKDC, Lysholm and Tegner scores, graft rupture, and osteoarthritis changes between a double- and single-bundle reconstruction. However, the meta-analysis included <300 patients from 5 studies. Hence, over the past 3 years, the enthusiasm for double-bundle reconstruction has waned.[12]

Graft choices in ACL reconstruction

No clear scientific data exist that clarifies whether one graft is superior to the other, however, there seems to be a slow shift in choice of graft, as hamstring tendons are now used at least as often as patellar tendon as an ACL graft because there appears to be less morbidity with hamstring graft use.

In a meta-analysis on graft choices for ACL reconstruction which compared objective stability scores, subjective IKDC and Lysholm scores, graft failure rates and pain scores, patients with a quadriceps tendon graft had lesser graft harvest site pain than BPTB graft, and better Lysholm score than hamstring autograft, while all the other variables were similar.[13] The rupture rates with BPTB grafts are lesser than hamstring autografts although the difference is miniscule. The objective stability and clinical outcomes do not differ.[14] Soft-tissue allografts are inferior to autografts for primary ACL reconstruction in terms of the lower IKDC score, and objective stability scores.[15] For revision knee reconstruction autografts and non-irradiated allografts have been found to have similar objective and subjective outcome scores. Irradiation of allografts makes them an inferior choice of graft for primary and revision cases.[16]

Graft comparative rate of infection

In terms of post-operative infection after ACL reconstruction, using a patellar tendon autograft has a 77% lesser incidence than hamstring autograft, and 66% lower incidence than all types of other grafts. At the same time, autografts and allografts did not differ in the incidence of infections.[17]

Antero-medial portal (AM) versus trans-tibial (TT) technique

A meta-analysis of randomized trials found that patients with AM technique had better subjective scores (IKDC, and

Lysholm) and objective stability (Lachman's, Pivot shift, and side to side difference) as compared to TT technique.[18]

Fixation devices

A Cochrane database review found very low quality evidence that bioabsorbable screws are associated with more treatment failures, including intra-operative breakage, although the subjective and objective outcome scores are similar.[19] A meta-analysis of level one studies did not find any difference between a cortical button, cross pin, and interference screw for fixation on the femoral side for hamstring autografts.[20] For quadrupled hamstring grafts aperture fixation led to >3 mm but <5 mm side to side difference on KT-1000 measurements and a significant increase in graft ruptures as compared to suspensory fixation. Other stability measures and patient outcome scores were similar.[21]

Return to sports

The rate of return to sports after a primary ACL reconstruction is 83%, with a 5.2% re-rupture rate.[22]

The reported rates of return to sports at the same level after revision ACL reconstruction is only 43%, even if 73% patients had a good to excellent subjective and objective result.[23] In children and adolescents, the rate of return to pre-injury level of sport was 78.6% and that to competitive level of sport was 81.0%. Overall, 13% patients had graft re- ruptures, and in 14% contralateral ACL injuries were reported.[24]

Remnant sparing ACL reconstruction

With the recent trend of preservation and repair in knee arthroscopy, surgeons are increasingly sparing viable ACL remnants during reconstruction [Figure 1]. Evidence suggests that preservation of the ACL remnant is beneficial in terms of vascularity and proprioception, which may improve recovery of joint position sense, and enhances revascularization and integration of the graft.[25-27] Remnant sparing may be in the form of tibial remnant re-tensioning, specific bundle reconstruction for partial ACL tears, and remnant sparing where the graft is passed through the tibial tunnel and within the remnant. The most recent meta-analysis of Levels 1 and 2 studies determined that remnant sparing ACL reconstruction is not vastly superior to traditional ACL reconstruction, and there is no difference in the healing of grafts, or the overall complication rates. However, remnant sparing results in better objective stability in terms of KT 1000/2000 measurements, and better Lysholm scores.[28]

Biologics in knee ligament surgery

Platelet-rich plasma (PRP), platelet-rich growth factor, and stem cells have all been used along with ACL reconstruction

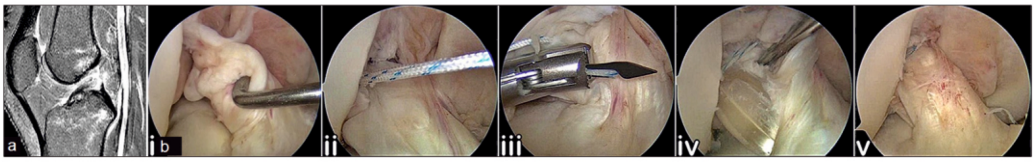

Figure 1: Remnant sparing anterior cruciate ligament (ACL) reconstruction. (a) MRI reveals a recent ACL femoral avulsion of Sherman Type II (b) arthroscopic technique involves (i) identifying the ACL femoral avulsion and creating tunnels at the anatomical insertion sites,
(ii) inserting a curved suture anchor anterior to the ACL femoral tunnel within the footprint of the ACL, (iii) passing one limb of the suture in mattress configuration through the ACL remnant, (iv) ACL graft passage while retracting the ACL stump, (v) a knot is now applied to the sutures so that the remnant envelopes the ACL graft and is fixed to the femoral insertion footprint.

and repair in an attempt to improve graft healing. Despite encouraging results in pre-clinical studies, a systematic review and level one study concluded that the role of these is still controversial. There does not seem to be any improved graft maturation over time, and no benefits in clinical outcome, bone integration, and prevention of bone tunnel enlargement.[29] Autologous bone marrow aspirate concentrate (BMAC) has shown promise in ACL femoral avulsions without retraction. However, further level one studies would be needed to prove the utility of bone marrow procedures.[30]

ACL reconstruction in skeletally immature patients

Several Levels 3 and 4 studies, and a meta-analysis of the studies,[31] have proven that early surgery is preferable in skeletally immature patients as compared to non-operative treatment. Delaying treatment for more than 12 weeks results in four-fold rise in medial meniscus injuries, and increased odds ratio of lateral condyle and medial condyle chondral injuries of 5.6 and 11.3, respectively.[32] There are three techniques of ACL reconstruction in skeletally immature patients: Transphyseal, physeal-sparing, and hybrid techniques. It is recommended that whenever the physis needs to be violated the tunnel should be as perpendicular and central in the physis as possible. The technique to be chosen has been defined according to bone age and physeal growth potential.[33]

Role of bony morphologyAn increased tibial slope, especially lateral tibial slope, has been shown to increase shear forces and stress across the ACL in biomechanical studies.[34] In a meta-analysis; an increased tibial slope has been associated with increased risk of ACL injury.[35] Decreasing posterior tibial slope has been shown to be vital in preventing failure in patients with increased tibial slope undergoing revision ACL reconstruction. It is believed that a posterior tibial slope of 13° or more needs to be corrected in the revision situation to around 5°.[36] The role of bony correction in primary ACL reconstruction is controversial.

Other bone morphological features which are postulated to predispose to increased risk of ACL injury and failure of ACL reconstruction are shallow medial tibial plateau (deeper medial tibial plateau constrains the femur better), a shorter medial tibial plateau, lower volume of medial tibial spine, a dome shaped inter-condylar notch (pyramidal notch maintains better stability), and spherical medial femoral condyle (ovoid shape is more stable).[37] Further studies using 3D imaging and statistical shape modeling may help in the future to better delineate the role of bony morphological variations in knee stability. This may also help to predict athletes at high risk for ligament tears, and perhaps formulate better guidelines for bony correction in primary ACL reconstruction.

The effect of hormones and ACL injury prevention programs

In females, the relative risk of ACL tear is highest during the ovulatory phase, followed by the follicular phase, and least in the luteal phase. Oral contraceptive pills provided 20% reduction in risk of injury.[38] Women had higher rate of second ACL injuries (6.84%) than men (5.67%). Overall women suffer more re-ruptures and contra-lateral ACL tears as compared to men.[39]

A meta-analysis found that ACL prevention programs did decrease the incidence of ACL injuries in all athletes by 50%, especially in female athletes.[40] Neuromuscular and proprioceptive training also decreases the rate of injuries, but no specific group of exercises is superior.[41]

Antero-lateral ligament (ALL) and lateral extra-articular tenodesis (LET)

The persistence of rotatory instability after ACL reconstruction has renewed interest in the anterolateral extra-articular stabilizing structures called the ALL. The anatomy, imaging features, role in knee stability, indications, and technique of ALL reconstruction have been debated.[42] The ALL expert group has published a consensus that ALL reconstruction affords internal rotation stability and reducedpivot shift after an ACL reconstruction.[43] Anatomic ALL reconstruction, in addition to ACL reconstruction, has been advocated in patients at high risk of ACL re-rupture, such as age <20 years, athletes engaged in pivoting sports, and patients with generalized ligament laxity. In patients with a Grade 3 pivot shift undergoing revision ACL reconstruction, an anatomic ALL reconstruction may be done to reduce the chances of failure. An alternative to ALL reconstruction is a LET which essentially involves a central band of iliotibial band being re-routed under the LCL and fixed to the tibia.[42-44] A level one study found that the addition of an extra-articular procedure decreases the pivot shift, and improves stability of the ACL reconstruction, while the subjective and objective scores remain the same.[45]

Posterior cruciate ligament (PCL)

The PCL remains less controversial as compared to the ACL and there has been increased consensus in its surgical treatment. There are various approaches described for PCL reconstruction, including single- or double-bundle, TT, and tibial inlay technique. A meta-analysis has demonstrated that although double-bundle reconstruction gives better objective posterior tibial stability and IKDC scores, patient reported outcomes are similar, and no technique is superior.[46] This added stability has been postulated to be important in the long term, and hence double-bundle PCL reconstruction is preferable. Similarly, both TT and tibial inlay methods are equivalent in terms of patient reported outcomes and objective scores with the tibial inlay technique being more prone to complications.[47] Dynamic bracing has been advised in the early phases of rehabilitation after PCL surgery. This brace offloads the PCL during deeper knee flexion angles and improves outcomes.[48] A meta-analysis found no difference in clinical outcomes between a single-bundle autograft and allograft PCL reconstruction. The patients with allograft had a longer duration of fever, higher white blood cell count, with a lower Tegner activity score, and lower objective stability scores.[49,50] Much like ACL, interest has been rekindled in PCL repair and recent studies reinforce the repair with suture tape. Long-term results and further developments in this field are awaited.[51]

Multiple ligament knee injury and knee dislocations

Knee dislocation presents a unique challenge in terms of the management of soft-tissue envelope, repair, and/or reconstruction of ligaments, with their timing and technique. Although an individualized approach is recommended for these complex injuries, numerous studies have enabled a consensus and algorithm for management of these challenging injuries.[52,53]

MENISCUS

The importance of the meniscus for normal knee function has been greatly appreciated in the past decade. It is increasingly recognized that it is important to repair, replace, or regenerate injured meniscus to prevent the progression of osteoarthritis. Meniscal preservation using different techniques has been shown to improve the clinical outcomes and delay degeneration. Meniscal repair can be achieved by all-inside, outside in, and inside out techniques and a variety of devices and instruments are available for the same [Figure 2].

Augmentation of meniscus repairs

Even with the latest techniques of meniscus repair failure rates as high as 24% have been reported, and are related to various factors including tear pattern, vascular anatomy, age, and limb alignment. Simple augmentation techniques including trephination, rasping, and abrasion of the synovium have been shown to improve healing in repaired meniscal tears.[54] Techniques such as fibrin clots sutured at the meniscus repair site, and PRP used either alone or with a variety of scaffolds, have given equivocal evidence in clinical studies. Further high level studies are necessary to prove their usefulness.[54] Newer methods which may hold promise are arthroscopic collagen sheath wrapping of complex tears with bone marrow aspirate injected under it, and a chitosan- PRP composite implant.[54]

Meniscal substitution

In some instances meniscus repair may not be feasible, and patients may have segmental, subtotal, or total loss of menisci. In such situations, meniscal substitution in the form

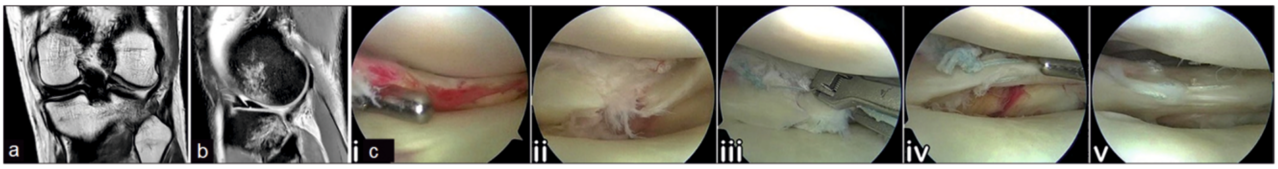

Figure 2: Meniscus repair for complex tear. (a) and (b) MRI reveals a complex displaced transection of lateral meniscus with locked knee.
(c) Arthroscopic technique involves (i) reduction of the locked displaced meniscus fragment, (ii) identifying the complex tear pattern to involve a peripheral longitudinal component and a radial component, (iii) suturing each component of the tear with an all-inside technique,
(iv) so as to achieve anatomical restoration of the lateral meniscus, (v) second-look arthroscopy after 4 months reveals a completely healed meniscus tear.of allograft transplant for subtotal or total meniscal loss, and artificial meniscal scaffolds for segmental defects are a viable option. In all these cases, the patient should be between 16 and 50 years of age, with a BMI <35, the knee should be stable with a normal alignment, and the cartilage should be well preserved with a ICRS grade of 2 or less.

Meniscal allografts

These have consistently given good results in appropriately selected patients in the long term.[55] However, there are concerns which include graft size mismatch, questionable long-term chondroprotection, low rate of return to sports, progressive joint degeneration, graft sterility and incompatibility, limited availability in many countries, and low rates of remodeling and stability.

Meniscal scaffolds

It may be useful when there is segmental loss of meniscus
<5 cm with an intact peripheral rim. A scaffold theoretically allows for native cells and tissue to grow in, while it biodegrades over a period of time. There are two different types of scaffolds: Collagen meniscus implant (CMI) made from bovine collagen matrix, and polycaprolactone- polyurethane scaffold (Actifit). Both have shown mixed results in patients with up to 10 year follow-up for CMI device,[56] and up to 6 years follow-up in case of Actifit device.[57] In a systematic review, both the devices have been found to be similar in terms of patient outcomes.[58] A 12.6% rate of complications has been reported which includes pain, effusion, infections, debridement for non-integrated scaffolds, re-tears, and scar tissue removal. A failure rate of 9.9% at 40 months for Actifit, and 6.7% at 44 months, for CMI device have been reported.[58] A scaffold which can produce high quality *in vivo* results in everyone has not yet been found.

Tissue engineering and regenerative medicine for scaffolds

Research is progressing in this field whereby these scaffolds will be 3D printed and impregnated with either autologous cells from the meniscus, or stem cells, and growth factors, which can then be cultivated in a bioreactor to get

a patient-specific tissue engineered meniscal implant which is fully biocompatible.[59]

Gene therapy for meniscus regeneration

Encouraging results have been reported by gene therapy, whereby favorable genes can be introduced into target meniscal cells to encourage regeneration.[60]

CARTILAGE

Cartilage defects and injuries are a formidable challenge in regenerative medicine. Cartilage treatment strategies can be characterized as palliation (chondroplasty and debridement), repair (drilling and microfracture), or restoration (autologous chondrocyte implantation [ACI], osteochondral autograft transfer [OAT], and osteochondral allograft [OCA]).

OATS and ACI

While OAT does result in hyaline cartilage regeneration; it has its own disadvantages, most important being its inability to be used in lesions larger than 3 cm^2. ACI has shown excellent results with all three generations [Figure 3]. The present generation of matrix ACI and fibrin ACI has the advantage of three-dimensional culture of chondrocytes which decreases the chondrocyte dedifferentiation noticed with earlier generations of the technique.[61] The key disadvantage of ACI remains that it requires a two stage procedure, and newer generations of this technique will aim toward a one-stage allograft ACI.

Scaffolds

Scaffold based cartilage regeneration can be applied for chondral or osteochondral defects. For chondral defects the defect may be repaired in one or two stages. The two stage technique utilizes the cartilage cells obtained from a normal area of the knee in the first stage, cultured *in vitro*, and impregnated into a variety of scaffolds. The scaffolds could be porcine collagen matrix, or a variety of synthetic substrates such as polylactic acid and polyglycolic acid, or natural substrates such as hyaluronic acid, collagen derivatives, agarose, alginate, or fibrin glue.[62] Single stage procedures

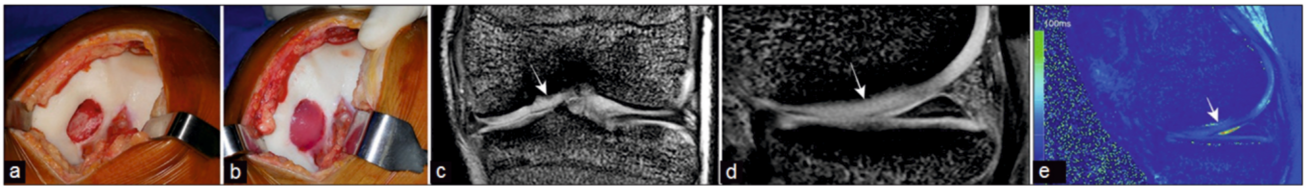

Figure 3: (a) Large osteochondritis dissecans (OCD) of medial femoral condyle of knee, (b) fibrin autologous chondrocyte implantation (ACI) cartilage repair, (c) and (d) 2-year follow-up MRI reveals a successful cartilage repair with MOCART score of 95, (e) T2 cartilage map performed 2 years after implantation reveals a hyaline rich cartilage repair (white arrows denote the cartilage repair site in c,d,e).utilize scaffolds impregnated with either fragmented cartilage tissue obtained from a healthy area of the knee or bone marrow. Another approach called as autologous matrix induced chondrogenesis (AMIC) utilizes a porcine collagen matrix to stabilize a blood clot obtained from microfracture. “AMIC plus” adds PRP for further biologic stimulation.

For osteochondral defects, scaffolds have been developed with a two or three layered structure, and are currently under investigation.[62] Similarly, 3D printed personalized scaffolds, nanofiber technology, and hydrogels are being investigated, and would be incorporated in cartilage repair in the future. 4D scaffolds are also an interesting development. These grafts are made from biomaterials which will respond to external stimuli and modify accordingly.[63]

Orthobiologics in focal cartilage defects

The orthobiologics used in cartilage defects are amniotic membrane derived mesenchymal stem cells (MSC), adipose- derived MSC, BMAC, PRP, and growth factors (BMP4 and BMP7).

MSCs either used alone or with scaffolds have shown promise in animal models but have not shown significant benefits in humans. Intra-articular injections of MSC have not been shown to improve outcomes in osteoarthritis.[64]

BMAC contains a large number of growth factors and cytokines which help in cartilage regeneration and healing. It has been used as an adjunct to microfracture alone, microfracture with BMAC and HA, and microfracture supplemented with a scaffold impregnated with BMAC. Human studies with scaffolds have shown complete defect filling in 80–100% of patients.[65] Clinical improvement has been reported in up to 100% patients at 5 years, and on second look arthroscopy was found to have regenerated near normal hyaline cartilage.[66] BMAC also been reported to give better results in OCA transplants in terms of graft incorporation and healing when used as an adjunct.[67]

PRP has shown good results in the treatment of osteoarthritis, but the results are mixed in focal chondral defects. This may be due the non-standardized ways of its preparation and heterogeneous reporting standards. It has been used in conjunction with micronized allograft articular cartilage, fibrin glue, scaffolds, and demineralized bone matrix for osteochondral defects; all with mixed results.[65]

BMP-4 and BMP-7 are the two main growth factors which are tested in animal models and have shown good cartilage growth and hyaline cartilage differentiation.[65]

The role of limb realignment including high tibial osteotomy as an adjunct to cartilage repair is important. The rationale is changing the mechanical axis of the lower limb so as to transfer the body weight across to healthy articular cartilage.

Several studies have shown that accurate correction is the leading predictor for success.[68,69]

PATELLOFEMORAL JOINT

Management of patellofemoral joint pathology is challenging as a result of the unique and complex organization of static forces and dynamic factors contributing to its functional capacity. The evaluation and treatment of patellofemoral instability (PFI) is based on static evaluation of the joint. Dynamic evaluation of this pathology may help us give better results. Various developments in this field in the form of cine MRI, dynamic ultrafast MRI, diffuse tension MRI, and its combination with fluoroscopy and ultrasound have given deeper insights into this pathology. Based on these, PFI measurements such as a quadriceps active ratio[70] and modified lateral patellar edge measurement have been proposed.[71] Recently, wearable devices have also been developed for dynamic evaluation of PFI. In future, Level 1 studies need to be developed to test these new diagnostic methods for better development of treatment methods.

The role of the medial patellofemoral ligament (MPFL) and its anatomy have been investigated for many years. Recent studies have defined a more broader medial attachment of the MPFL fanning across the upper half of the patella and the distal medial quadriceps tendon. Hence, this structure has now been called the medial patello-femoral complex. There is considerable variability in this attachment with 57.3% of this complex attached to the patella and the rest attached to the quadriceps tendon.[72] In the skeletally immature patients the femoral origin of the MPFL has a wide variability, with the average origin 4.7–10 mm distal to the femoral physis with the superior most fibers overlying the physis.[73] Fulkerson defined a new entity called medial quadriceps tendon femoral ligament, its attachments, role in lateral patellar stability, and its reconstruction technique. The medial attachment is to the distal quadriceps tendon, and femoral attachment is distal and anterior to the adductor tubercle immediately above the MPFL attachment.[74]

Although the position of the knee during MPFL tensioning is varied; biomechanical studies confirm that a 2N tension with the knee placed in 30–60° of flexion is the best.[75] Practically, tensioning such that a lateral patellar translation of one quadrant is achieved, at 30° knee flexion, is the best way to ensure avoiding over constraining the patella.[76,77] A double-bundle graft has been shown to decrease the graft failure rates from between 10.6%-26.9% in single bundle grafts to 4.5%-5.5% in double bundle grafts.[78,79] Several new techniques have been described to avoid the complications associated with patella tunnels and suture anchors. One such technique utilizes the central quadriceps tendon 10–12 mm in width and 3 mm depth left attached to the patella andrerouted in layer two of the knee to be fixed in the femoral isometric tunnel with an interference screw.[77]

MPFL repair may be indicated in young patients having first time dislocation with a patellar osteochondral fragment which needs fixation, where a distinct rupture from the patella, or less commonly from the femur, can be recognized. Similarly, imbrication of the MPFL may be sufficient in knees where bony realignment procedures have resulted in stable patella in the trochlea with a lax medial retinacular structure.[80]

Patellofemoral cartilage defects

These present unique challenges as patella-femoral joint loads may reach 6.5 times body weight, patella has the thickest cartilage in the body, femoral cartilage may not a good substitute, and an arthrotomy is needed to manage patellar cartilage defects.[81] For this reason, microfracture and bone marrow stimulation techniques have not been able to replicate the good results seen in the tibiofemoral joint. For smaller lesions (<3 cm^2) OAT, and for larger lesions (>2 cm^2) ACI and OCA have given consistently good results with lower rates of failure seen in ACI (5% vs. 16%). Hence, it is suggested that OCA be reserved for salvage and revision situations.[82] The medial and lateral trochlea which are the usual donors for OATS can be used in these cases for only small patellar defects. Scaffolds for patellar cartilage regeneration have given disappointing results with a 90% failure and 70% re-operation rate. Going forward scaffolds with better stress resistance need to be developed.[82]

Algorithmic approach to recurrent lateral patellar instability

The goals of patellofemoral realignment surgery should be to create both a stable environment for optimal extensor mechanism performance, and an appropriate load transmission for optimal cartilage wear and joint loading. An algorithmic approach has been proposed to deal with all aspects of lateral patellar instability.[83]

a. For genu valgum more than 10° with more than 1 year of growth remaining a medial femoral epiphysiodesis is necessary. Similarly, if there is excessive femoral or tibial valgus after skeletal maturity then a medial closing wedge osteotomy is necessary
b. Excessive femoral anteversion >20° and external tibial extorsion should be corrected by derotational osteotomy. Femoral derotation may be performed at the subtrochanteric level or at the distal metaphysis. Tibial torsion is corrected at proximal physis
c. If alignment is acceptable, the tibial tubercle to trochlear groove distance beyond 20 mm, calculated preferably on CT scan, or less so on MRI, should be corrected to

   between 10 and 15 mm with an anteromedialization of the tibial tubercle (Fulkerson). Patella alta can be calculated on MRI using the patella-trochlear index or Caton-Deschamps index, which if more than 1.3 should be corrected with distalization of the tibial tubercle
d. Trochlear dysplasia has been classified into four types. Type A usually does not require correction and only an MPFL reconstruction is sufficient. Types B and D can be treated with sulcus deepening trochleoplasty [Figure 4]. Type C warrants a complex procedure with lack of evidence, and includes lateral facet elevation, proximal recession wedge trochleoplasty, or groove deepening trochleoplasty
e. MPFL tear requires a MPFL reconstruction as detailed earlier.

COMPUTER-ASSISTED NAVIGATION IN KNEE ARTHROSCOPIC SURGERY (CANS OR CAS)

Computer-assisted navigation was developed to improve the accuracy of tunnel positioning in knee ligament reconstructions, and enable precise correction in osteotomy around the knee. While there are conflicting reports on its utility, many studies support the use of navigation. The added invasiveness and complexity, along with huge increase in costs, have limited the use of CANS in routine knee arthroscopic ligament surgery.[84]

At present, it is used to study knee kinematics and in the following research applications:

1. To compare the efficacy of different techniques of ACL reconstruction
2. To assess the efficacy and need for extra-articular procedures
3. Scientific tool in studying the pivot shift test
4. Pre- and post-operative outcomes
5. For individualizing ACL reconstruction and in difficult revision situations.

ROBOTIC AND IMAGE GUIDED KNEE ARTHROSCOPY

Knee arthroscopy is technically demanding. Current arthroscopes do not provide depth of vision, are rigid, cannot negotiate curved spaces in the knee easily, and have a limited field of vision. All these factors, along with human error, can lead to suboptimal outcomes. While all the advancements given below are in the development stage, advances in robotics can help in the future.[85] There are presently four areas of development: Steerable robotic tools, leg manipulators, miniature stereo cameras, and 3D/4D imaging systems.

Steerable robotic tools have extra degrees of freedom, such as bending and rotation, which help to reach and perform the intended procedure with ease. These will have sensors which

Figure 4: Recurrent patellar lateral dislocations with severe trochlear dysplasia and MPFL tear. (a) CT scan axial cut reveals a Dejour Type 4 trochlear dysplasia, (b) 3D CT scan further defines the bony deformity, (c) MRI sagittal cut reveals the supratrochlear spur, (d) MRI axial cut demonstrates patellar chondral status, (e) arthroscopic evaluation from superolateral portal reveals lateral patellar mal-tracking with trochlear dysplasia and minimal patellar chondral lesion, (f) an open exposure for trochleoplasty is performed, (g) groove deepening trochleoplasty is completed with lateralization of the trochlear groove to compensate for increased tibial tubercle to trochlear groove distance, (h) post- operative lateral radiograph at 3 months reveals healing of trochleoplasty with anatomical femoral insertion site for MPFL reconstruction.

will make it easy to detect, and steer the path, to the desired location, and plan the surgery.

Autonomous leg manipulators will have algorithms fed into the system depending on the surgeon preference, type of surgery, and stage of surgery. This along with sensors placed outside the knee, and in the arthroscope, will allow the leg holder to position the knee accurately.

Robotic tools need depth realization to work in space. Hence, miniature stereoscopic cameras are being developed to gain depth information. Along with 3D/4D ultrasound modalities being developed, they will help in mapping the anatomy of the soft-tissue inside and outside the knee such as the ligaments, menisci, neurovascular structures, and tendons to allow for surgery.

An extension of the robotic technology may in the future allow for full autonomous surgery under the supervision of an expert.

CONCLUSION

Recent advances in arthroscopic knee surgery have enabled accurate restoration of anatomy with successful techniques involving repair, reconstruction, and replacement. With research and studies progressing in multiple directions, better outcomes in biological repair and augmentation can be expected in the future. Rapid strides in tissue engineering, regenerative medicine, and understanding of cellular mechanism, may help in the future to obviate the need for harvesting autografts and allografts. Technology may offer individualized human tissue scaffolds to replace ligaments, cartilage, and menisci, if repair at an early stage fails.

Declaration of patient consent

Patients consent not required as patients identity is not disclosed or compromised.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Bucci G, Moatshe G, Lebus GF, Singleton SB. Arthroscopic primary repair of the anterior cruciate ligament: A narrative review of the current literature. JSM Sports Med Res 2019;3:1-10.

2. DiFelice GS, Van Der List JP. Arthroscopic primary repair of proximal anterior cruciate ligament tears. Arthrosc Tech 2016;5:e1057-61.

3. Hoffmann C, Friederichs J, Von Rüden C, Schaller C, Bühren V, Moessmer C. Primary single suture anchor re- fixation of anterior cruciate ligament proximal avulsion tearsleads to good functional mid-term results: A preliminary study in 12 patients. J Orthop Surg Res 2017;12:171.

4. Bigoni M, Gaddi D, Gorla M, Munegato D, Pungitore M, Piatti M, *et al*. Arthroscopic anterior cruciate ligament repair for proximal anterior cruciate ligament tears in skeletally immature patients: Surgical technique and preliminary results. Knee 2017;24:40-8.

5. Heusdens CH, Hopper GP, Dossche L, Roelant E, Mackay GM. Anterior cruciate ligament repair with independent suture tape reinforcement: A case series with 2-year follow-up. Knee Surg Sports Traumatol Arthrosc 2019;27:60-7.

6. Jonkergouw A, Van Der List JP, DiFelice GS. Arthroscopic primary repair of proximal anterior cruciate ligament tears: Outcomes of the first 56 consecutive patients and the role of additional internal bracing. Knee Surg Sports Traumatol Arthrosc 2019;27:21-8.

7. Smith JO, Yasen SK, Palmer HC, Lord BR, Britton EM, Wilson AJ. Paediatric ACL repair reinforced with temporary internal bracing. Knee Surg Sports Traumatol Arthrosc 2016;24:1845-51.

8. Ahmad SS, Schreiner AJ, Hirschmann MT, Schröter S, Döbele S, Ahrend MD, *et al*. Dynamic intraligamentary stabilization for ACL repair: A systematic review. Knee Surg Sports Traumatol Arthrosc 2019;27:13-20.

9. Murray MM, Kalish LA, Fleming BC, Henderson RN, Flutie B, Freiberger C, *et al*. Bridge-enhanced anterior cruciate ligament repair: Two-year results of a first-in-human study. Orthop J Sports Med 2019;7:2325967118824356.

10. Hensler D, Van Eck CF, Fu FH, Irrgang JJ. Anatomic anterior cruciate ligament reconstruction utilizing the double-bundle technique. J Orthop Sports Phys Ther 2012;42:184-95.

11. Tiamklang T, Sumanont S, Foocharoen T, Laopaiboon M. Double-bundle versus single-bundle reconstruction for anterior cruciate ligament rupture in adults. Cochrane Database Syst Rev 2012;11:CD008413.

12. Chen H, Chen B, Tie K, Fu Z, Chen L. Single-bundle versus double-bundle autologous anterior cruciate ligament reconstruction: A meta-analysis of randomized controlled trials at 5-year minimum follow-up. J Orthop Surg Res 2018;13:50.

13. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: A systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone-patellar tendon- bone and hamstring-tendon autografts. Am J Sports Med 2019;47:3531-40.

14. Samuelsen BT, Webster KE, Johnson NR, Hewett TE, Krych AJ. Hamstring autograft versus patellar tendon autograft for ACL reconstruction: Is there a difference in graft failure rate? A meta-analysis of 47,613 patients. Clin Orthop Relat Res 2017;475:2459-68.

15. Wang HD, Zhang H, Wang TR, Zhang WF, Wang FS, Zh

ang YZ. Comparison of clinical outcomes after anterior cruciate ligament reconstruction with hamstring tendon autograft versus soft-tissue allograft: A meta-analysis of randomised controlled trials. Int J Surg 2018;56:174-83.

16. Grassi A, Nitri M, Moulton SG, Marcheggiani Muccioli GM, Bondi A, Romagnoli M, *et al*. Does the type of graft affect the outcome of revision anterior cruciate ligament reconstruction? A meta-analysis of 32 studies. Bone Joint J 2017;99-B:714-23.

17. Bansal A, Lamplot JD, VandenBerg J, Brophy RH. Meta- analysis of the risk of infections after anterior cruciate ligament reconstruction by graft type. Am J Sports Med 2018;46:1500-8.

18. Chen H, Tie K, Qi Y, Li B, Chen B, Chen L. Anteromedial versus transtibial technique in single-bundle autologous hamstring ACL reconstruction: A meta-analysis of prospective randomized controlled trials. J Orthop Surg Res 2017;12:167.

19. Debieux P, Franciozi CE, Lenza M, Tamaoki MJ, Magnussen RA, Faloppa F, *et al*. Bioabsorbable versus metallic interference screws for graft fixation in anterior cruciate ligament reconstruction. Cochrane Database Syst Rev 2016;7:CD009772.

20. Hurley ET, Gianakos AL, Anil U, Strauss EJ, Gonzalez- Lomas G. No difference in outcomes between femoral fixation methods with hamstring autograft in anterior cruciate ligament reconstruction-a network meta-analysis. Knee 2019;26:292-301.

21. Browning WM 3rd, Kluczynski MA, Curatolo C, Marzo JM. Suspensory versus aperture fixation of a quadrupled hamstring tendon autograft in anterior cruciate ligament reconstruction: A meta-analysis. Am J Sports Med 2017;45:2418-27.

22. Lai CC, Ardern CL, Feller JA, Webster KE. Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: A systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. Br J Sports Med 2018;52:128-38.

23. Andriolo L, Filardo G, Kon E, Ricci M, Della Villa F, Della Villa S, *et al*. Revision anterior cruciate ligament reconstruction: Clinical outcome and evidence for return to sport. Knee Surg Sports Traumatol Arthrosc 2015;23:2825-45.

24. Kay J, Memon M, Marx RG, Peterson D, Simunovic N, Ayeni OR. Over 90 % of children and adolescents return to sport after anterior cruciate ligament reconstruction: A systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc 2018;26:1019-36.

25. Matsumoto T, Kubo S, Sasaki K. Acceleration of tendon-bone healing of anterior cruciate ligament graft using autologous ruptured tissue. Am J Sports Med 2012;40:1296-302.

26. Mifune Y, Ota S, Takayama K. Therapeutic advantage in selective ligament augmentation for partial tears of the anterior cruciate ligament: Results in an animal model. Am J Sports Med 2013;41:365-73.

27. Takazawa Y, Ikeda H, Kawasaki T, Ishijima M, Kubota M, Saita Y, *et al*. ACL reconstruction preserving the ACL remnant achieves good clinical outcomes and can reduce subsequent graft rupture. Orthop J Sports Med 2013;1:2325967113505076.

28. Wang H, Liu Z, Li Y, Peng Y, Xu W, Hu N, *et al*. Is remnant preservation in anterior cruciate ligament reconstruction superior to the standard technique? A systematic review and meta-analysis. Biomed Res Int 2019;2019:1652901.

29. Nin JR, Gasque GM, Azcárate AV, Beola JD, Gonzalez MH. Has platelet-rich plasma any role in anterior cruciate ligament allograft healing? Arthroscopy 2009;25:1206-13.

30. Centeno CJ, Pitts J, Al-Sayegh H, Freeman MD. Anterior cruciate ligament tears treated with percutaneous injection of autologous bone marrow nucleated cells: A case series. J Pain Res 2015;8:437-47.

31. Ramski DE, Kanj WW, Franklin CC, Baldwin KD, Ganley TJ. Anterior cruciate ligament tears in children and adolescents: A meta-analysis of nonoperative versus operative treatment. Am J Sports Med 2014;42:2769-76.

32. Lawrence JT, Agrawal N, Ganley TJ. Degeneration of the knee joint in skeletally immature patients with a diagnosis of an anterior cruciate ligament tear: Is there harm in delay of treatment? Am J Sports Med 2011;39:2582-7.

33. Anderson CN, Anderson AF. Management of the anterior cruciate ligament-injured knee in the skeletally immature athlete. Clin Sports Med 2017;36:35-52.

34. Marouane H, Shirazi-Adl A, Hashemi J. Quantification of the role of tibial posterior slope in knee joint mechanics and ACL force in simulated gait. J Biomech 2015;48:1899-905.

35. Zeng C, Cheng L, Wei J, Gao SG, Yang TB, Luo W, *et al*. The influence of the tibial plateau slopes on injury of the anterior cruciate ligament: A meta-analysis. Knee Surg Sports Traumatol Arthrosc 2014;22:53-65.

36. Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. Knee Surg Sports Traumatol Arthrosc 2015;23:2846-52.

37. Lansdown D, Ma CB. The influence of tibial and femoral bone morphology on knee kinematics in the anterior cruciate ligament injured knee. Clin Sports Med 2018;37:127-36.

38. Herzberg SD, Motu'apuaka ML, Lambert W, Fu R, Brady J, Guise JM. The effect of menstrual cycle and contraceptives on ACL injuries and laxity: A systematic review and meta- analysis. Orthop J Sports Med 2017;5:2325967117718781.

39. Nawasreh Z, Adams G, Pryzbylkowski O, Logerstedt D. Influence of patient demographics and graft types on ACL second injury rates in ipsilateral versus contralateral knees: A systematic review and meta-analysis. Int J Sports Phys Ther 2018;13:561-74.

40. Webster KE, Hewett TE. Meta-analysis of meta-analyses of anterior cruciate ligament injury reduction training programs. J Orthop Res 2018;36:2696-708.

41. Dargo L, Robinson KJ, Games KE. Prevention of knee and anterior cruciate ligament injuries through the use of neuromuscular and proprioceptive training: An evidence- based review. J Athl Train 2017;52:1171-2.

42. Musahl V, Herbst E, Burnham JM, Fu FH. The anterolateral complex and anterolateral ligament of the knee. J Am Acad Orthop Surg 2018;26:261-7.

43. Sonnery-Cottet B, Daggett M, Fayard JM, Ferretti A, Helito CP, Lind M, *et al*. Anterolateral ligament expert group consensus paper on the management of internal rotation and instability of the anterior cruciate ligament-deficient knee. J Orthop Traumatol 2017;18:91-106.

44. Kraeutler MJ, Welton KL, Chahla J, LaPrade RF, McCarty EC. Current concepts of the anterolateral ligament of the knee: Anatomy, biomechanics, and reconstruction. Am J Sports Med 2018;46:1235-42.

45. Rezende FC, De Moraes VY, Martimbianco AL, Luzo MV, Da Silveira Franciozi CE, Belloti JC. Does combined intra- and extraarticular ACL reconstruction improve function and stability? A meta-analysis. Clin Orthop Relat Res 2015;473:2609-18.

46. Chahla J, Moatshe G, Cinque ME, Dornan GJ, Mitchell JJ, Ridley TJ, *et al*. Single-bundle and double-bundle posterior cruciate ligament reconstructions: A systematic review and meta-analysis of 441 patients at a minimum 2 years' follow-up. Arthroscopy 2017;33:2066-80.

47. Lee DY, Park YJ. Single-bundle versus double-bundle posterior cruciate ligament reconstruction: A

meta-analysis of randomized controlled trials. Knee Surg Relat Res 2017;29:246-55.

48. LaPrade RF, Smith SD, Wilson KJ, Wijdicks CA. Quantification of functional brace forces for posterior cruciate ligament injuries on the knee joint: An *in vivo* investigation. Knee Surg Sports Traumatol Arthrosc 2015;23:3070-6.

49. Tian P, Hu WQ, Li ZJ, Sun XL, Ma XL. Comparison of autograft and allograft tendons in posterior cruciate ligament reconstruction: A meta-analysis. Medicine (Baltimore) 2017;96:e7434.

50. Lee YS, Lee SH, Lee OS. Graft sources do not affect to the outcome of transtibial posterior cruciate ligament reconstruction: A systematic review. Arch Orthop Trauma Surg 2018;138:1103-16.

51. Hopper GP, Heusdens CH, Dossche L, Mackay GM. Posterior cruciate ligament repair with suture tape augmentation. Arthrosc Tech 2018;8:e7-10.

52. Pardiwala DN, Rao NN, Anand K, Raut A. Knee dislocations in sports injuries. Indian J Orthop 2017;51:552-62.

53. Pardiwala DN, Soni S, Raut A. Knee dislocations: Classification and treatment algorithm. In: Margheritini F, Espregueira- Mendes J, Gobbi A, editors. Complex Knee Ligament Injuries. Berlin, Heidelberg: Springer; 2019.

54. Ghazi Zadeh L, Chevrier A, Farr J, Rodeo SA, Buschmann MD. Augmentation techniques for meniscus repair. J Knee Surg 2018;31:99-116.

55. Elattar M, Dhollander A, Verdonk R, Almqvist KF, Verdonk P. Twenty-six years of meniscal allograft transplantation: Is it still experimental? A meta-analysis of 44 trials. Knee Surg Sports Traumatol Arthrosc 2011;19:147-57.

56. Monllau JC, Gelber PE, Abat F, Pelfort X, Abad R, Hinarejos P, *et al*. Outcome after partial medial meniscus substitution with the collagen meniscal implant at a minimum of 10 years' follow-up. Arthroscopy 2011;27:933-43.

57. Filardo G, Kon E, Perdisa F, Sessa A, Di Martino A, Busacca M, *et al*. Polyurethane-based cell-free scaffold for the treatment of painful partial meniscus loss. Knee Surg Sports Traumatol Arthrosc 2017;25:459-67.

58. Houck DA, Kraeutler MJ, Belk JW, McCarty EC, Bravman JT. Similar clinical outcomes following collagen or polyurethane meniscal scaffold implantation: A systematic review. Knee Surg Sports Traumatol Arthrosc 2018;26:2259-69.

59. Cengiz IF, Pereira H, Espregueira-Mendes J, Oliveira J, Reis RL. Treatments of meniscus lesions of the knee: Current concepts and future perspectives. Regen Eng Transl Med 2017;3:1-19.

60. Cengiz IF, Silva-Correia J, Pereira H, Espregueira-Mendes J, Oliveira JM, Reis RL. Advanced regenerative strategies for human knee meniscus. In: Regenerative Strategies for the Treatment of Knee Joint Disabilities. New York: Springer; 2017.p. 271-85.

61. Wang M, Yuan Z, Ma N, Hao C, Guo W, Zou G, *et al*. Advancesand prospects in stem cells for cartilage regeneration. Stem Cells Int 2017;2017:4130607.

62. Filardo G, Kon E, Roffi A, Di Martino A, Marcacci M. Scaffold- based repair for cartilage healing: A systematic review and technical note. Arthroscopy 2013;29:174-86.

63. Qasim M, Chae DS, Lee NY. Advancements and frontiers in nano-based 3D and 4D scaffolds for bone and cartilage tissue engineering. Int J Nanomedicine 2019;14:4333-51.

64. Kim SH, Ha CW, Park YB, Nam E, Lee JE, Lee HJ. Intra- articular injection of mesenchymal stem cells for clinical outcomes and cartilage repair in osteoarthritis of the knee: A meta-analysis of randomized controlled trials. Arch Orthop Trauma Surg 2019;139:971-80.

65. Southworth TM, Naveen NB, Nwachukwu BU, Cole BJ, Frank RM. Orthobiologics for focal articular cartilage defects. Clin Sports Med 2019;38:109-22.

66. Haleem AM, Singergy AA, Sabry D, Atta HM, Rashed LA, Chu CR, et al. The clinical use of human culture-expanded autologous bone marrow mesenchymal stem cells transplanted on platelet-rich fibrin glue in the treatment of articular cartilage defects: A pilot study and preliminary results. Cartilage 2010;1:253-61.

67. Oladeji LO, Stannard JP, Cook CR, Kfuri M, Crist BD, Smith MJ, et al. Effects of autogenous bone marrow aspirate concentrate on radiographic integration of femoral condylar osteochondral allografts.. Am J Sports Med 2017;45:2797-803.

68. Frank RM, Cotter EJ, Strauss EJ, Gomoll AH, Cole BJ. The utility of biologics, osteotomy, and cartilage restoration in the knee. J Am Acad Orthop Surg 2018;26:e11-25.

69. Kahlenberg CA, Nwachukwu BU, Hamid KS, Steinhaus ME, Williams RJ 3rd. Analysis of outcomes for high tibial osteotomies performed with cartilage restoration techniques. Arthroscopy 2017;33:486-92.

70. Barroso Rosa S, Bahho Z, Doma K, Hazratwala K, McEwen P, Manoharan V, et al. The quadriceps active ratio: A dynamic MRI-based assessment of patellar height. Eur J Orthop Surg Traumatol 2018;28:1165-74.

71. Beckert MW, Albright JC, Zavala J, Chang J, Albright JP. Clinical accuracy of J-sign measurement compared to magnetic resonance imaging. Iowa Orthop J 2016;36:94-7.

72. Tanaka MJ. The anatomy of the medial patellofemoral complex. Sports Med Arthrosc Rev 2017;25:e8-11.

73. Shea KG, Martinson WD, Cannamela PC, Richmond CG, Fabricant PD, Anderson AF, et al. Variation in the medial patellofemoral ligament origin in the skeletally immature knee: An anatomic study. Am J Sports Med 2017;46:1-7.

74. Fulkerson JP, Edgar C. Medial quadriceps tendon-femoral ligament: Surgical anatomy and reconstruction technique to prevent patella instability. Arthrosc Tech 2013;2:e125-8.

75. Stephen JM, Kaider D, Lumpaopong P, Deehan DJ, Amis AA. The effect of femoral tunnel position and graft tension on patellar contact mechanics and kinematics after medial patellofemoral ligament reconstruction. Am J Sports Med 2014;42:364-72.

76. Elias JJ, Jones KC, Lalonde MK, Gabra JN, Rezvanifar SC, Cosgarea AJ. Allowing one quadrant of patellar lateral translation during medial patellofemoral ligament reconstruction successfully limits maltracking without overconstraining the patella. Knee Surg Sports Traumatol Arthrosc 2018;26:2883-90.

77. Fink C, Veselko M, Herbort M, Hoser C. MPFL reconstruction using a quadriceps tendon graft: Part 2: Operative technique and short term clinical results. Knee 2014;21:1175-9.

78. Wang CH, Ma LF, Zhou JW, Ji G, Wang HY, Wang F, et al. Double-bundle anatomical versus single-bundle isometric medial patellofemoral ligament reconstruction for patellar dislocation. Int Orthop 2013;37:617-24.

79. Weinberger JM, Fabricant PD, Taylor SA, Mei JY, Jones KJ. Influence of graft source and configuration on revision rate and patient-reported outcomes after MPFL reconstruction: A systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc 2017;25:2511-9.

80. Duchman KR, Bollier MJ. The role of medial patellofemoral ligament repair and imbrication. Am J Orthop (Belle Mead NJ) 2017;46:87-91.

81. Brophy RH, Wojahn RD, Lamplot JD. Cartilage restoration techniques for the patellofemoral

joint. J Am Acad Orthop Surg 2017;25:321-9.

82. Andrade R, Nunes J, Hinckel BB, Gruskay J, Vasta S, Bastos R, et al. Cartilage restoration of patellofemoral lesions: A systematic review. Cartilage. 2019;2019:1947603519893076.

83. Weber AE, Nathani A, Dines JS, Allen AA, Shubin-Stein BE, Arendt EA, et al. An algorithmic approach to the management of recurrent lateral patellar dislocation. J Bone Joint Surg Am 2016;98:417-27.

84. Zaffagnini S, Urrizola F, Signorelli C, Grassi A, Di Sarsina TR, Lucidi GA, et al. Current use of navigation system in ACL surgery: A historical review. Knee Surg Sports Traumatol Arthrosc 2016;24:3396-409.

85. Wu L, Jaiprakash A, Pandey AK, Fontanarosa D, Jonmohamadi Y, Antico M, et al. Robotic and image-guided knee arthroscopy. In: Handbook of Robotic and Image-Guided Surgery. San Diego: Elsevier; 2019.

How to cite this article: Rao NN, Pardiwala DN. Recent advances and future trends in knee arthroscopy. J Arthrosc Surg Sport Med, doi: 10.25259/JASSM_15_2020

FOCAL DOME CONDYLAR OSTEOTOMY: EARLY RESULTS OF ALIGNMENT OF A COMBINED INTRA- AND EXTRA-ARTICULAR HIGH TIBIAL OSTEOTOMY

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Abstract

Background and Aims: Extra-articular high tibial osteotomies reliably treat varus deformities seen in medial compartment osteoarthritis of knee (MCOA). Recently, attention has turned to the detection and treatment of intra-articular knee deformity to treat MCOA. Tibial condylar valgus osteotomy (TCVO) is an intra-articular osteotomy (IAO) that corrects the varus by elevating the medial tibial condyle and is fixed with a plate. TCVO improves joint line convergence angle (JLCA), spine edge angle (SEA), and spine vertical distance (SVD), which measure intra-articular deformity. It may undercorrect the mechanical axis to <50%. Focal dome condylar osteotomy (FDCO) is recently described and claims to correct both the intra- and extra-articular deformities in MCOA. We aimed to study the immediate results of FDCO and compare its efficacy with TCVO. **Patients and Methods:** We performed ten FDCO procedures on ten patients over the last year. The mean age was 57 years. We compared the results with a similar retrospective cohort of ten TCVO patients. **Results:** The mean preoperative (bo) mechanical axis deviation (MAD) in FDCO was −13.8% and improved to 51.6%. TCVO group had a similar mean postoperative (po) MAD of 43.5% ($P = 0.38$). Although 6 of 10 FDCOs had MAD >50%, only two of TCVOs crossed the midline. The mean bo medial proximal tibial angle in FDCO was 85.9° and improved significantly po to 93°. Hip knee ankle angle, ankle joint line orientation, and knee joint line orientation improved significantly as did JLCA, SEA, and SVD. Condylar plateau angle did not change. **Conclusion:** FDCO is an IAO with a vertical limb that passes through the lateral tibial spine and a medial curved limb. This single osteotomy can correct the intra-articular and extra-articular varus deformity. Although there was no significant difference in the correction of intra- and extra-articular deformity parameters between FDCO and TCVO, we feel that it was part of our learning curve. FDCO has the potential for better correction of the mechanical axis along with intra-articular deformities.

Keywords: *Focal condylar dome osteotomy, high tibial osteotomy, medial compartment osteoarthritis, tibial condylar valgus osteotomy, varus knee*

Introduction

Medial compartment osteoarthritis (MCOA) is treated with high tibial osteotomies (HTO), correcting the varus deformities in the lower limb. Closing wedge,[1] open wedge,[2,3] and focal dome[4,5] are some osteotomies that correct the extra-articular varus of the upper tibia.

Intra-articular deformities arising from the knee joint also contribute to MCOA. Moderate to large varus mechanical axis deviation (MAD) visible as a dynamic varus gait and elicitable as mediolateral laxity of the knee suggests an intra-articular deformity. Joint line convergence angle (JLCA) and condylar plateau angle (CPA) confirm the intra-articular deformity.[6] Spine edge angle (SEA) and spine vertical distance (SVD), introduced recently, help monitor the changes after intra-articular osteotomies (IAO).[7]

The tibial condylar valgus osteotomy (TCVO) described by Chiba corrects the intra-articular deformity.[6,8,9] It reduces point loading of medial femoral and tibial condyles, increases weight-bearing area, and stabilizes the knee to relieve pain. Since this osteotomy passes through the knee joint at the level of the medial tibial spine, medial to the patellar ligament (PL), it frequently undercorrects the mechanical axis. Since it is generally accepted that a corrected mechanical axis improves long-term results, efforts have been underway to increase the lateral passage of the mechanical axis with TCVO.[8]

How to cite this article: Bhadiyadra R, Apte AP, Chaudhary M. Focal dome condylar osteotomy: Early results of alignment of a combined intra- and extra-articular high tibial osteotomy. J Limb Lengthen Reconstr 2022;8:40-6.

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Kuwashima *et al*.[10] showed how to calculate the need for an additional extra-articular osteotomy (EAO). This second osteotomy may be an opening wedge or a closing wedge fixed in the same plate as the TCVO or a distal dome, fixed with an Ilizarov fixator. The latter has effectively improved lateral passage of the mechanical axis, albeit with the inconvenience of wearing a fixator. The need to improve mechanical axis correction after an IAO without an additional osteotomy was obvious. Igarashi *et al*.[11] have possibly solved this problem by the focal dome condylar osteotomy (FDCO) in 2020. Although FDCO is similar to TCVO, it approaches the knee joint at the level of the lateral tibial spine (LTS), lateral to the PL, and hence should correct the mechanical axis to approximately 60% of the knee joint width. FDCO contrasts with TCVO, whose vertical limb is medial to the PL.

We reported the results of our early efforts with the FDCO over the past year. We aimed to focus on changes in the mechanical axis and parameters that measure articular incongruity. We also discussed the difficulties and learning curve with this elegant yet technically challenging intra-cum-EAO. We also compared its results with a similar cohort of patients who underwent a TCVO previously.

Patients and Methods

We performed ten FDCO in ten patients suffering from MCOA in our institute since April 2021. There were three right and seven left limbs. Nine were female, with a lone male patient [Table 1].

We took informed consent and institutional review board approval for this retrospective study of radiological measurements. We also performed a chart review to note any complications during and after surgery. Statistical analysis of the data was performed using MS-Excel. The *t*-test was used to compute the comparison of the means, and the significance level was set at $P < 0.05$.

Surgical technique

The FDCO is like a TCVO[6] and differs in a few details. We prepared and positioned the patient similar to that for TCVO. A medial and lateral patellar retinacular release was done for patellofemoral joint line pain.[12] The incision was extended medially beneath the tibial tuberosity (TT). The pes anserinus and superficial medial collateral ligament were elevated subperiosteally to expose the posteromedial tibia. A K-wire marked the LTS under the image intensifier (II). It was near the lateral border of the PL. With a sharp knife, the PL was gently elevated laterally

from the TT, and the upturned lateral edge was temporarily sutured to its medial border.

In most cases, we limited this elevation to <20% of the PL footprint. Another vertical K-Wire marked the end of the vertical osteotomy line coming down from the LTS [Figure 1a]. A curved cutting jig was mounted on the CORA wire. A curved osteotomy was made with either a sharp osteotome or a reciprocating saw from the TT and extended medially, proximal to the superficial medial collateral ligament. Due to its curved dome shape, the osteotomy remained stable and retained bony contact when opened. The posterior cortex of the vertical limb was cut carefully under II control. Before opening the osteotomy,
1 mm and 1.2 mm K-wires were passed subchondral
from medial and lateral sides to prevent the spreading of medial and lateral tibial condyles and protect the hinge. Two long, flexible wires were inserted from just below the lateral joint line, passing laterally to the vertical limb of the osteotomy. These wires prevented a fracture at the narrow lateral cortex just lateral to the TT [Figure 1b].

A manual valgus force gently opened the osteotomy, and an arthrodesis spreader kept it open. The mechanical axis was checked with II with a rod or radiolucent grid. When found satisfactory, the osteotomy was fixed with a locking plate. Since the PL was elevated laterally and its footprint narrowed, it could get avulsed with unrestrained knee flexion. A spiked washer and screw can prevent this [Figure 1c]. The wound was closed over a drain. All patients were mobilized, toe-touch weight-bearing for the first 3 weeks. They were later allowed, partial weight-bearing for the next 6 weeks, and full weight-bearing at around 9–12 weeks postsurgery.

Knee range of motion (ROM) was started from postoperative day 2. However, knee flexion beyond 30° was permitted after 4 weeks in patients needing more PL footprint elevation.

Results

FDCO improved the mean MAD from a preoperative (bo) −13.8% to postoperative (po) of 51.6% of the knee joint width [Figure 2a and b]. Medial proximal tibial Angle (MPTA), hip knee ankle angle (HKA), knee joint line orientation (KJLO), and ankle joint line orientation (AJLO) all changed significantly. As expected, the mechanical lateral distal femoral angle did not change [Table 2]. The mean ΔMAD (amount of correction of MAD) was 65.4%.

We recorded intra-articular deformity parameters and their change as summarized in Table 3. JLCA, SEA, and SVD

Table 1: Demographic data

Total patients	Male	Female	Total knees	Mean age (range)	Side (right:left)
10	1	9	10	57 (42□76)	3:7

changed. CPA did not change (P = 0.07). The results of a matched cohort of ten patients who underwent TCVO were similar [Tables 4 and 5]. JLCA and KJLO did not change significantly (P = 0.09 and P = 0.3) in the TCVO group.

FDCO: Focal dome condylar osteotomy

However, postoperative standard deviation and range were much lower for AJLO in FDCO than TCVO.

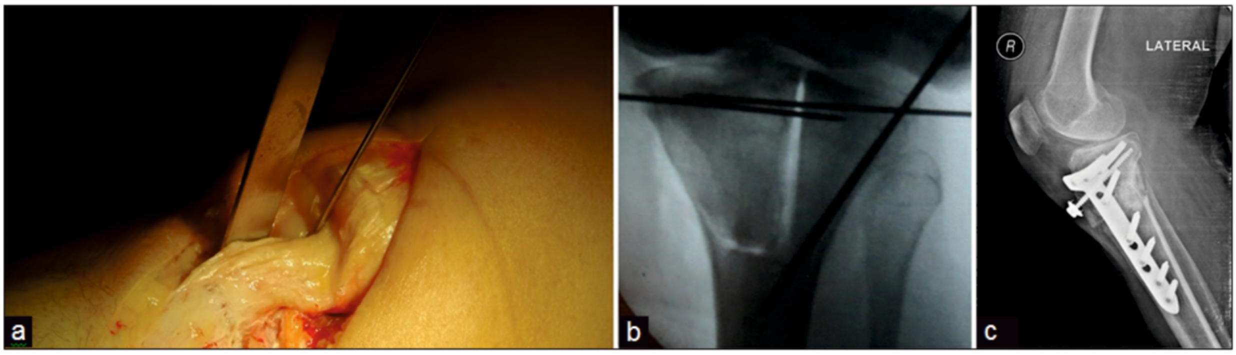

Figure 1: (a) Clinical photograph depicting vertical limb of the osteotomy being made lateral to the patellar ligament; (b) vertical limb of osteotomy passes near lateral tibial spine. Curved osteotomy is directed medially from tibial tuberosity, ending above insertion of superficial medial collateral ligament. Two transverse K-wires protect hinge at joint level and prevent separation of condyles. Two additional K-wires inserted from lateral side to prevent fracture of narrow lateral cortex; (c) Lateral X-ray shows osteotomy fixed with locking plate. It shows a screw with spiked washer to prevent patellar ligament avulsion

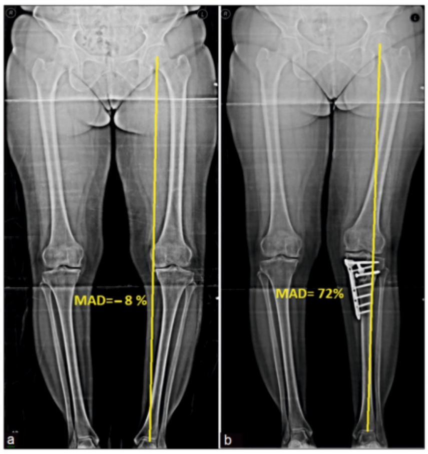

Figure 2: (a) Preoperative full-length X-ray of a 62-year-old female with left MCOA, MAD is at −8%; (b) postoperative full-length X-ray after FDCO showing left lower limb MAD is at 72%. MCOA: Medial compartment osteoarthritis, MAD: mechanical axis deviation, FDCO: Focal dome condylar osteotomy

There was no statistically significant difference between TCVO and FDCO based on the matched comparison of ten patients [Table 6].

Complications

Superficial infection developed in one patient and was resolved by antibiotics. One patient had a wound breakdown, which resolved with regular dressing. One patient had a lateral cortex fracture, which required protected weight-bearing and eventually united without alignment change [Figure 3]. We could not improve the mechanical axis in our first patient, which went from bo MAD −2% to po MAD 9%. A few months after the osteotomy healed, we performed an infratuberosity focal dome osteotomy in a second surgery. We fixed it

with an Ilizarov, which eventually corrected the MAD to 59% [Figure 4 a-d].

Discussion

EAOs correct the mechanical axis to offer pain relief in MCOA. Heijens explained how JLCA could be corrected by the coronal hypomochlion.[13] Improving the HKA angle to 2° valgus is enough to shift loading away from the medial compartment, regardless of an intra-articular deformity. A distal femoral osteotomy combined with HTO maintains KJLO and may reduce JLCA.[14] However, such a double osteotomy extracts a double price in implants and physiology. Nakayama recommended staging the two osteotomies in elderly patients, again inconvenient.[15] Hence a single tibial osteotomy that does the job of two should prove advantageous.

Chiba[6,9] described an IAO of the upper tibia where the predominant cause of MCOA was an intra-articular deformity. Their role is slowly being appreciated. We learned TCVO from Teramoto[16] in 2014 and have used it since then. We now understand how to look for and recognize intra-articular deformities causing MCOA by clinical and radiographic examination. Clinical signs include a large varus deformity, increased mediolateral laxity, and a dynamic varus gait. An increased JLCA and CPA help verify intra-articular deformity on X-rays [Tables 3 and 5]. There is also a moderate correlation between MAD <0% and a high CPA.[8] Hence, patients with a large varus MAD (<−10%) should be suspected to have an intra-articular deformity. We have previously reported[8] our experience of TCVO, which adequately corrected intra-articular deformity parameters but undercorrected the mechanical axis. We attempted to improve the mechanical axis correction by adding a second distal osteotomy, fixed with the Ilizarov fixator and called TCVO-I.[17]

Adding a second osteotomy may be considered a disadvantage. This second osteotomy may be an opening or a closing wedge. Both types can be fixed within the same locking plate.[10] However, a large varus needs an additional dome osteotomy performed distally and fixed with an Ilizarov fixator. We could improve the mechanical

Table 2: Alignment-deformity parameters of focal dome condylar osteotomy

FDCO	Mean bo±SD (range)	Mean po±SD (range)	Mean delta (po-bo)	*P*
MAD (%)	−13.8±15.3 (−42‐ 11)	51.6±12.9 (28–72)	65.4	6.89E−09
HKA (°)	166.5±3.8 (163–174.6)	178.8±4.7 (170.6–185.5)	12.25	5.78E−06
MPTA (°)	85.9±2.1 (81.2–88.7)	93±4.3 (85.9–99.9)	7.1	0.0004
KJLO (°)	1.5±1.3 (0–4.8)	3.8±2.5 (0.2–7.6)	2.3	0.02
AJLO (°)	9.9±7.1 (0.7–21.9)	1.7±2.7 (−2.5‐ 6)	−8.2	0.005
mLDFA (°)	90.2±2.8 (85.7–95.4)	90±3.4 (83.7–93.8)	−0.2	0.9

bo: Preoperative, po: Postoperative, MAD: Mechanical axis deviation, HKA: Hip knee ankle angle, MPTA: Medial proximal tibial angle, KJLO: Knee joint line orientation, AJLO: Ankle joint line orientation, mLDFA: Mechanical lateral distal femoral angle, SD: Standard deviation, FDCO: Focal dome condylar osteotomy

Table 3: Intra-articular deformity parameters of focal dome condylar osteotomy

FDCO	Mean bo±SD (range)	Mean po±SD (range)	Mean delta (po-bo)	*P*
SEA	149.5±4.7 (143.4–155.7)	157.7±5.5 (150.4–168.2)	8.3	0.002
SVD	9.9±1.0 (7.7–11.3)	7.7±1.2 (5.2–9.4)	−2.2	0.0004
JLCA	7.0±3.4 (1.7–12.3)	2.3±3.6 (−3.9‐ 6.9)	−4.6	0.009
CPA	24.8±8.4 (11.3–37.4)	17.9±7.9 (8.2–30.4)	−7	0.07

bo: Preoperative, po: Postoperative, SEA: Spine edge angle, SVD: Spine vertical distance, JLCA: Joint line convergence angle, CPA: Condylar plateau angle, SD: Standard deviation, FDCO: Focal dome condylar osteotomy

Table 4: Alignment-deformity parameters of tibial condylar valgus osteotomy

TCVO	Mean bo±SD (range)	Mean po±SD (range)	Mean delta (po-bo)	*P*
MAD (%)	−15.4±16.3 (−42‐ 12)	43.5±9.0 (26–58)	58.9	8.92E−08
HKA (°)	165.6±3.2 (159.1–170.1)	178.0±4.4 (168.1–184.3)	12.4	1.84E−06
MPTA (°)	83.9±4.0 (77–88.6)	91.7±3.4 (85–96.1)	7.9	0.0002
KJLO (°)	0.7±4.9 (−8.3‐ 8.9)	2.8±3.8 (−6.2‐ 7)	2.1	0.3
AJLO (°)	10.0±4.2 (4–17.6)	1.5±6.6 (−12‐ 12.4)	−8.5	0.004
mLDFA (°)	91.4±3.7 (82.9–96)	89.9±3.2 (82.7–93.4)	−1.5	0.3

bo: Preoperative, po: Postoperative, MAD: Mechanical axis deviation, HKA: Hip knee ankle angle, MPTA: Medial proximal tibial angle, KJLO: Knee joint line orientation, AJLO: Ankle joint line orientation, mLDFA: Mechanical lateral distal femoral angle, SD: Standard deviation, TCVO: Tibial condylar valgus osteotomy

Table 5: Intra-articular deformity parameters of tibial condylar valgus osteotomy

TCVO	Mean bo±SD (range)	Mean po±SD (range)	Mean delta (po-bo)	*P*
SEA	148.5±4.9 (139–154.3)	156.8±2.4 (152.8–159.9)	8.3	0.0004
SVD	10.4±1.6 (8.5–13.7)	8.0±0.9 (6.7–9.8)	−2.4	0.001
JLCA	5.8±4.8 (1.2–17)	2.8±2.3 (0–7.2)	−3.0	0.1
CPA	16.4±11.5 (1.8–39.6)	13.2±13.3 (0.4–33.6)	−3.1	0.57

bo: Preoperative, po: Postoperative, SEA: Spine edge angle, SVD: Spine vertical distance, JLCA: Joint line convergence angle, CPA: Condylar plateau angle, SD: Standard deviation, TCVO: Tibial condylar valgus osteotomy

axis accurately using the Ilizarov but using the fixator may not be acceptable to all surgeons and patients.

An osteotomy that corrects intra- and extra-articular deformities, uses a locking plate for fixation, and corrects the mechanical axis beyond neutral would be more convenient for surgeons and patients.

In 2020,[11] Igarashi *et al*. described the FDCO, which corrects intra- and extra-articular deformities through a single combined vertical and curved osteotomy. It is similar to the TCVO, but its vertical cut is at the level of the LTS, and the horizontal cut is curved medially and retains bony contact. It is indicated when the CORA formed by the intended mechanical axis line passing through the LTS intersects with the mechanical axis of the tibia. The CORA was present near LTS in all our FDCO cases. FDCO does not alter limb length or worsen AJLO.

We wished to judge if FDCO could correct the intra-articular deformity and the mechanical axis beyond neutral. FDCO did improve the MAD to a mean of 51.6%, but it was not significantly different in a matched cohort of TCVO (43.5%, P = 0.12). Six of the ten FDCO patients achieved MAD ≥50%, whereas only two of the ten with TCVO did. While we were disappointed with the lack of statistical significance, we feel that the change in the mechanical axis is clinically relevant and enthuses us to improve our results with FDCO even further. We are new to this technique, possibly responsible for a lower mean change of MAD.

Challenges that may have prevented us from achieving better postoperative MAD include osteoporosis and inadequate soft tissue releases. A stout arthrodesis spreader can break the thin lateral cortex near the TT while opening a large wedge. We did use two 1.8 mm wires to protect the thin cortex [Figure 1b]. We may have inadequately released soft tissues posteromedially in some of our cases. The difficulty gauging the endpoint of any dome osteotomy has possibly contributed to the slight under correction.[18] Opening and closing wedge osteotomies have definite endpoints, whereas domes do not. We may be

Figure 3: AP X-ray depicting lateral cortical fracture which developed after early full weight-bearing in a 65-year-old patient. AP: Anterior posterior

able to improve the mechanical axis with the FDCO as we master and flatten its learning curve.

IAO relieve pain by improving congruent contact between the medial and lateral tibiofemoral condyles. The resulting larger weight-bearing area reduces point loading in the medial compartment. The edges of medial and lateral condyles are elevated, measured by an increased SEA. The decreased SVD, which measures the lowering of intercondylar eminence, mildly stretches and stabilizes the cruciate ligaments.[7] CPA did not change significantly in TCVO or FDCO [Tables 3 and 5]. We have previously

Table 6: Comparison of parameters between two groups (focal dome condylar osteotomy vs. tibial condylar valgus osteotomy)

FDCO versus TCVO (delta)	*P*
MAD (%)	0.38
HKA (°)	0.96
MPTA (°)	0.64
KJLO (°)	0.87
AJLO (°)	0.92
mLDFA (°)	0.13
SEA (°)	0.99
SVD (mm)	0.76
JLCA (°)	0.41
CPA (°)	0.27

MAD: Mechanical axis deviation, HKA: Hip knee ankle angle, MPTA: Medial proximal tibial angle, KJLO: Knee joint line orientation, AJLO: Ankle joint line orientation, mLDFA: Mechanical lateral distal femoral angle, SEA: Spine edge angle, SVD: Spine vertical distance, JLCA: Joint line convergence angle, CPA: Condylar plateau angle, TCVO: Tibial condylar valgus osteotomy, FDCO: Focal dome condylar osteotomy

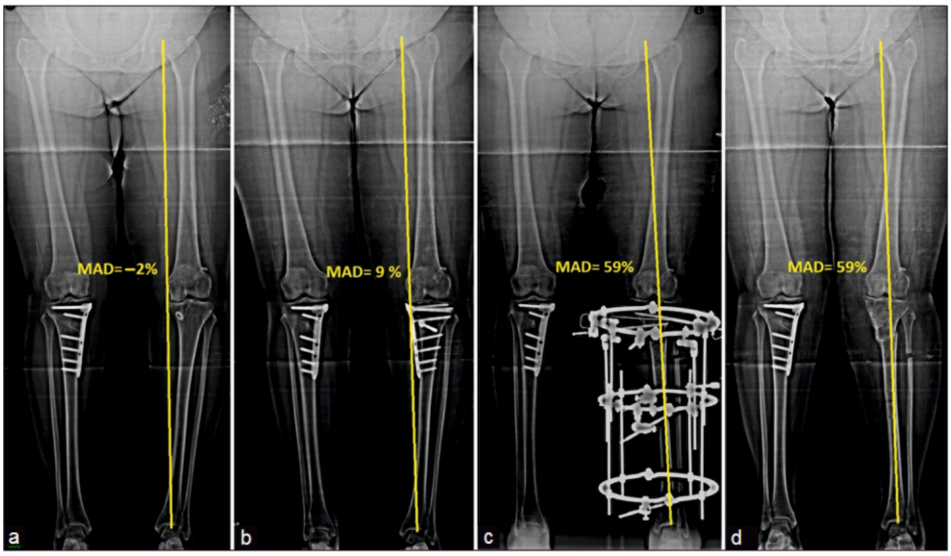

Figure 4: (a) Preoperative full-length X-ray of a 48-year-old female with left MCOA, MAD is at −2%; (b) postoperative FDCO full-length X-ray, MAD is undercorrected to only 9%. This was our first case of FDCO; (c) repeat osteotomy was performed after 5 months, as a distally convex focal dome, fixed with an Ilizarov fixator. MAD improved to 59%. Proximal fibular osteotomy needed to achieve angulation–translation of the focal dome; (d) four months after surgery Ilizarov fixator removed. Correction maintained at 59% of joint width. FDCO: Focal dome condylar osteotomy, MAD: mechanical axis deviation, MCOA: Medial compartment osteoarthritis

described the difficulties in measuring CPA accurately. SEA and SVD may not be diagnostic of an intra-articular deformity but accurately measure the change between pre- and post-operative status[7] [Tables 3 and 5].

We have reported our use of TCVO elsewhere and explained that we added a second distal dome osteotomy fixed with an Ilizarov fixator (TCVO-I) to improve the MAD. Although an effective strategy, it has come at the expense of wearing a fixator for 4 months.

The vertical limb of FDCO passes through the LTS, which corresponds approximately to the Fujisawa point or 60% of knee joint width. Elevating the PL laterally from the TT is necessary to allow a straight vertical osteotomy, which does not fracture the lateral tibial cortex. The PL is sutured to the lateral soft tissues after the osteotomy. A spiked washer was inserted in six of our ten FDCO patients to prevent avulsion of the narrowed footprint of PL [Figure 1c]. We did go slow with the knee ROM rehabilitation in our FDCO patients compared to TCVO patients. We have not experienced any avulsion of the PL in our patients.

The vertical limb of TCVO passes medial to the PL, which corresponds to 40% of the joint width. Hence, further elevation of the medial tibial condyle to better correct the mechanical axis could spread the tibial condyles apart, possibly damaging the anterior cruciate ligament (ACL) or changing the kinesiology of the knee. It may be presumed that CORA for the two osteotomies is different: more laterally for FDCO, making it easier to correct the mechanical axis beyond neutral. The PL stayed with the stable lateral fragment of TCVO but moved with the mobile medial fragment of FDCO.

Ogawa *et al*.[19] recommended not correcting MPTA to more than 95° to prevent stressing the ACL or patella-femoral cartilage. Only two of ten patients in each group had po MPTA >95°. AJLO improved to a similar extent in both osteotomies ($P = 0.92$). CPA did not change after surgery in both groups (FDCO P = 0.07, TCVO = 0.57), which reinforces our research that CPA cannot accurately diagnose or monitor intra-articular deformities. KJLO changed in FDCO ($P = 0.02$) but not in TCVO ($P = 0.3$), which we believe could reflect a greater change in overall alignment, though not reflected in the P values of MAD. JLCA reduced significantly in FDCO ($P = 0.009$) but not in TCVO ($P = 0.09$). However, in a yet unpublished larger cohort of TCVO patients we have studied, JLCA was also reduced significantly. The smaller sample size of this study does not reflect this change in JLCA in TCVO.

The major limitation of our study is the small sample size and less follow-up of the new osteotomy of

FDCO. The comparison with the TCVO group was not randomized and was retrospective. We have also not measured any patient-reported outcomes in either group. The attempt

merely measures the alignment changes in the newly described osteotomy.

Conclusion

Igarashi *et al*.[11] recently described the FDCO to correct intra- and extra-articular deformities through a single osteotomy. It has a vertical limb that passes through the LTS and a medially curved limb that rises above the superficial medial collateral ligament. It should correct the mechanical axis beyond the neutral or close to 60% without resorting to an additional EAO. We failed to demonstrate a statistically significant change in the postoperative MAD in FDCO compared with TCVO. However, it is clinically relevant and, with more experience, may allow us to correct large varus deformities with an intra- and extra-articular component through a single osteotomy without worsening either the knee or ankle joint orientation. Further experience and randomized trials with TCVO or other osteotomies may shed more light on the use of FDCO.

Acknowledgment

The senior author wishes to thank Dr. Tsuchiya for the help in understanding the surgical technique of focal dome condylar osteotomy.

Declaration of patient consent

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

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Coventry MB. Upper tibial osteotomy for osteoarthritis. J Bone Joint Surg Am 1985;67:1136-40.

2. Staubli AE, De Simoni C, Babst R, Lobenhoffer P. TomoFix: A new LCP-concept for open wedge osteotomy of the medial proximal tibia – Early results in 92 cases. Injury 2003;34 Suppl 2:B55-62.

3. Koshino T, Saito T, Orito K, Mitsuhashi S, Takeuchi R, Kurosaka T. Increase in range of knee motion to obtain floor sitting after high tibial osteotomy for osteoarthritis. Knee 2002;9:189-96.

4. Paley D. Realignment for mono-compartment osteoarthritis of knee. In: Herzenberg JE, editor. Principles of Deformity Correction. Berlin, Heidelberg: Springer-Verlag; 2005.p. 479-507.

5. Warner SJ, O'Connor DP, Brinker MR. Subtubercle osteotomy for medial compartment osteoarthritis of the knee using ilizarov technique: Survival analysis and clinical outcomes. J Bone JointSurg Am 2018;100:e1.

6. Chiba K, Yonekura A, Miyamoto T, Osaki M, Chiba G. Tibial condylar valgus osteotomy (TCVO) for osteoarthritis of the knee: 5-year clinical and radiological results. Arch Orthop Trauma Surg 2017;137:303-10.

7. Chaudhary M, Apte AP, Manna J, Badigar R, Herode P. New measurements to determine changes after intra-articular high tibial osteotomy. J Limb Lengthen Recons 2021;7:132-7.

8. Chaudhary M. Tibial Condylar Valgus Osteotomy (TCVO): An Intra-Articular Osteotomy for Severe Varus Deformities: Rationale and Short-Term Results. ESSKA Acad; 2019. p. 286-385. Available from: https://academy.esska.org/esska/2019/esska-speciality-days/286385/milind. [Last accessed 2022 May 18].

9. Chiba G. Reposition mechanism of the sublated knee by high tibial osteotomy in medial osteoarthritis. Japanese J Rheum Jut Surg 1996;15:125-36.

10. Kuwashima U, Yonekura A, Itoh M, Itou J, Okazaki K. Tibial condylar valgus osteotomy – Indications and technique. J Exp Ortop 2020;7:30.

11. Igarashi K, Yamamoto N, Hayashi K, Matsubara H, Takeuchi A, Miwa S, *et al*. Distal tibial tuberosity focal dome osteotomy combined with intra-articular condylar osteotomy (focal dome condylar osteotomy) for medial osteoarthritis of the knee joint. Arthrosc Tech 2020;9:e1079-86.

12. Christodoulou NA, Tsaknis RN, Sdrenias CV, Galanis KG, Mavrogenis AF. Improvement of proximal tibial osteotomy results by lateral retinacular release. Clin Orthop Relat Res 2005;441:340-5.

13. Heijens E, Kornherr P, Meister C. The coronal hypomochlion: A tipping point of clinical relevance when planning valgus producing high tibial osteotomies. Bone Joint J 2016;98-B: 628-33.

14. Elbardesy H, McLeod A, Ghaith HS, Hakeem S, Housden P. Outcomes of double level osteotomy for osteoarthritic knees with severe varus deformity. A systematic review. SICOT J 2022;8:7.

15. Nakayama H, Iseki T, Kanto R, Kambara S, Kanto M, Yoshiya S, *et al*. Physiologic knee joint alignment and orientation can be restored by the minimally invasive double level osteotomy for osteoarthritic knees with severe varus deformity. Knee Surg Sports Traumatol Arthrosc 2020;28:742-50.

16. Teramoto T. Clinical results of tibial condylar valgus osteotomy (TCVO) for varus type osteoarthritis of the knee joint. In: 8th ASAMI International Conference, Scientific Programme and Abstracts Handbook. Goa: ASAMI India; 2014. p. 86-7.

17. Chaudhary MM. Role of the Ilizarov fixator in high tibial osteotomy. J Clin Orthop Trauma 2021;25:101724.

18. Chaudhary MM. Can fixator-assisted plating of focal dome osteotomy accurately correct varus deformity in medial compartment osteoarthritis? J Limb Lengthen Reconstr 2016;2:94-101.

19. Ogawa H, Matsumoto K, Ogawa T, Takeuchi K, Akiyama H. Preoperative varus laxity correlates with overcorrection in medial opening wedge high tibial osteotomy. Arch Orthop Trauma Surg 2016;136:1337-42.

A COMPARATIVE MORPHOMETRIC ANALYSIS OF OPERATIVE WINDOWS FOR PERFORMING OLIF AMONG NORMAL AND DEFORMITY GROUP IN LOWER LUMBAR SPINE

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1 3**Abstract**

Purpose To assess the radiological morphometric parameters of OLIF surgical technique in lower lumbar spine among normal and in patients with adult degenerative spine (levoscoliosis and dextroscoliosis).

Method Standing AP radiographs and MRI in supine position were taken. Patients were divided into 3 groups based on Cobbs' angle into normal, levo and dextro scoliosis. Moros classification was used to calculate bare window (BW), vascular window (VW), Psoas window (PW), psoas major height (pmh) and width (pmw) at lower lumbar levels and measurements were done on PACS.

Results Seventy five patients (25 in each group) were assessed. BW has trend from L2-L3 > L3-L4 > L4-L5 in dextro and levoscoliosis. PW has trend from L3-L4 > L2-L3 > L4-L5 in levoscoliosis and normal group. VW has trend from L4-L5 > L3-L4 > L2-L3 in dextro and levoscoliosis; pmw has trend from L4-L5 > L3-L4 > L2-L3 in Levo and dextroscoliosis; pmh has trend from L4-L5 > L3-L4 > L2-L3 in levoscoliosis and normal group.

Conclusion BW was noted to be highest at L3-4, lowest at L4-5 in normal group. VW was constant, BW showed a reverse trend with PW across all the levels. Though levoscoliosis group of patients had significantly higher BW, psoas retraction issues are to be kept in mind in view of anatomically taught psoas.

Keywords Adult degenerative scoliosis · OLIF window · Morros classification · Psoas major width · Psoas major height

Introduction

Sagittal balance correction is an important determinant of outcomes in corrective surgery for adult degenerative scoliosis (ADS) [1, 2]. It is imperative to restore normal spin- opelvic balance to maximize functional outcomes, reduce pain and avoid complications. In the present era, the high success rate of minimally invasive spine surgery technology has propelled surgeons in the innovation and also extend the indications of newly developed techniques that include XLIF, ALIF and OLIF [1, 3 -7]. OLIF has been a novel technique increasingly performed by spine surgeons in ADS in recent times.

The natural cavity access between the psoas muscle and blood vessels to approach the intervertebral disc has been the main advantage in OLIF surgery [1, 2, 8-11]. The indications of OLIF have expanded over time to include a wide spectrum of degenerative disorders from single level lumbar pathology to multilevel ADS [12, 13]. Large-sized spacers are thought to be effective in restoring the sagittal and coronal balance of patients in ADS [14-19]. For a spine surgeon, a clear understanding of the local anatomical features and surgical window helps in achieving a good outcome. The studies till now have reported OLIF window anatomy in a normal spine [1, 3, 10]. There is limited literature on regional anatomical variations of OLIF operative window in patients with ADS.

We retrospectively analysed the anatomical details of ADS on MRI imaging and also compared normal patients with left scoliosis and right scoliosis. The aim of our study was (a) to measure magnetic resonance imaging (MRI) based on anatomic parameters concerning OLIF operative windows from L2-L3 to L4-L5 levels in normal patients and patients with ADS. (b) To assess various anatomical changes that determine the feasibility of the OLIF technique following MRI based morphometric evaluation in ADS. The present study will provide an anatomical database for under- standing the complex anatomy of ADS with regard to OLIF.

Materials and methods

The study was approved institutional ethical committee and has been registered in clinical trial registration of India (CTRI/2022/02/040128). Among 1210 patients who were investigated for different spine pathologies at our centre

between Jan 2020 and Sept 2020, 75 patients were included in the study who had either one of the criteria on stand- ing lumbo-sacral Anteroposterior (AP)radiographs. On the standing lumbo–sacral AP radiograph, Cobbs' angle was measured as the angle subtended between the upper end- plate of L1 and S1. All the patients were divided into three groups: Group Normal (< 10 degrees), Group Dextrosco- liosis- Right convexity (> 10 degrees), Group Levoscolio- sis–Left convexity (> 10 degrees) (Fig. a, b, c). Exclusion criteria were patients with infection, trauma, tumours, idio- pathic scoliosis, old operated for lumbar spine and/or history of retroperitoneal surgeries. All the patients underwent MR scanning in neutral supine position.1.5 T MRI imaging of lumbo-sacral spine was performed on Philips multiva imag- ing system. Acquired images were analysed on the Picture Archiving and Communication System (PACS) software version 5.0.1.3 by a spine surgeon and a radiologist with more than 10 years experience in spine.

MRI analysis

Mid-Sagittal T2W MR image and corresponding mid-discal axial image were identified, and the level noted. T2W axial images were analysed and images that were not parallel to the endplate were excluded from the study. The disc level at L2-3, L3-4 and L4-5 was identified on both sagittal and axial images and appropriate image was taken for the analy- sis. Moro's classification was used to identify the location of psoas at each disc level. The related parameters of major artery and left psoas major were analysed in an axial plane at the corresponding mid-discal level on sagittal plane at L2-L3, L3-L4 and L4-L5.

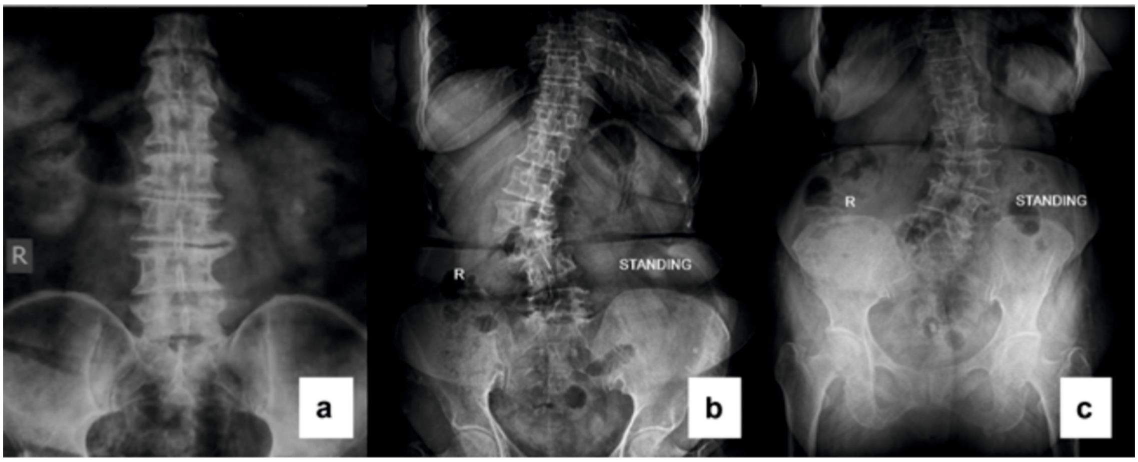


Fig. 1 Radiographs showing degenerative lumbar spine with **a** Cobbs' angle < 10 degree (Normal group), **b** right-sided convexity cobbs' angle > 10 degrees (Dextroscoliosis group) **c** left-sided convexity cobbs' angle > 10 degrees (Levoscoliosis group)

To study the left psoas major, axial plane of intervertebral discs was divided into six zones, and the front tangential lines of the left psoas muscle were noted. The area between the anterior and posterior edge of the intervertebral disc was divided into zones I, II, III, and IV. The area anterior to the anterior edge and the area posterior to the posterior edge of the intervertebral disc was defined as zone A and zone P, respectively. If the front tangential line of the left psoas muscle was on the borderline, it was more in the frontal zone. The modified Moro's classification was used when the psoas was noted in zone A []. A zone was further sub- divided into four zones named AI–AIV which are a mirror image of the equally divided zones I–IV. To study the major artery, axial plane of three intervertebral discs was divided into 5 zones, and the left tangential lines of the major artery were measured. The area between the median line (pass- ing through the center of the disc and the spinous process) and the left edge of the intervertebral disc were divided into zones a, b, and c. The median line that passed through the center of disc and the spinous process varied according to the degree of rotation of the vertebra. The area right to the median line and the area left to the left edge of the interver- tebral disc were defined as zone R and zone L, respectively. (Fig. a, b).

At the mid-discal level (sagittal plane) at L2-L3, L3-L4

and L4-L5 the following parameters were evaluated in axial plane. Bare window-BW (bare unobstructed disc portion bounded by abdominal aorta or left iliac vessels medially and left psoas major laterally), psoas major win- dow-PW (left front portion of disc space which is covered by left psoas major from its anterior portion up to middle frontal plane), vascular window-VW (the distance from the left boundary of the abdominal aorta or left iliac vessels to the median sagittal plane), psoas major width-PMW

(width of left psoas major on the middle frontal plane of the intervertebral disc space), psoas major height-PMH (distance from farthermost portion of psoas perpendicular to the middle frontal plane of the intervertebral disc space) (Fig. a, b, c).

Statistical analysis

The data were analysed using NCSS software, version 12. The data were checked for normality using Shapiro–Wilk test and checking distributions in histograms. The demo- graphic variables were calculated and compared across groups. The continuous variables were compared using one-way ANOVA and the categorical variables were com- pared using the chi-squares test. The data for Bare win- dow, Psoas major width and height, Psoas window and Vascular window were compared across the different spine levels (L2-L3, L3-L4 and L4-L5) for the three groups of patients (dextroscoliosis, levoscoliosis and normal curva- ture) using 2-way mixed-model ANOVA. The post hoc analysis for pairwise comparisons to find the group and level differences, in case of significant interactions, was done using Tukey Kramer tests. The level of significance for all tests was $p < 0.05$.
The effects of gender on the Bare window, psoas major width and height were compared across the groups using 2-way ANOVA tests. The data were compared and aver- aged across the levels for this analysis. The bare window was also compared across the levoscoliosis and dextro- scoliosis groups and levels (L2-L3, L3-L4 and L4-L5) across angles of scoliosis (10°–20°, 21°–30° and > 31°) and age categories (≤40 and > 40 years) using separate 3-way mixed-model ANOVA tests.

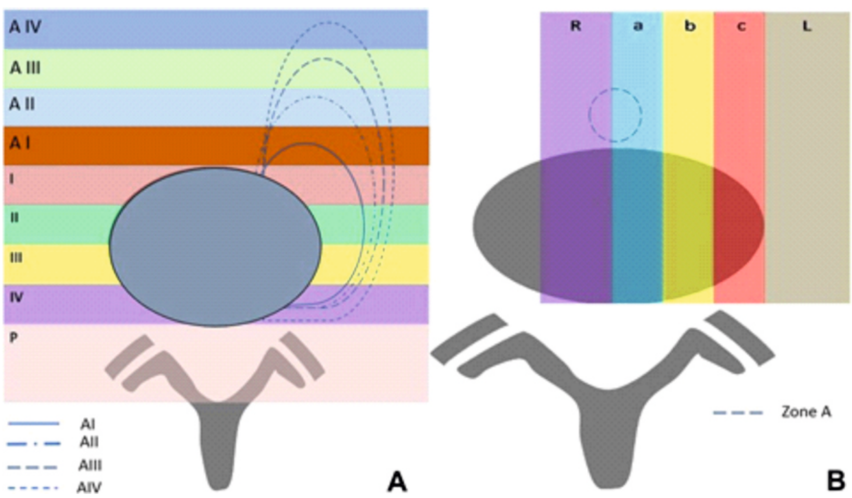


Fig. 2 a Diagrammatic representation of the position of psoas at different levels in Modified Morros Classification **b** Diagrammatic representation of the position of the aorta in different zones in Morros Clas- sification.

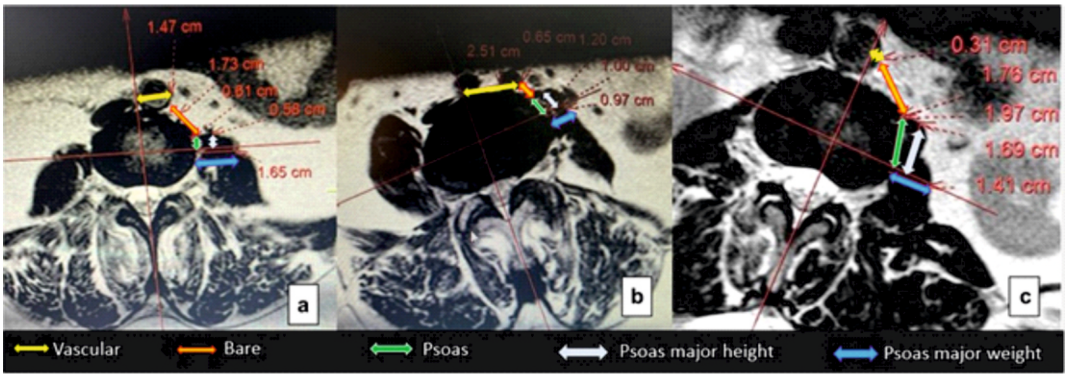


Fig. 3 Measurement of the vascular window, bare window, psoas window, psoas major width and psoas major height **a** Normal group **b** Dextro- scoliosis **c** Levoscoliosis.

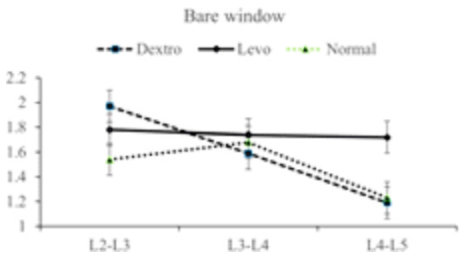


Fig. 4 Graphical representation showing bare window across all groups

Results

Bare window

There were significant interactions between the group and levels ($F = 2.62$, df = 4/144, $p = 0.037$) for the bare window analysis. The post hoc tests suggested that the bare window was significantly larger at the L2-L3 level (1.97 ± 0.7) as compared to the L4-L5 level (1.19 ± 0.8) for the dextroscoliosis group of patients. The bare window has a decreasing trend from L2-L3 > L3-L4 > L4-L5 in Dextro- scoliosis and Levoscoliosis whereas in the Normal group it was L3-L4 > L2-L3 > L4-L5. At L3-L4 and L4-L5 the bare window had a decreasing trend from levoscoliosis > nor- mal > Dextroscoliosis ($p < 0.05$) (Fig.) (Table).

Psoas window

There was a significant interaction between group and level ($F = 3.50$, df = 4/144, $p = 0.009$). Post hoc com- parisons revealed that the levoscoliosis group had a

significantly smaller (0.74 ± 0.07) psoas window at L4-L5 level as compared to dextroscoliosis group (1.24 ± 0.07) The psoas window has a decreasing trend from L3-L4 > L2-L3 > L4-L5 in levoscoliosis and nor- mal group and L3-L4 > L4-L5 > L2-L3 in dextroscolio- sis group. ($p < 0.05$) Levoscoliosis has the lowest psoas window at L2-L3, L3-L4 and L4-L5 levels compared to normal and dextroscoliosis (Fig.).

Vascular window

There was a significant main effect of level ($F = 15.40$, df = 2, $p < 0.0001$) for vascular window. Post hoc tests reveal that the corridor was significantly higher at L4-L5 level (1.77 ± 0.07) as compared to the other levels (1.27 ± 0.07). The Vascular window has a decreasing trend from L4-L5 > L3-L4 > L2-L3 in dextroscoliosis and lev- oscoliosis whereas it has L4-L5 > L2-L3 > L3-L4. Post hoc tests revealed that the corridor was significantly higher at the L4-L5 level as compared to the other levels. ($p < 0.05$) (Fig.).

Psoas major width

There were significant interactions between the group and levels ($F = 4.02$, df = 4/144, $p = 0.004$) for psoas major width. The post hoc tests suggested that the psoas major width significantly increased across each level for the levoscoliosis and dextroscoliosis groups and for the nor- mal curve, the psoas major width was significantly higher for the L4-L5 level as compared to the L2-L3 and L3-L4 level. The Psoas major width had a decreasing trend from L4-L5 > L3-L4 > L2-L3 in the levoscoliosis and dextrosco- liosis group and the psoas width was significantly higher for

Table 1 Comparison of the age, sex, vascular window, bare window, psoas window, psoas major height and psoas major width across (a) Normal group (b) Dextroscoliosis © Levoscoliosis

Variable	Dextro	Levo	Normal	*p*
Age	62.44 ± 9.5	61.72 ± 8.6	57.48 ± 8.3	0.106
Gender	18 females, 7 males	23 females, 2 males	17 females, 8 males	0.09
Angle	19.24° ± 8.9°	18.84° ± 5.6°		0.84
Bare corridor				
L2-L3	1.97 ± 0.7[a]	1.78 ± 0.6	1.54 ± 0.5	0.137
L3-L4	1.59 ± 0.7[ab]	1.74 ± 0.5	1.68 ± 0.6	
L4-L5	1.19 ± 0.8[b]	1.72 ± 1.0	1.23 ± 0.8	
Psoas corridor				
L2-L3	0.96 ± 0.5	0.90 ± 0.4	1.08 ± 0.4	
L3-L4	1.26 ± 0.5	1.22 ± 0.5	1.25 ± 0.4	
L4-L5	1.24 ± 0.4	0.74 ± 0.4	1.03 ± 0.4	
Vascular corridor				
L2-L3	1.26 ± 0.6[a]	1.20 ± 0.6[a]	1.36 ± 0.5[a]	0.531
L3-L4	1.41 ± 0.6[a]	1.22 ± 0.6[a]	1.21 ± 0.5[a]	
L4-L5	1.77 ± 0.9[b]	1.66 ± 0.8[b]	1.91 ± 0.9[b]	
Psoas height				
L2-L3	0.81 ± 0.4[a]	1.05 ± 0.4[a]	1.14 ± 0.5[a]	< 0.0001
L3-L4	1.19 ± 0.5[ae]	1.46 ± 0.6[bd]	1.88 ± 0.7[b]	
L4-L5	1.94 ± 0.6[be]	2.18 ± 1.0[cd]	2.97 ± 0.7[c]	
Psoas width				
L2-L3	0.99 ± 0.5[a]	1.02 ± 0.3[a]	0.93 ± 0.5[a]	0.0095
L3-L4	1.61 ± 0.8[b]	1.74 ± 0.6[bd]	1.26 ± 0.6[a]	
L4-L5	2.55 ± 0.7[ce]	2.75 ± 0.9[cd]	1.94 ± 0.8[b]	

Assignment of alphabets in the superscript denotes tests across different levels. Assignment of different alphabets suggests statistically significant difference whereas assignment of same alphabet denotes no dif- ference. The p values signify difference across the groups

[d]Suggests statistical difference between levoscoliosis and normal group

[e]Suggests statistical difference between dextroscoliosis and normal group

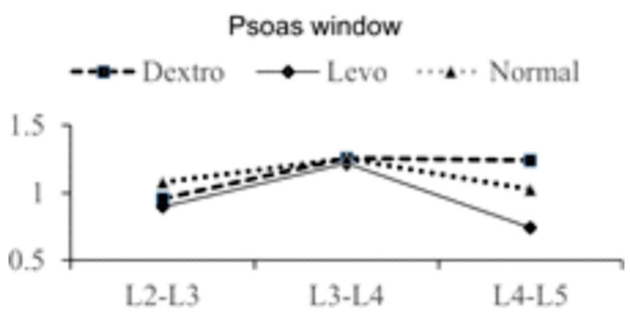


Fig. 5 Graphical representation showing psoas window across all groups

the L4-L5 level compared to the L2-L3 and L3-L4 levels. ($p < 0.05$) (Fig.).

Psoas major height

There were significant interactions between the group and levels ($F = 5.52$, df = 4/144, $p = 0.0003$) for psoas major height. The post hoc tests suggested that the psoas major height significantly increased across each level for the levoscoliosis and normal curve groups whereas, in the

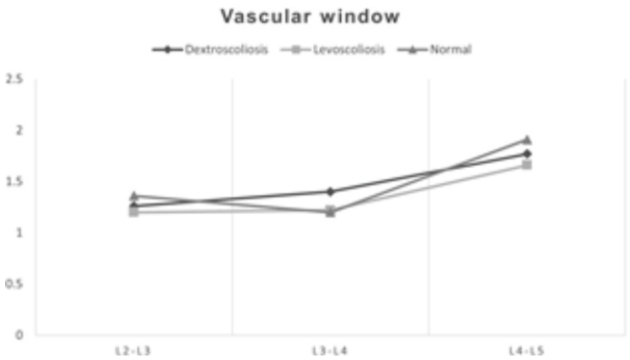


Fig. 6 Graphical representation showing vascular window across all groups

dextroscoliosis group, it was significantly higher in the L4-L5 level as compared to the other levels. The psoas major height has a decreasing trend from L4-L5 > L3-L4 > L2-L3 in levoscoliosis and normal whereas, in the dextroscoliosis group, it was significantly higher in the L4-L5 level compared to the other levels. ($p < 0.05$) (Fig.).

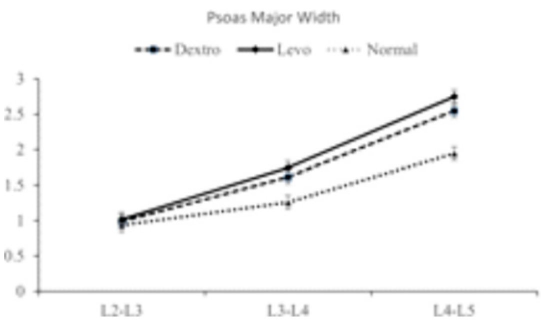


Fig. 7 Graphical representation showing psoas major width across all groups

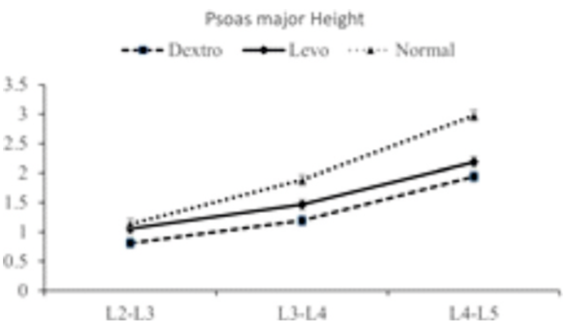


Fig. 8 Graphical representation showing psoas major height across all groups

Age and gender

The bare window was statistically insignificant with increase in age and had no correlation among all groups ($p < 0.05$). The sex had a significant main effect ($F = 5.36$, $p = 0.021$) on the bare corridor with the males showing a significantly larger dimension (1.85 ± 0.10) than the females (1.55 ± 0.05) averaged over all groups. At the L2-L3 level, the bare window has decreasing trend from Levoscoliosis > Nor- mal > Dextroscoliosis ($p < 0.05$). Males had a significantly higher bare window than females ($p < 0.05$). The psoas major width with a significantly highest width in males as compared to females ($p < 0.05$).

Angle of scoliosis

The three-way ANOVA tests resulted in a significant main effect of level only with the bare corridor at L4-L5 signifi- cantly lower than L2-L3 to L3-L4 level. There were no sig- nificant effects of age category or angle category.

Discussion

ADS is a potentially debilitating spine condition with multiaxial rotational deformity. Majority of the degenera- tive changes are seen in lower lumbar spine ensuing loss of lumbar lordosis and sagittal plane deformity. Although

the exact mechanism of vertebral rotation in ADS has not been explained, it was assumed that asymmetrical degen- eration of facet is worth considering [–]. In view of the complexity and unclear anatomy of pedicle in ADS, the chances of pedicle breach and aortic injury in posterior pedicle screw placement surgeries have been documented. For surgeries pertaining to anterior and oblique approaches such as ALIF, OLIF in ADS detailed anatomical studies are scarce. In 2014, Davis et al. studied the related anatomy of OLIF at L2-S1 with cadavers []. In 2015, Molinares et al. documented the oblique corridors of 100 American patients through magnetic resonance imaging (MRI) analysis []. In 2016, Liu et al. observed the applied physiologic anatomic parameters of OLIF operative windows through computed tomography angiography. Liu et al. suggested that anatomic measurements made in vivo are closer to the human surgi- cal state and are more credible []. In a study by Xiaoqing Chen et al., physiologic anatomic parameters of OLIF in 400 Chinese subjects through MRI was studied []. Zhang et al., studied the positional changes of surgical corridors on MRI []. All the studies till now reported anatomical details in patients without structural deformity. Hence an attempt was made to understand the changes in anatomical parameters pertaining to OLIF surgery in ADS.
In group Normal, BW was noted to be highest at L3-4 and

lowest at L4-5 levels. At L3-4 level, where BW was the high- est, VW was the lowest and PW was high. This states that L3-4 level is more accessible area for OLIF in normal indi- viduals without scoliosis. These findings are in accordance with the literature [, ,]. In group Levoscoliosis, BW was seen to be maximum at L2-3 and L3-4 levels. Though the BW was lower when compared to group Normal, was significantly higher on comparison to group Dextroscoliosis. In accordance to the findings, PW and VW was noted to be minimum. In our study, we found that group Levoscolio- sis patients were the most suitable candidates for perform- ing surgical procedures like OLIF via left-sided approach. According to Regev et al., the bare window decreased to 40% in levoscoliosis spines (least safe) and 61% in dextro- scoliosis spines compared with 70% in nonscoliotic group []. In group Dextroscoliosis, BW was seen to be maxi- mum at L2-3 and L3-4 levels. Among all the groups, group Dextroscoliosis had the lowest window. Though statistically insignificant, these findings may be secondary to higher PW resulting in lower BW.

The position of VW is most commonly reported to be in zone a, b or c and less commonly in zone R and L []. Few studies have reported the change in position of abdominal aorta in relation to vertebral body in adolescent idiopathic scoliosis (AIS) [, ,]. Studies have shown that the aorta is positioned more towards the concavity of the curve in AIS and few reported that it varies with vertebral rotation. Y Laing and Su et al. in their study on adult degenerative

scoliosis (ADS) reported no significant correlation between the vertebral rotation and the position of the aorta []. Our study did not notice any significant change in the VW in different groups. VW gains its importance from the surgical point of view as the vessels on the concave side of curvature were positioned relatively posterior, thereby posing the risk of the surgeon unintentionally drifting anteriorly []. Even the vessels on the contralateral side are at greater risk during annular release [].

BW is the area between the left psoas and the abdominal aorta. The width of the BW depends on the relative posi- tion of VW and PW. In patients without scoliosis, the VW is nearly constant, and the BW partly depends on the PW [,]. In our study, BW showed a reverse trend with PW at the L3-L4 level in all the three groups. Few studies have proven that the VW does not change its position in ADS that implies that BW is dependent on PW [,]. And also group Levoscoliosis showed higher BW when compared to group Normal and Dextroscoliosis. These findings were also related to PW as the latter showed lower values.

We have noted that the psoas major of men is wider and thicker than the psoas major of women. Psoas major muscle was seen in zone I, zone II which is the normal anatomical feature of psoas major muscle. Our result was consistent with the previous studies []. In addition, it was found that the older the age group, the smaller the psoas major width. This change may be caused by atrophy of the psoas, how- ever, change in the thickness of the psoas major was not observed. In general, we deem that older women tend to have weaker psoas major and are more likely to have more scope of operation through traction [].

The width and height of the psoas major probably indi- cate the difficulties of the psoas retraction. Many studies reported that the width and thickness of the psoas major were L4-5 > L3-4 > L2-3. This finding is consistent with the physiologic anatomy of the human body, as the lower the psoas muscle, the wider and thicker it is. In our study, we noted the same findings. Psoas major width and height gradually increased from L2-3 to L4-5 irrespective of the type of deformity. Psoas major height was noted to be more in group Normal followed by group Levoscoliosis at all the levels when compared to group Dextroscoliosis. Psoas major width was noted to be more in group Levoscoliosis followed by group Normal and group Dextroscoliosis. These find- ings indicate that the difficulties of psoas retraction during surgery are less in group Dextroscoliosis compared to other groups. The anatomical explanation for this finding can be correlated to relaxed psoas on left side in patients with right- sided convexity and left concavity (group Dextroscoliosis). On the contrary, group Levoscoliosis patients though have adequate PW, may have psoas retraction issues in view of anatomically taut and stretched psoas, however, it depends on apex of curve [].

Our study is the first to compare normal patients to lev- oscoliosis and also dextroscoliosis. We also have studied in detail regarding the psoas dimensions not only the psoas window but also psoas height and width. Any study has its limitations, and the present study is not an exception. First, all the MRIs were taken in the supine position. Surgery is performed in the right lateral position. So further studies need to be carried out in different positions to get a clear understanding. Second, given the rotation of the vertebra, the distance between two points is not a straight line and may not give actual distance and is calculated to the near- est millimetre. Third, though we have taken the reference lines to calculate the zones, vertebral rotation angle is not calculated in our study. Future studies on MRI on different positions may enhance understanding related to positional changes in various windows in ADS and also correlation to intra-operative findings will help surgeons for safe sur- gery. MRI in right lateral position need to be performed for better evaluation of bare window and radiological fea- tures need to be correlated intraoperatively. A 3D imaging and intra-operative use of navigation would give a better understanding of the rotation in not only in sagittal and axial but also in the frontal plane.

Conclusion

In group Normal, BW was noted to be highest at L3-4 and lowest at L4-5 levels. When compared among lev- oscoliosis and dextroscoliosis group, levoscoliosis group had significantly higher BW. These group of patients may have psoas retraction issues in view of anatomically taut and stretched psoas, however it depends on apex of curve. VW was constant, BW showed a reverse trend with

PW across all the levels.

Author contributions DD: approved the version to be published, drafted the article. VP: acquisition/analysis/interpretation of data. BD: conception of work. AK: drafted the work. SM: drafted the work. RRR: interpretation of data. SB: acquisition and analysis of data. PA: approved the article version. PA: investigated and resolved questions related to the integrity of work.

Funding No funding was received for this work.

Declarations

Conflict of interest No conflict of interest.

Ethical approval The study was approved institutional ethical com- mittee and has been registered in the clinical trial registration of India (CTRI/2022/02/040128).

References

1. Kaul R, Kumar H, Jeyaraman M et al (2021) MRI-based mor- phometric study regarding operative windows of oblique lumbar interbody fusion in Indian population. Indian J Orthop. https://doi.org/10.1007/s43465-021-00393-7

2. Silvestre C, Mac-Thiong JM, Hilmi R et al (2012) Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients. Asian Spine J 6(2):89–97. https://doi.org/10.4184/asj.2012.6.2.89

3. Wang Z, Liu L et al (2020) The OLIF working corridor based on magnetic resonance imaging: retrospective research. J Orthop Surg Res 15(1):141. https://doi.org/10.1186/s13018-020-01654-1

4. Ohtori S, Orita S et al (2015) Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for lum- bar spinal degeneration disease. Yonsei Med J 56(4):1051. https:// doi.org/10.3349/ymj.2015.56.4.1051

5. Sato J, Ohtori S, Orita S et al (2017) "Radiographic evaluation of indirect decompression of mini-open anterior retroperitoneal lum- bar interbody fusion: oblique lateral interbody fusion for degener- ated lumbar spondylolisthesis" by Jun by Jun Sato et al. Eur Spine J 2017(26):671–678. https://doi.org/10.1007/s00586-017-5326-x

6. Jin C, Jaiswal MS, Jeun S-S et al (2018) Outcomes of oblique lateral interbody fusion for degenerative lumbar disease in patients under or over 65 years of age. J Orthop Sur Res 13(1):38. https:// doi.org/10.1186/s13018-018-0740-2

7. Ozgur BM, Aryan HE, Pimenta L et al (2006) Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. Spine J 6(4):435–443. https://doi.org/10.1016/j.spinee.2005.08.012

8. Mayer HM (1997) A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine (Phila Pa 1976) 22:691–699

9. Moro T, Kikuchi S-I et al (2003) An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery. Spine 28(5):423–427. https://doi.org/10.1097/01.brs.0000049226.87064.3b

10. Chen X, Chen J, Zhang F (2019) Imaging anatomic research of oblique lumbar interbody fusion in a

Chinese population based on magnetic resonance. World Neurosurg 128:e51–e58. https://doi.org/10.1016/j.wneu.2019.03.244

11. Davis TT, Hynes RA et al (2014) Retroperitoneal oblique cor- ridor to the L2–S1 intervertebral discs in the lateral position: an anatomic study. J Neurosurg Spine 21:785–793. https://doi.org/10.3171/2014.7.SPINE13564

12. Watkins RG, Hanna R et al (2014) Sagittal alignment after lumbar interbody fusion. J Spinal Disord Tech 27(5):253–256. https://doi. org/10.1097/BSD.0b013e31828a8447

13. Fujibayashi S, Kawakami N et al (2017) Complications associated with lateral interbody fusion. Spine. https://doi.org/10.1097/brs. 0000000000002139

14. LiMobbs JXRJ et al (2018) Morphometric MRI imaging study of the corridor for the oblique lumbar interbody fusion technique at L1-L5. World Neurosurg 111:e678–e685. https://doi.org/10. 1016/j.wneu.2017.12.136

15. Elowitz E, Yanni D, Chwajol M et al (2011) Evaluation of indirect decompression of the lumbar spinal canal following minimally invasive lateral transpsoas interbody fusion: radiographic and outcome analysis. Min Minim Invasive Neurosurg 54:201–206. https://doi.org/10.1055/s-0031-1286334

16. Oliveira L, Marchi L et al (2010) A radiographic assessment of the ability of the extreme lateral interbody fusion proce- dure to indirectly decompress the neural elements. Spine 35(Supplement):S331–S337. https://doi.org/10.1097/brs.0b013 e3182022db0

17. Yuan W, Kaliya-Perumal A-K et al (2019) Does lumbar interbody cage size influence subsidence? A biomechanical study. Spine. https://doi.org/10.1097/brs.0000000000003194

18. Zhu G, Hao Y et al (2018) Comparing stand-alone oblique lumbar interbody fusion with posterior lumbar interbody fusion for revi- sion of rostral adjacent segment disease. Medicine 97(40):e12680. https://doi.org/10.1097/MD.0000000000012680

19. Kim D-B, Shin M-H et al (2018) Vertebral body rotation in patients with lumbar degenerative scoliosis: surgical implication for oblique lumbar interbody fusion. World Neurosurg. https://doi. org/10.1016/j.wneu.2018.12.073

20. Ng JP, Kaliya-Perumal AK, Tandon AA et al (2020) The oblique corridor at L4–L5: a radiographic-anatomical study into the feasibility for lateral interbody fusion. Spine (Phila Pa 1976) 45(10):E552–E559. https://doi.org/10.1097/BRS.0000000000003346

21. Regev GJ, Kim CW (2014) Safety and the anatomy of the retro- peritoneal lateral corridor with respect to the minimally invasive lateral lumbar intervertebral fusion approach. Neurosurg Clin N Am 25(2):211–218. https://doi.org/10.1016/j.nec.2013.12.001

22. Silva FE, Lenke LG (2010) Adult degenerative scoliosis: evalua- tion and management. Neurosurg Focus 28(3):E1. https://doi.org/ 10.3171/2010.1.focus09271

23. TempelGandhoke ZJGS et al (2014) Radiographic and clinical outcomes following combined lateral lumbar interbody fusion and posterior segmental stabilization in patients with adult degen- erative scoliosis. Neurosurg Focus 36(5):E11. https://doi.org/10. 3171/2014.3.focus13368

24. Birknes JK, Harrop JS et al (2008) Adult degenerative scoliosis. Neurosurgery 63(Supplement):A94–A103. https://doi.org/10. 1227/01.neu.0000325485.49323.b2

25. Aebi M (2005) The adult scoliosis. Eur Spine J 14(10):925–948. https://doi.org/10.1007/s00586-005-1053-9

26. Molinares DM, Davis TT et al (2016) Retroperitoneal oblique corridor to the L2–S1 intervertebral discs: an MRI study. J Neuro- surg Spine 24(2):248–255. https://doi.org/10.3171/2015.3.SPINE 13976

27. Liu L, LiangZhang YH et al (2016) Imaging anatomical research on the operative windows of oblique lumbar interbody fusion. PLoS ONE 11(9):e0163452. https://doi.org/10.1371/journal.pone. 0163452

28. Zhang F, Xu H et al (2017) Does right lateral decubitus position change retroperitoneal oblique corridor? A radiographic evalua- tion from L1 to L5. Eur Spine J 26(3):646–650. https://doi.org/10.1007/s00586-016-4645-7

29. Milbrandt TA, Sucato DJ (2007) The position of the aorta rela- tive to the spine in patients with left thoracic scoliosis. Spine 32(12):E348–E353. https://doi.org/10.1097/brs.0b013e318059aeda

30. Sevastik B, Xiong B, Hedlund R et al (1996) The position of the aorta in relation to the vertebra in patients with idiopathic thoracic scoliosis. Surg Radiol Anat 18(1):51–56. https://doi.org/10.1007/ bf03207763

31. Liang Yan, Shuai Xu, Zhao Yongfei et al (2021) The effects of vertebral rotation on the position of the aorta relative to the spine in patients with adult degenerative scoliosis. Therapeutic. https:// doi.org/10.1177/20206223211027108

with adult degenerative scoliosis. Therapeutic. https:// doi.org/10.1177/20206223211027108

UNUSUAL USE OF THE LISFRANC SCREW : NEW POSSIBILITY OF FIXATION IN THE LISFRANC INJURY

Dr.Kishor Dudhat,

Dr.Rajiv Shah

Introduction

Lisfranc injury refers to those injuries which affect the TMT and inter-cuneiform joints of the foot including metatarsal bases, cuneiforms and interconnecting ligaments. Fracture pattern variations are common in the Lisfranc injury. It may complicate treatment strategy if there is severely comminuted fracture at the base of the second metatarsal. Here we tried newer entry for home run screw, from the base of the third metatarsus to get compression at second TMT joint. They are relatively uncommon, affecting approximately 0.2% of all fractures

Case presentation

A male of 42 year old sustained a foot injury due to fall from stepladder .He got huge swelling and pain at his left foot. He was diagnosed after radiological evaluation as the Lisfranc fracture dislocation case. X-ray film shows comminuted fracture of the second metatarsus base and disruption of the second & third TMT joint. CT scan was done to do further assessment this case for better understanding. Initially treated with below knee plaster splint for 10 days .definite fixation done after wrinkle sign appeared on his foot through single dorsal midline approach, fracture fixed with locking plate and screw for the second & third TMT joint spanning. Third metatarsal base used to get entry of the Lisfranc screw for compression at the second TMT joint. Inter-metatarsal screw achieves good stabilization of the lisfranc joint (8). Post operative protocol was followed properly with good rehabilitation therapy.

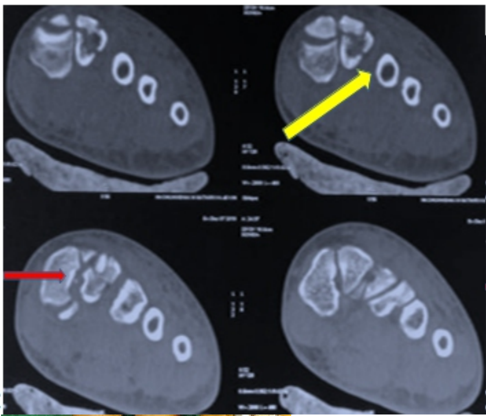
Conclusion

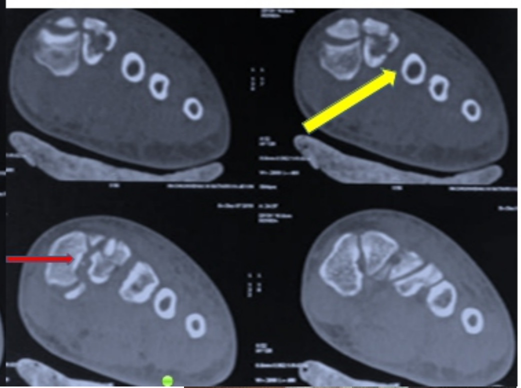
Success of the Lisfranc joint fixation depends on proper reduction and stability achieved at TMT joint (8). Inter-metatarsal screw gives enough stability to heal this injury (9).

Background

The Lisfranc injury requires a strategic approach for a better outcome. Routinely this injury is treated with positional screw or spanning plate (5). The second & third TMT joint usually fixed rigid but the fourth & fifth TMT joint should be fixed with temporary k-wire which can be removed at 6 week (8). This surgery can be done with either single or double dorsal approach on foot. literature suggest screw direction of the lisfranc screw from the base of the second metatarsus to medial cuneiform or from medial cuneiform to the second metatarsus base, but when the base of second metatarsal is fractured, one can't get good hold or compression at the joint, so in that situation this technique helps the surgeon to get stability through inter metatarsus screw from third metatarsal to medial cuneiform direction. Supplementary spanning plate augmentation of the second & third TMT joint required. Postoperativelypatient should be kept non weight bear for six week along with below knee splint. Then partial weight bearing allowed for another six to eight weeks, with cane support and arch support for six month.

Pre operative xray film of left foot





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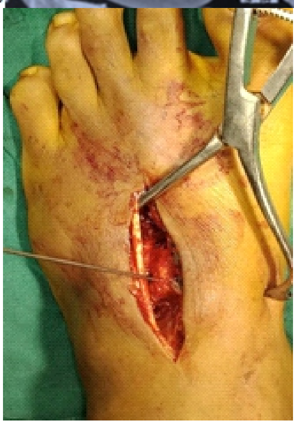
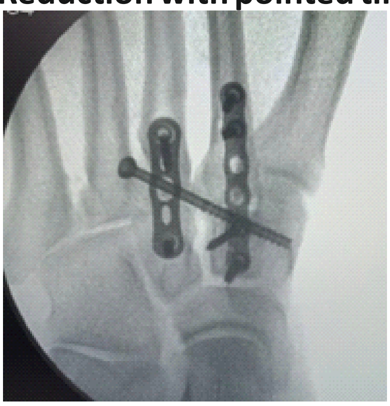


Midline dorsal incision

(Reduction with pointed tinaculum forcep)



Final result at 4 Year

Discussion and conclusion

As per literature suggest instead of trans-articular screw, a joint spanning plate fixation gives good outcome in the Lisfranc injury **(5).** We used that principle but the lisfranc screw is one which gives proper stability in this case, so inter-metatarsal screw through the base of metatarsal gives god stability

(9). Routinely this screw can be inserted from the base of the second metatarsal **(10),** but in this case there was fracture, so through fracture one can't get enough compression of diastases, better to use the third metatarsal base, only problem for this entry is horizontal arch needs to be addressed while compressing with reduction tool.

AcknowledgementsThe author thanks Dr. Rajiv Shah (2), a well- known foot and ankle specialist surgeon for guidance and technical support and Dr. Vinod Panchbhavi (3), Dr.Kartik Hariharan (4) sir for their helpful comments on this case and inspiring us to report this case

Funding

No funding to declare

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Consent for publication

Written informed consent was taken from patient and his relatives for publication of this case report and any images.

COMPETING INTERESTS

The authors declare that they have no competing interests

References

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(5).Lisfranc fracture-dislocations: current management Inmaculada Moracia-OchagavíaE. Carlos Rodríguez-Merchán Jul 2 2019;4(7): 430-444 :Effort open Reviews PMID:31423327

(6). Ligamentous Lisfranc joint injuries: a biomechanical comparison of dorsal plate and trans-articular screw fixation.
journal of orthopedic trauma: November 2020-Volume34-Issue11-p e420-e423

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(7)
Evaluation of the Area of the Lisfranc Ligament Damaged by Screw Fixation
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March-2018

(8)

Lisfranc Fixation Techniques and Postoperative Functional Outcomes: A Systematic Review

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Biomechanical Testing of a Transmetatarsal Base Screw in Lisfranc Injuries

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(10)

Orientation of the “Lisfranc Screw”

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Journal of Orthopaedic Trauma: November 2012 - Volume 26 - Issue 11 - p e221-e224

MANAGEMENT OF COMPLEX OPEN DISTAL FEMUR FRACTURES WITH FIBULA AND CANCELLOUS GRAFT: CASE SERIES

Dr. Keyur Patel

Abstract

Purpose:

To report functional and radiological outcomes of using lateral plate and debridement in stage 1 followed by fibular strut graft together with cancellous graft and medial plating in second stage after 3-4 weeks in distal femoral fractures. In 5 cases, 3 were operated in staged manner and 2 cases with single stage bone grafting and platting amongst which one case (33-A3) with vascular injury operated with single lateral plate and fibula & cancellous graft in second stage.

Method:

A retrospective study on 5 patients with comminuted distal femoral open grade fractures managed single/dual stage single/dual plate and fibula & cancellous grafting by Swashbuckler approach has been conducted. Only distal femoral fractures type 33-A3, 33-C2, and 33-C3, were included. The patient's mean age was 25.2 years. Evaluation included operative time, blood loss, time to union, knee range of motion, Sanders scoring, and presence of complications.

Results:

All patients had no postoperative knee stiffness with a range of motion (90–120°) during follow-up. The time for radiological union was at 3 months, with no cases of non-union. The average follow-up period was 3 to 4 months and 6month & yearly follow up are yet to come. Mean intraoperative blood loss was 325 ml, and mean operative time was 76.87 min without anaesthesia. All patients had a knee range of motion (90–120°<full>) during follow-up. Time for union at 3 months, with no cases of non-union. A total of 5 patients 3 (60%) showed excellent functional outcomes, and the remaining 2 (40%) showed good functional outcomes according to the Sanders scoring system. Only one cases had late infections (1yr post op) managed by implant removal after 1 year. No post-operative deformity, loss of reduction, or implant failure was observed until the end of follow-up period

Conclusion:

Staged debridement with single plate f/b 2nd fibular grafting and medial plate in more contaminated and single staged procedure in non-contaminated cases BG and dual plating of comminuted distal femur fractures in patients is an effective technique with higher rates of union and lower re-operation rates compared to other fixation modalities.

Introduction

Distal femoral fractures are high-energy injuries that account for 5 % to 10 % of all open fractures.

Patients with these fractures frequently exhibit critical bone defects caused by high-energy trauma in the supracondylar areas.

Critical bone defects have been characterized in the literature as defects with a length of >1 to 2 or >2 cm and circumferential loss of >50% [1]. Current treatment methods include bone transplantation, distraction osteogenesis, and the induced membrane technique (Masquelet technique) [2].

We herein present a case involving a patient who underwent treatment of an acute bone defect with a fibular graft and was followed up for 3-4 month and further yearly follow up is going on. Informed consent was obtained prior to treatment, and the case was registered.

The purpose of this paper is to present a treatment option for patients with this type of severe femoral injury.

Materials and methods

A retrospective study of patients with distal femur fractures was conducted. We searched our medical records for patients with distal femur fractures managed by double plating and fibular grafting technique with 2 stage or single staged procedure.

Inclusion criteria included all age, displaced isolated or with polytrauma distal femoral fracture with metaphyseal comminution (AO/OTA 33-A3, 33-C2, 33-C3) fractures.

Exclusion criteria were polytrauma patients with severe head injury, open fractures with non-coverable open wounds, pathological fractures, patients not fit for surgery, and non-ambulatory patients.

Patient charts and radiographs collected from the electronic medical record were reviewed for demographic data, AO/OTA classification, operative time, intraoperative blood loss, time to union, complications, reinterventions, and functional outcome scoring at the end of follow-up was evaluated according to the Sanders scoring system [3].

5 patients met the inclusion criteria between 2016 and 2019 and were enrolled in this study, 0 females and 5 males, with a mean age of 25.2 years. Informed written consent was taken regarding the study. 1 patient was classified as 33-A3, 1 patient 33-C3, and the majority were classified as 33-C2(3 patients). The average time of surgery was 76.87 minutes.Demographic data of the studied patients are as listed in table 1.

Table: 1

Sr. No.	Age	Sex	Ao/OTA classification	Follow up
1	19	Male	33-C2	3 M & 7 M
2	20	Male	33-C2	3 M
3	22	Male	33-A3	6 M and 6yr
4	26	Male	33-C3	3 M
5	39	Male	33-C2	1yr & 1yr 1 month

Sr no 2,4 are recently operated and needed 6 M and Yearly follow ups.

Surgical technique

The procedure was done under combined spinal anaesthesia. The surgery was done on a translucent orthopaedic table in a supine position with a bolster underneath the knee. No tourniquet was used. One gram of third generation cephalosporins was given at induction and continued for 3-4 days post-operatively.

All the patients are operated by mod swashbuckler approach. The patient is usually positioned supine with the knee flexed with a roll or triangle. A midline anterior knee incision is made from above the fracture laterally across the patella. The incision is extended directly down to the fascia of the quadriceps and incised in line with the skin incision. The iliotibial band is bluntly retracted from the vastus lateralis muscle laterally. The vastus lateralis muscle is then detached from lateral intermuscular septum and quadriceps muscle is displaced medially to access distal femur. Further exposure distally includes lateral parapatellar arthrotomy to expose the femoral condyles. [4]. Perforating vessels may be ligated and vastus lateralis is elevated to completely expose the distal femur [5].

The modified Swashbuckler approach is proposed by defining patellar anastomotic ring 'safety margins' while performing knee arthrotomy. So, in modified approach, arthrotomy is done with a minimum margin of 2 cm from the lateral border of the patellar tendon and at the base of the patella the incision deviated slightly, aiming for the posterior depression of the vastus lateralis till it reached the anterolateral aspect of the thigh. [5]. [6].In the case of the Mini-swashbuckler approach, we can use a 12 cm incision from the lateral edge of the tibial tubercle upwards to the superolateral margin of patella. Full-thickness skin flaps are elevated to identify the underlying lateral patellar retinaculum. To expose the knee joint, a trapezoidal-shaped incision is made in the patellar retinaculum which remains within the lateral retinaculum and does not violate the vastus muscle belly. For extending proximally traditional Swashbuckler approach may be used. [5].

First, thorough debridement and anatomical reduction of the articular surface with preliminary k wiring and interfragmentary screws is done, followed by reduction and fixation by lateral plate aiming for anatomical shaft/condyle relation regarding length, varus/valgus alignment aided by image intensifier and distal femoral locked plate fixed with screws. All loose avascular pieces removed.

Regarding the metaphyseal comminution gap kept as it is or one big piece with attachment kept at medial border of fracture which can be fixed by one screw from lateral plate hole.

Ipsilateral or opposite fibular graft harvest was done either using a standard protocol. A lateral incision over the fibula according to the desired length of the graft is made, keeping in mind to be 5 cm distal to the neck fibula proximally and 10 cm proximal to lateral malleolus distally to avoid complications. After fascial incision, retraction of peroneal muscles and incision of fibular periosteum is done. All muscles were subperiosteally dissected off using periosteum elevator, careful dissection is mandatory proximally to avoid damaging the peroneal nerve, then a bone saw is used to harvest the graft. The harvested fibular graft is then fashioned according to fracture gap.


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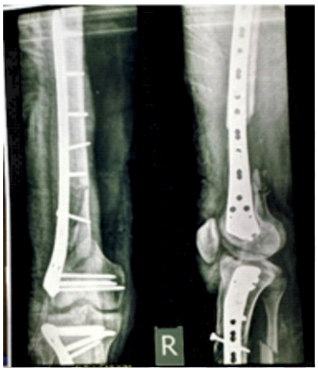


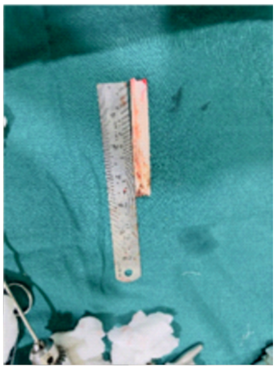

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Fig. 1
Male patient 19 years old 33-C2, Sanders functional scoring 37 points with ROM 110°, no pain, and unrestricted walking at the end of the follow-up period (07 months). **a** Clinical picture. **b, c.** Pre op x rays. **d** Comminution and huge gap following anatomical reduction. **e, f** At Second stage huge gap and the fashioned fibular graft according to gap size. **g** Post op x ray second stage with fibular graft and TCP granules. **h** Post op 2month. **i** Clinical image at 2 months. **j** post-operative x ray shows good union. **k, l** Clinical images at 7 month Follow up

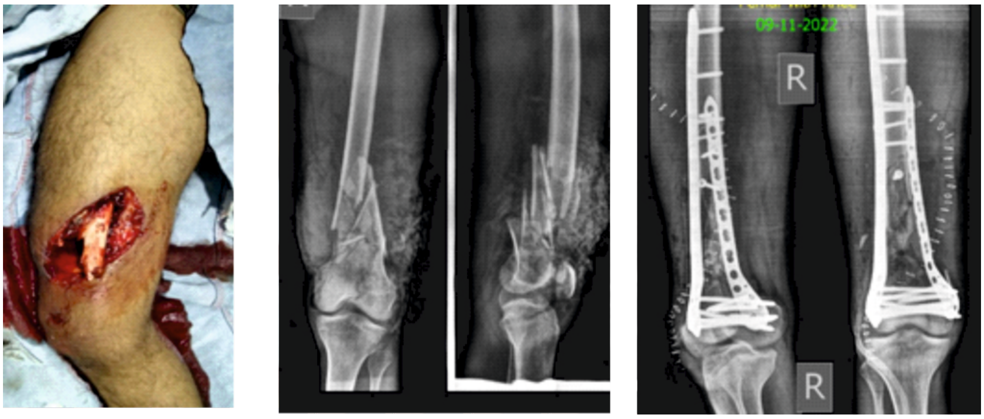

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Fig. 2
Male patient 20 years old 33-C2, Sanders functional scoring 40 points with ROM 130°(Full), no pain, and unrestricted walking at the end of the follow-up period (03 months). **a** Clinical pe op picture. **b.** Pre op x rays. **c.** Post op x rays with metaphyseal bone loss **d.** At Second stage (4 weeks) the fashioned fibular graft according to gap size. **e** Post op x ray at 3 Months. **F, g** Clinical images at 3 month Follow up

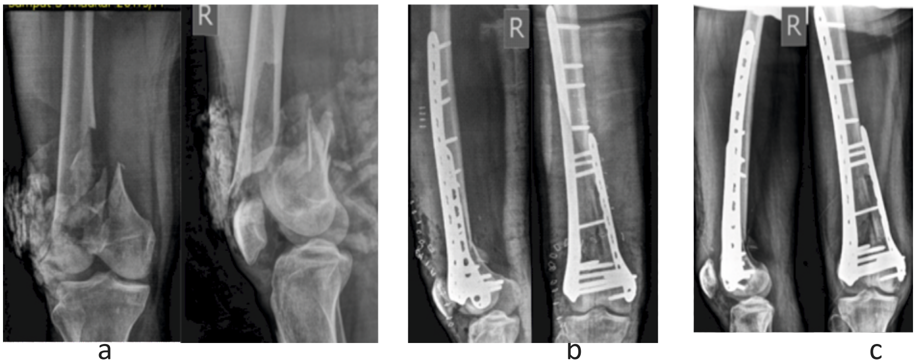


Fig. 3
Male patient 26 years old 33-C3, Sanders functional scoring 31 points with ROM 130°(Full), no pain, and unrestricted walking at the end of the follow-up period (03 months). **a.** Pre op x rays. **b.** Post op x rays with fibula and cancellous graft **c.** Post op x ray at 3 Months

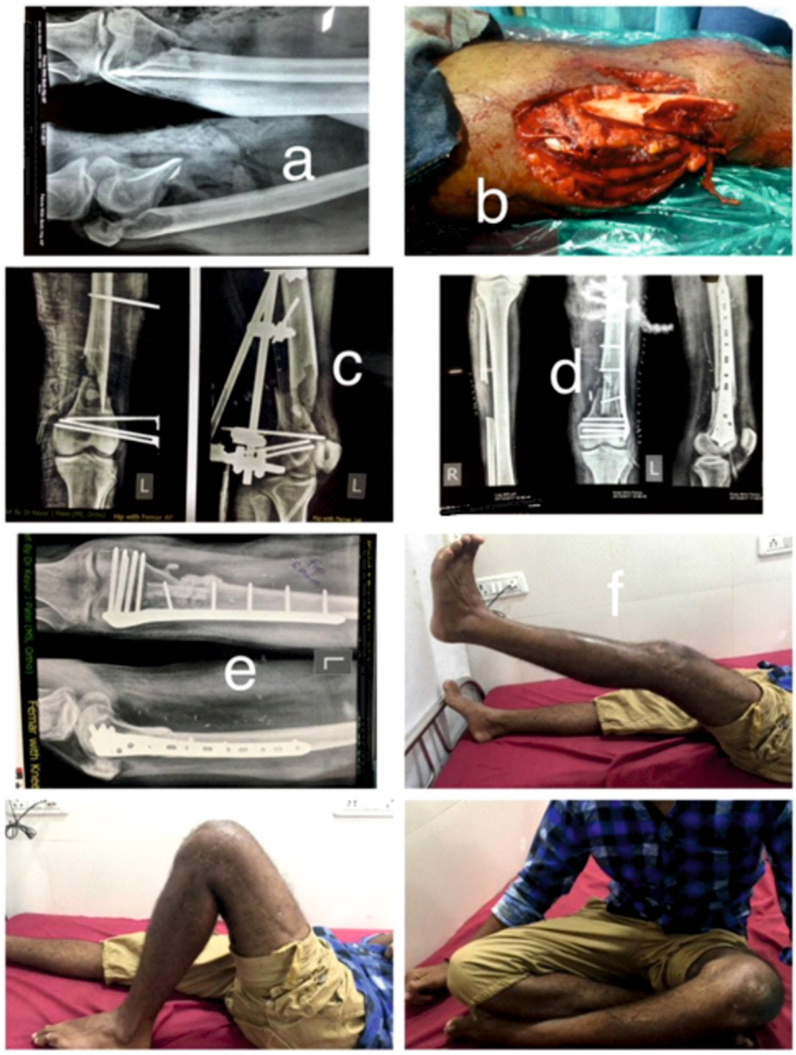


Fig. 4
Male patient 22 years old 33-A3, Sanders functional scoring 38 points with ROM 120°, no pain, and

unrestricted walking at the end of the follow-up period (03 months). **a** Pre op x rays. **b.** Clinical pre op picture. **c.** Post op x rays with Ex Fix as there was vascular injury. **d.** At Second stage (4 weeks) the fashioned fibular graft according to gap size and lateral plate. **e** Post op x ray at 3 Months. **F** Clinical images at 3 month Follow up

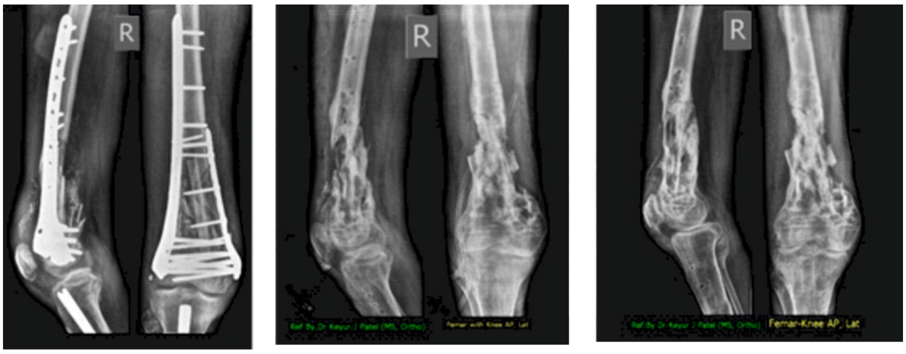


Fig. 5
a. Male patient 39 years old 33-C2 operated before 1 year with platting and fibula grafting single stage with sanders score 25. Came with hot swelling around surgical area. **b** Post implant removal with debridement immediate post op x rays. **c.** union increased at 1 month Follow up

Closure of the extensor mechanism was done with knee flexed 90° in a watertight manner after drain insertion, followed by subcutaneous and skin closure in layers without tension.
Post-operatively, post-operative plain X-rays were done, and quadriceps strengthening exercises started immediately from the second post-operative day. An enhanced rehabilitation program with early range of motion using continuous passive motion (CPM) device gradually increased daily as tolerated reaching 90° at three weeks and progressing to the full range at six weeks compared to the other side. Non weight bearing walking was encouraged starting from the first week. Full weight-bearing was initiated at 2-2.5 months whether callus formation was evident or not.

Follow-up protocol After their discharge, patients were followed up in the outpatient clinic at weekly to ensure incision healing. All stich removal done at 15-18 days. Radiological follow-up in the 3-4 weeks was done and admitted for second stage procedure in staged plan patients. Radiological follow-up was done monthly for 3 -4 months to assess any loss of reduction with early-assisted weight-bearing, followed by a plain X-ray advised for six months, and then every six months until the end of follow-up period. Fracture union was defined by bridging callus at least in three out of four cortices and no pain clinically at fracture site.

Results:

Sr no	Operated time stage1/2 (min)	Blood loss (ml)	Time to union (months)	Sander's scoring
1	90/60	350/300	3	37
2	100/65	325/300	3	40
3	20/70	300/200	3	31
4	120	525	3	38
5	90	300	United	25

All patients had no postoperative knee stiffness with a range of motion (90–120°) during follow-up. The time for radiological union was at 3 months, with no cases of non-union.

The average follow-up period was 3 to 4 months and 6month & yearly follow up are yet to come. Mean intraoperative blood loss was 325 ml, and mean operative time was 76.87 min without anaesthesia. All patients had a knee range of motion (90–120°<full>) during follow-up. Time for union at 3 months, with no cases of non-union. A total of 5 patients 3 (60%) showed excellent functional outcomes, and the remaining 2 (40%) showed good functional outcomes according to the Sanders scoring system. Only one cases had late infections (1yr post op) managed by implant removal after 1 year . No post-operative deformity, loss of reduction, or implant failure was observed until the end of follow-up period.

Discussion

Ongoing studies are being done on optimal management of distal femoral osteoporotic fractures in elderly, as fractures ultimately lead to exacerbation of underlying comorbidities, resulting in increased mortality. Faced by reduced healing and remodeling ability, challenges of fixation and attaining union in this population have been reported by several studies [7,8], with nonunion rates up to 25% and implant failure rates up to 16% in some recent reports of locked lateral plating alone [7,8,9]. Peschiera et al. [9], in their study to detect predictive factors for fixation failure in distal femoral fractures found that lack of bone support with metaphyseal comminution, malalignment, and inadequate fixation were the main causes.

Dual plating was proven by several investigators to provide superior stability by decreasing the lever arm acting on femoral axis thus lowering applied load on the fracture [10,11]. Also, stabilizing both columns and providing a stronger fixation in osteoporotic comminuted distal femur fractures [12]. In a recent biomechanical study, artificial femora simulating osteoporotic bone with fixed distal femoral fractures were subjected to axial, torsional, and quasi-static loading, and dual plating showed significantly lesser longitudinal and shear displacement than single plating [13]. Another earlier biomechanical study by Prayson et al. [14]on synthetic bone stated that in highly comminuted metaphyseal fractures, supplementing the medial column by medial plating is highly recommended to prevent varus collapse.

Using Hak et al. [15]and Lujan et al. [16] recommendations regarding the effect of a large comminution gap in decreasing callus formation, primary grafting can abolish that effect and promote healing, thus reduces incidence of implant failure and the need for secondary intervention. Zlowodzki et al. [17] also documented that performing primary grafting is better in cases with severe comminution and stated that delaying secondary bone grafting was the main cause for fixation failure.

To the best of the author's knowledge, no previous studies discussed using two staged debridement and lateral distal femur locking plate in first stage and fibular grafting combined with cancellous and medial plate in second stage in contaminated OG 3B (33-C3) for distal femoral fractures, added to that the paucity of available literature discussing double plating in distal femur fractures.

In the current study, Mod Swashbuckler approach was used for fracture reduction and fixation, and it allowed better visualization, especially the intraarticular extension, avoiding malalignment, and better assessment of comminution gap to determine size of needed fibular graft.

The autogenous fibular graft served several purposes during our 2nd stage surgical technique. Once in situ, the fibula acted as a bone substitute to fill the metaphyseal void, bony strut supporting medial and lateral cortices, and additional cortices enhancing screw fixation. Addition of cancellous graft from same side ASIS or TCP granules adds gap filling around fibula and ensures union. Full weight-bearing was allowed after nearly 2 months not restricted to bony union as being a cortical strut; the fibula compared to iliac graft used in previous studies had no potential for resorption. Afterward, the fibula was used to assess progression of union and alignment.

Staged procedure to ensure that bone graft remains un infected and 2nd stage allows arthrolysis and intra-articular fibrotic band-like adhesions, found in some cases, were released using a sharp dissection. In all the cases there were extra-articular as well as intra-articular adhesions which was released in second stage. The vastus intermedius was released and excised extraperiosteally in all cases.

Vastus lateralis and vastus medialis were released at least up to the upper third of the thigh if needed. Gentle manipulation was performed to achieve at least more than 90° knee flexion. This adds golden improvement in ROM of knee.

Our results are highly comparable to previous studies in operative time, blood loss, and postoperative range of motion, but superior in an earlier full weight-bearing at two months and union period around 12-16 weeks with better functional outcome scoring, with no cases of delayed or non-union.
Our study has limited number of patients and further follow up is ongoing.

Conclusion:

Staged debridement with single plate f/b 2nd stage fibular grafting and medial plate in more contaminated and single staged procedure in non-contaminated cases BG and dual plating of comminuted distal femur fractures in patients is an effective technique with higher rates of union and lower re-operation rates compared to other fixation modalities

References:

1. Schemitsch E.H. Size matters: defining critical in bone defect size, *J. Orthop. Trauma.* 2017;31(10): S20–S22. [PubMed] [Google Scholar]

2. Roddy E., DeBaun M.R., Daoud-Gray A., Yang Y.P., Gardner M.J. Treatment of critical-sized bone defects: clinical and tissue engineering perspectives. *Eur. J. Orthop. Surg. Traumatol.* 2018;28(3):351–362. [PubMed] [Google Scholar]

3. Sanders R, Swiontkowski M, Rosen H, Helfet D. Double-plating of comminuted, unstable fractures of the distal part of the femur. *J Bone Joint Surg Am.* 1991;73(3):341–346. doi: 10.2106/00004623-199173030-00004. [PubMed] [CrossRef] [Google Scholar]

4. Harahap R. Surgical incision technique approach on distal femur fracture a literature review. *Al-Iqra Medical Journal : Jurnal Berkala Ilmiah Kedokteran.* 2021;4(1):31–39. doi: 10.26618/aimj.v4i1.4903. [CrossRef] [Google Scholar]

5. Starr A.J., Jones A.L., Reinert C.M. The "swashbuckler": a modified anterior approach for fractures of the distal femur. *J Orthop Trauma.* 1999;13(2):138–140. doi: 10.1097/00005131-199902000-00012. [PubMed] [CrossRef] [Google Scholar]

6. Ahire D.R., Jindal D.S., Phuljhele D.S., Sahu D.N.D., Kashyap D.G. A comparative study between swashbuckler approach (Modified Anterior Approach) and lateral approach for the distal femur fractures. *Int J Orthop Sci.* 2018;4(3):184–188. doi: 10.22271/ortho.2018.v4.i3d.34. [CrossRef] [Google Scholar]

7. Ricci WM, Streubel PN, Morshed S, Collinge CA, Nork SE, Gardner MJ. Risk factors for failure of locked plate fixation of distal femur fractures: an analysis of 335 cases. *J Orthop Trauma.* 2014;28(2):83–89. doi: 10.1097/BOT.0b013e31829e6dd0. [PubMed] [CrossRef] [Google Scholar] [Ref list]

8. Moloney GB, Pan T, Van Eck CF, et al. Geriatric distal femur fracture: are we underestimating the rate of local and systemic complications? *Injury.* 2016;47:1732–1736. doi: 10.1016/j.injury.2016.05.024. [PubMed] [CrossRef] [Google Scholar] [Ref list]

9. Peschiera V, Staletti L, Cavanna M, Saporito M, Berlusconi M. Predicting the failure in distal femur fractures. *Injury.* 2018;49(Suppl 3):S2–S7. doi: 10.1016/j.injury.2018.10.001. [PubMed] [CrossRef] [Google Scholar] [Ref list]

10. Ziran BH, Rohde RH, Wharton AR. Lateral and anterior plating of intra-articular distal femoral fractures treated via an anterior approach. *Int Orthop.* 2002;26(6):370–373. doi: 10.1007/s00264-002-0383-z. [PMC free article] [PubMed] [CrossRef] [Google Scholar] [Ref list]

11. Steinberg EL, Elis J, Steinberg Y, Salai M, Ben-Tov T, et al. A double-plating approach to distal femur fracture: a clinical study. *Injury.* 2017;48(10):2260–2265. doi: 10.1016/j.injury.2017.07.025. [PubMed] [CrossRef] [Google Scholar] [Ref list]

12. Tripathy SK, Mishra NP, Varghese P, et al. Dual-plating in distal femur fracture: a systematic review and limited meta-analysis. *Indian Journal of Orthopaedics.* 2022;56:183–207. doi: 10.1007/s43465-021-00489-0. [PMC free article] [PubMed] [CrossRef] [Google Scholar] [Ref list]

13. Todorov D, Zderic I, Richards RG, Lenz M, Knobe M, et al. Is augmented LISS plating biomechanically advantageous over conventional LISS plating in unstable osteoporotic distal femoral fractures? *J Orthop Res.* 2018;36(10):2604–2611. doi: 10.1002/jor.24047. [PubMed] [CrossRef] [Google Scholar] [Ref list]

14. Prayson MJ, Datta DK, Marshall MP. Mechanical comparison of endosteal substitution and lateral plate fixation in supracondylar fractures of the femur. *J Orthop Trauma.* 2001;15(2):96–100. doi: 10.1097/00005131-200102000-00004. [PubMed] [CrossRef] [Google Scholar] [Ref list]

15. Hak DJ, Toker S, Yi C, Toreson J. The influence of fracture fixation biomechanics on fracture healing. *Orthopedics.* 2010;33:752–755. doi: 10.3928/01477447-20100826-20. [PubMed] [CrossRef] [Google Scholar] [Ref list]

16. Lujan TJ, Henderson CE, Madey SM, Fitzpatrick DC, Marsh JL, Bottlang M. Locked plating of distal femur fractures leads to inconsistent and asymmetric callus formation. *J Orthop Trauma.* 2010;24:156–162. doi: 10.1097/BOT.0b013e3181be6720. [PubMed] [CrossRef] [Google Scholar] [Ref list]

17. Zlowodzki M, Bhandari M, Marek DJ, Cole PA, Kregor PJ. Operative treatment of acute distal femur fractures: systematic review of 2 comparative studies and 45 case series (1989 to 2005) *J Orthop Trauma.* 2006;20:366–371. doi: 10.1097/00005131-200605000-00013. [PubMed] [CrossRef] [Google Scholar] [Ref list]

PROSPECTIVE STUDY OF SHAFT CLAVICLE FRACTURE WITH TITANIUM ELASTIC NAIL

DR. PARTH PANCHAL

INTRODUCTION:

Some research published in the last 50 years has documented a very satisfactory outcome for fracture healing and restoration of function following midclavicular fractures.[1] However, these fractures are frequently underestimated in terms of pain and disability during the first three weeks following an incident.[2] According to reports, between 10% and 30% of patients had clinically, radiographically, and subjectively unsatisfactory results due to shoulder shortening, nonunion, or impaired function.[3,4,5] When compared to conservative treatment, surgical methods are associated with poor cosmetic results and a higher incidence of nonunion and refractures.[6,7] The surgical approach and early results of treating 104 midclavicular fractures are given in this study. A titanium nail was used to treat the fractures.

MATERIALS AND METHODS:

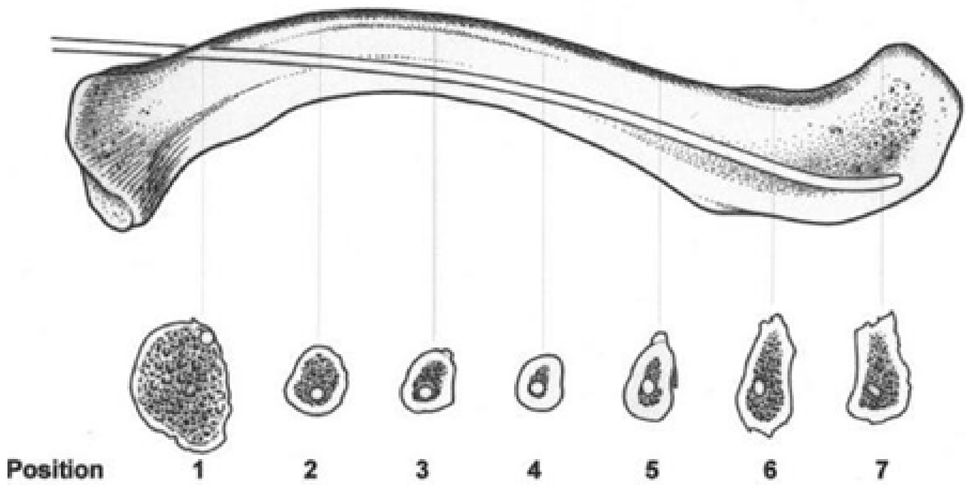
Patients ranging in age from 18 to 55 years old were enrolled in this study. Patients with displaced mid-shaft clavicle fractures with a displacement or shortening of more than 2 cm, comminuted or segmental fractures, impending open or clinical deformity, floating and bilateral fractures, ipsilateral ribs and upper extremity injury, and patients with high functional demands were treated. This study excluded patients with non-union, those under the age of 18, those above the age of 55, and those with pathological fractures. Clinical and radiological examinations were used to determine the results. VAS score and shoulder abduction ability were assesses pre-operatively and 3 days after the surgery. Constant-Murley Score was noted at 6 weeks, 3 months, 6 months, and 1 year. Plain radiographs were taken right after surgery, three weeks later, six weeks later, three months later, six months later, and one year later.

OPERATIVE TECHNIQUE:

The patient lies supine on a radiolucent table with with saline bottle in interscapular region. . A small incision of 1–1.5 cm is made under the sternal end of the clavicle. Medial entry was taken for all the patients. After superficial and deep soft tissue dissection, entry is taken with awl at costal tuberosity medially. A flexible titanium nail with an average thickness of 2.0–3.0 mm is mounted on a Jacob's chuck, and is inserted forward in the medullary canal manually. The selection of the nail is determined according to the diaphyseal diameter. The small and flattened tip serves for adjustment of the nail and prevents perforation through the cortex. The original curvature of the nail tip should be straightened slightly, however, in order to facilitate better gliding in the small medullary canal. With image intensification, the implant is advanced to the fracture site. When the tip reaches the fracture, reduction is performed manually by lifting the shoulder and giving traction laterally or percutaneously by means of a reduction clamp, inserting the nail into the lateral fracture fragment. If this does not succeed, the tip of the nail is introduced under direct view after performing a second small (2–3-cm) skin incision directly over the fracture site. The sparingly exposed soft tissue, which is sometimes interposed, should be closed and fixed with few fascia and periosteal sutures over the fracture after reduction. The nail is thenadvanced manually or gently tapped with a hammer until it is just medial to the AC joint. At the transition to the acromional end of the clavicle, the tip of the nail is likely to perforate the curved thin dorsal cortex; thus, accurate maneuvering of the tip is necessary under image intensifier control. After reaching the end position, the nail is cut close to the entry point in order to minimize soft tissue irritation, at the same time leaving sufficient surface for extraction later.

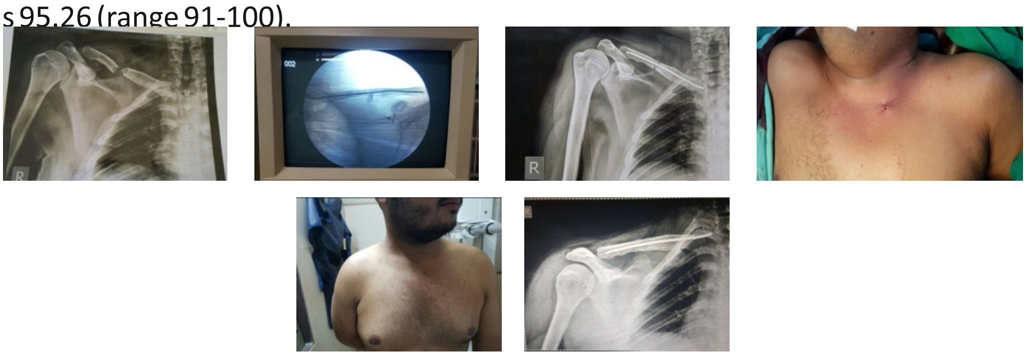
Finally, both the fragments are compressed by thumping with one hand over the shoulder and another over the contralateral chest.

Patients were kept in a sling for 4 weeks. Active range of shoulder and elbow movements were started from the first post-op day as tolerated by the patient alongwith shoulder pendulum exercises. Resistance exercises were started after 6 weeks of surgery.



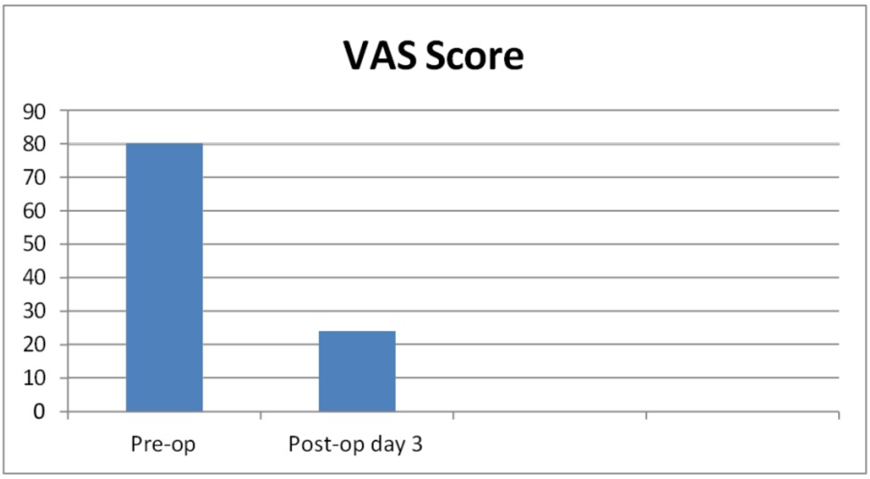
RESULTS:

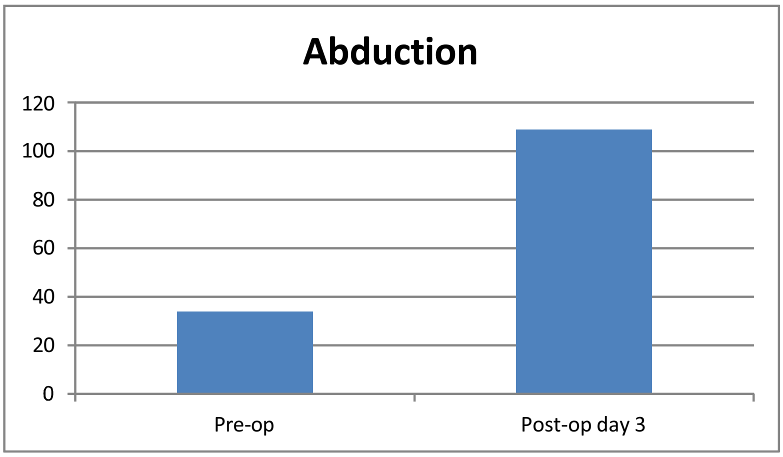
The study included 139 patients. 27 patients underwent plating as the medullary canal was too narrow. 8 patients were lost to follow-up. The final study included 104 patients. Because of marked displacement 78 patients were operated on. 12 patients with multiple appendicular skeleton fractures were operated on to enable them to ambulate using crutches. 14 patients were operated on because of instability of the ipsilateral shoulder caused by glenoid fracture or shoulder dislocation. Surgery was done at a mean of 2.2 days (range, 0–5 days; median, 2.7 days) after injury. The diameter of the Ti nails was 2.0 mm in 1 patient, 2.5 mm in 84 patients and 3 mm in 19 patients. Closed reduction was successful in 59 fractures. An additional incision of the skin above the fracture site was necessary in 45 fractures. In the group of patients who needed an additional skin incision, 30 fractures consisted of more than two fragments. In the group of patients with closed reduction there were only four fractures with more than two fragments. Mean operative time was 22.8 mins.Patients with additional fractures learned to walk using crutches on Day 1 after surgery for a minimum of 10 minutes twice a day. They were guided by a physiotherapist. On Day 3 all these patients walked on crutches for a minimum of 30 minutes twice a day during physiotherapy and on day 6 after surgery, they were mobilized and walked on crutches without assistance. 78 patients with isolated clavicular fractures were asked about pain 1 day before and 3 days after surgery. Patients reported a mean of 80 VAS score 1 day before surgery. Three days after surgery, subjective pain was significantly lower with a mean of 24 points ($p < 0.001$). At the same time there was a significant increase ($p < 0.001$) in abduction ability of the injured shoulder from. Mean time to union was 8.3 weeks. No nonunions were noted. Functional outcomes were assessed using Constant-Murley score. Mean Constant-Murley score at 6 weeks was 54.14 (range: 44-72), 3 months was 90.54 (range: 54-98), 6 months was 92.24 (range: 64-100) and 12 months was 95.26 (range 91-100).



Out of 30 patients with comminution, secondary shortening was seen in 18 patients.

Shortening was assessed by the distance between centre of jugular fossa and lateral tip of acromion. Difference of more than 5 mm compared to opposite side was considered as shortening. 1 patient had superficial skin infection which healed with antibiotics by 2 weeks. 4 patients had a lateral cut-out of nail. 2 of these patients were uneventful and fracture united by 6 weeks. In 1 patient, nail was removed and open reduction and internal fixation with plate was done. In the last patient, lateral protruding end of the nail was cut flush to the bone and it healed uneventfully at 8 weeks. Keloid formation was noted at the medial entry site in 1 patient.





DISCUSSION:

Intramedullary nailing of clavicle was introduced by Peroni in 1950.[8] The periosteal blood supply to the clavicle might remain intact in simple fractures. Increasing stability using ESIN in a biological favourable environment might, therefore, lead to a significant faster osseous healing and lower rates of non-union and delayed union of simple fractures, which was observed in our study.[9]

From a biomechanical point of view, intramedullary positioning of the implant is ideal.

The diameter of the Ti nail used for intramedullary fixation was small; however, no implant displacement or material breakage occurred. Because of anatomic features of the clavicle, devices for intramedullary fixation need to be flexible. Beside the need for flexibility, the implant needs to be stable enough to neutralize the potential disruptive forces acting on the fracture after stabilization. The implant also has to be small enough to enable its passage through the medullary space which is narrow especially in the middle 1/3 of the clavicle.[1]

Nonoperative treatment can achieve good functional results in most non-displaced clavicular fractures.[10,11,12] When more than 1 cm of displacement or comminution is treated nonoperatively, the results are poor.[12] Hill et al[13] reported unsatisfactory results in one-third of instances, and the rate of nonunions was determined to be 15% in a systematic review.[12] Smith et al[14] found 12 nonunions in 35 displaced clavicle fractures treated nonoperatively in a prospective randomised study. Complete displacement or shortening of the fracture is a predisposing factor for nonunion.[15,16,17] Furthermore, Nowak et al[18] showed in a prospective study that 93 of 222 patients (42%) still had sequelae 9 years after trauma. In cases with open clavicle fractures, threat of skin perforation by fracture ends, complete displacement or neurovascular compromise, open reduction and internal fixation is indicated.[19,20,21]Due to the high complication rate with plate fixation, such as soft tissue infection, implant failure, nonunion, and poor cosmetic appearance of the incision,[19] it is advisable to use intramedullary nails.[22,23] However, steel nails or wires, which were used nearly 100 years ago by A. Lambotte, are also associated with increased complications such as infection, nonunion, implant migration, or implant breakage.[24,25,26] Thus, this technique has not gained widespread acceptance.[27]

Elastic stable intramedullary nailing (ESIN) through a titanium nail with increased bending rigidity is a new concept. In contrast to Knowles pinning, predrilling of the intramedullary canal is not necessary.[22] Jubel et al[1] and Walz et al[28] concluded from their treatment of small groups of patients with clavicle fractures (53 and 35, respectively) that ESIN is a minimally invasive surgical technique that leads to excellent functional and cosmetic results.

We evaluated 104 patients using these intramedullary titanium nails at an average follow- up time of 12 months. None of the patients had malunion or non-union unlike Kettler et al.[29] These numbers are clearly superior to the complication rate reported by Bostman et al[19] when using a plate fixation.

The better results of ESIN as compared to plate fixation might be due to the smaller incision with less soft tissue dissection. Bending and torsional loads in the clavicle are better compensated for by an intramedullary flexible nail than a rigid plate, which is only fixed on one side of the bone. This might be the reason for the increased rate of loosening that has been reported, especially with the use of short plates.[19]

Compared with intramedullary nailing with unreamed or reamed steel wires, the risk of implant dislocation is lower because of a stable jamming of the flexible titanium nail in the clavicle at its flat outer end. In order to obtain a good locking, the nail must be brought as far as possible into the lateral fragment.[1] Minimally invasive fixation of the displaced midclavicular fracture with TEN should be used carefully in the patient with 1) a small clavicular canal; 2) a too distal clavicular fracture; or 3) a comminuted clavicular fracture.[31]

Our findings indicate that ESIN is eligible in simple fractures and comminuted fractures with moderate shortening(<7%). In severe shortening (>7%), plate osteosynthesis is the preferred treatment.

REFERENCES:

1. Jubel A, Andermahr J, Schiffer G, Tsironis K, Rehm KE. Elastic stable intramedullary nailing of midclavicular fractures with a titanium nail. Clinical Orthopaedics and Related Research®. 2003 Mar 1;408:279-85.

2. Rowe CR: An atlas of anatomy and treatment of midclavicular fractures. Clin Orthop 58:29–42, 1968.

3. Hill JM, McGuire MH, Crosby LA: Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J Bone Joint Surg 79B:537–539, 1997

4. Matis N, Kwasny O, Gaebler C, Vecsei V: Effects of clavicle shortening after clavicle fracture. Hefte Unfallchirurg 275:314–315, 1999

5. White RR, Anson PS, Kristiansen T, Healy W: Adult clavicle fractures: Relationship between mechanism of injury and healing. Orthop Trans 13:514–515, 1989.
6. Bronz G, Heim D, Pusterla C, Heim U: Osteosynthesis of the clavicle. Unfallheilkunde 84:319–325, 1981.

7. Everke H, Kinj K: Results of conservative and surgical treatment of clavicular fractures. Chirurg 40:129–132, 1969.

8. Peroni L. Medullary osteosynthesis in the treatment of clavicle fractures. *Arch Ortop.* 1950;63:398–405.

9. Smekal V, Irenberger A, El Attal R, Oberladstaetter J, Krappinger D, Kralinger F. Elastic stable intramedullary nailing is best for mid-shaft clavicular fractures without comminution: results in 60 patients. Injury. 2011 Apr 1;42(4):324-9.

10. Nordqvist A, Petersson C J, Redlund-Johnell I. Mid-clavicle fractures in adults: end result study after conservative treatment. J Orthop Trauma 1998; 12: 572-6

11. Robinson C M. Fractures of the clavicle in the adult. Epidemiology and classification. J Bone Joint Surg (Br) 1998; 80: 476-84.

12. Zlowodzki M, Zelle B A, Cole P A, Jeray K, McKee M D. Treatment of acute midshaft clavicle fractures: systematic review of 2144 fractures: on behalf of the Evidence-Based Orthopaedic Trauma Working Group. J Orthop Trauma 2005; 19: 504-7.

13. Hill J M, McGuire M H, Crosby L A. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J Bone Joint Surg (Br) 1997; 79: 537-9.

14. Smith C A R J, Crosby L A. Results of operative versus nonoperative treatment of 100% displaced mid-shaft clavicle fractures (abstract). Proceedings From the 68th Annual Meeting of the AAOS, San Francisco, 2001.

15. Jupiter J B, Leffert R D. Non-union of the clavicle. Associated complications and surgical management. J Bone Joint Surg (Am) 1987; 69: 753-60.

16. Wick M, Muller E J, Kollig E, Muhr G. Midshaft fractures of the clavicle with a shortening of more than 2 cm predispose to nonunion. Arch Orthop Trauma Surg 2001; 121: 207-11

17. Lazarides S, Zafiropoulos G. Conservative treatment of fractures at the middle third of the clavicle: the relevance of shortening and clinical outcome. J Shoulder Elbow Surg 2006; 15: 191-4.

18. Nowak J, Holgersson M, Larsson S. Sequelae from clavicular fractures are common: a prospective study of 222 patients. Acta Orthop 2005; 76: 496-502.

19. Bostman O, Manninen M, Pihlajamaki H. Complications of plate fixation in fresh

displaced midclavicular fractures. J Trauma 1997; 43: 778-83.

20. Enneking T J, Hartlief M T, Fontijne W P. Rushpin fixation for midshaft clavicular nonunions: good results in 13/14 cases. Acta Orthop Scand 1999; 70: 514-6.

21. Denard P J, Koval K J, Cantu R V, Weinstein J N. Management of midshaft clavicle fractures in adults. Am J Orthop 2005; 34: 527-36.

22. Chu C M, Wang S J, Lin L C. Fixation of mid-third clavicular fractures with knowles pins: 78 patients followed for 2-7 years. Acta Orthop Scand 2002; 73: 134-9

23. Jubel A, Andermahr J, Schiffer G, Tsironis K, Rehm K E. Elastic stable intramedullary nailing of midclavicular fractures with a titanium nail. Clin Orthop 2003; (408): 279-85.

24. Schwarz N, Leixnering M. Failures of clavicular intramedullary wire fixation and their causes. Aktuelle Traumatol 1984; 14: 159-63

25. Leppilahti J, Jalovaara P. Migration of Kirschner wires following fixation of the clavicle--a report of 2 cases. Acta Orthop Scand 1999; 70: 517-9.

26. Grassi F A, Tajana M S, D'Angelo F. Management of midclavicular fractures: comparison between nonoperative treatment and open intramedullary fixation in 80 patients. J Trauma 2001; 50: 1096-100

27. Jubel A, Andermahr J, Schiffer G, Rehm K E. Technique of intramedullary osteosynthesis of the clavicle with elastic titanium nails. Unfallchirurg 2002; 105: 511-6

28. Walz M, Kolbow B, Auerbach F. Elastic, stable intramedullary nailing in midclavicular fractures - a change in treatment strategies?. Unfallchirurg 2006; 109: 200-11.

29. Kettler M, Schieker M, Braunstein V, König M, Mutschler W. Flexible intramedullary nailing for stabilization of displaced midshaft clavicle fractures: technique and results in 87 patients. Acta Orthopaedica. 2007 Jan 1;78(3):424-9.

30. Liu PC, Chien SH, Chen JC, Hsieh CH, Chou PH, Lu CC. Minimally invasive fixation of displaced midclavicular fractures with titanium elastic nails. Journal of orthopaedic trauma. 2010 Apr 1;24(4):217-23.\

LIPOMA ARBORESCENS: A RARE CAUSE OF KNEE SWELLING

Dr. Amol C. Patel, Dr. Shubhdeep Chugh

Dr. Keyur Buddha, Dr. Kamlesh Jain

Learning Point of the Article : Lipoma arborescens is one of the rare benign cause of knee swelling which can be missed with various other common causes of knee swelling, but have to treated as can lead to arthritis and affects in individuals activity of daily living and can not be left

Introduction: Lipoma Arborescens is a chronic, slow growing intra articular lesion of benign nature which is commonly seen in the supra patellar region of the knee joint. It is characterised by villous proliferation of the synovium, with the replacement of the sub synovial connective tissue with fat cells. It is not a neoplasm but non-specific reactive response to chronic synovial irritation, due to mechanical or inflammatory insults. We highlight this condition to raise awareness to be kept as a differential diagnosis in knee joint affected by various slow, progressive chronic inflammatory conditions.

Case Report: We present case of 51-year female with severe knee swelling since 3 to 4 years with episodes of remission and regression on and off. She was diagnosed with lipoma arborescens after MRI and confirmed after post operative histology.

Conclusion: We in this case study highlight this rare condition with its imaging characteristics and arthroscopic treatment. Keeping in mind that lipoma arborescens though benign in nature and as one of the rare causes for knee swelling, has to be treated to get an optimal outcome.

Keywords: Lipoma Arborescens, synovial membrane, Magnetic Resonance, Arthroscopy.

Introduction

Lipoma Arborescens also referred as villous lipomatous proliferation of the synovial membrane, diffuse lipoma of the joint or diffuse synovial lipoma, is a rare benign intra articular lesion is characterised by villous proliferation of the synovium. [1,4] The villous proliferation of the synovium has the sub synovial connective tissue replaced with mature fat cells.[2] Albert Hoffa, a German surgeon, made the first description of lipoma arborescens in 1904.

Lipoma arborescens typically affects adults. It most commonly involves the knee, but other locations have also been described (shoulder, ankle, hip, wrist, elbow). Bilateral affection of the knee is also described [3,4]. Also, extra articular location like tendon

sheath and periarticular bursa can also be seen affected by it. [3,5]

Lipoma Arborescens is usually diagnosed with MRI and early diagnosis help in differentiating it from other intra articular lesion and chronic inflammatory condition

Case Report

A Female patient 50 years old presented with right knee swelling since 4 years. The swelling was gradually increasing since last 1 years. Initially the swelling used to increase and decrease on its own. Pain was mild and not affecting activities of daily living. No night pains. No complains of fever, multiple joint pain, bleeding

Figure 1: Massive swelling of the Knee Joint

tendencies, loss of weight and trauma.

Conservative treatment was taken at multiple places in form of medication, physiotherapy, knee aspiration and also local kenacort injection given.

Clinical examination revealed massive joint swelling (Fig. 1) with terminal range of motion restricted and painful. No signs of inflammation were noted. Test for meniscus, collateral and cruciate ligament was negative.

X-Ray showed early osteoarthritis changes with area of dense soft tissue opacity in the supra patellar region.

Blood investigation showed increase in ESR :66mm and CRP:23mg/dl levels, with normal Anti-CCP, S. uric acid, ANA, Rheumatoid factor, bleeding time, clotting time and blood counts.

MRI showed large effusion distending the suprapatellar and infra patellar region with frond like fatty area seen in peri condylar and joint cavity. Synovial thickening and hypertrophy noted, F/S/O Lipoma arborescens. Associated medial compartment degeneration was noted. (Fig. 2)

Arthroscopic synovectomy was planned. Prior to arthroscopy knee was aspirated yielding 350 cc of citrulline coloured fluid. In Arthroscopy we could visualize diffuse synovitis with frond like masses (Fig. 3) throughout the joint more in the supra patellar

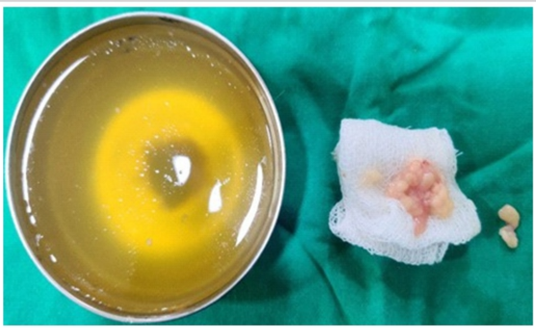


Figure 3: Knee Aspirate and Synovial Tissue removed for biopsy

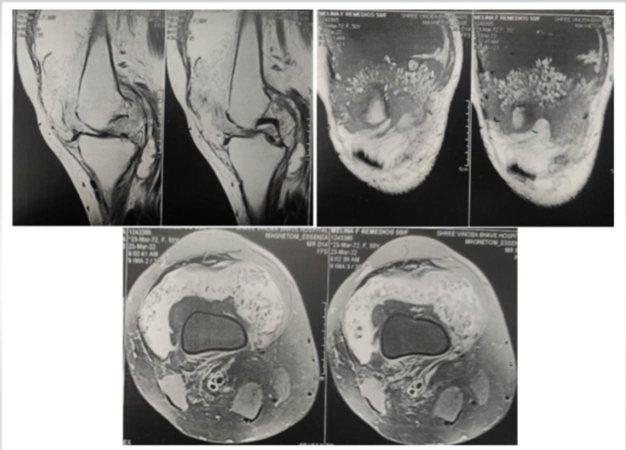


Figure 2: MRI of the Knee Joint showing Synovial Lipoma Arborescens

and infra patellar area. The villous type synovitis showed yellow-coloured nodules within it. Complete arthroscopic synovectomy (Fig. 4) was done using anterior medial, anterolateral, supra patellar portals and posterior medial portal.

Post-surgical physiotherapy was started immediately with passive knee bending and weight bearing as tolerated with knee brace. Static Quadricep exercise and ice fomentation was given. Brace was removed within 2 weeks. Cycling was also encouraged after 2 weeks.

Postoperative histological studies showed synovial hyperplasia and hypertrophy with distinct lobules of mature adipocytes replacing a significant portion of sub synovial tissue, in keeping with the diagnosis of lipoma arborescens

Discussion

Lipoma Arborescens is a rare pathology which is described from early 20th century, it has been consolidated as a disorder related to slowing evolving, recurrent, and generally painless monoarthritis and progresses with articular effusion and decreased range of motion.[6]

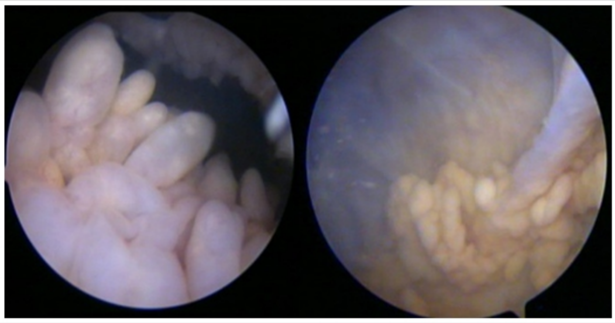


Figure 4: Arthroscopic view of Synovium of Lipoma Arborescens

Though first described by Hoffa in 1904, more detailed description was done by Arzimanoglu in 1957.[4,7] The term lipoma is misleading as lesion does not show any features of lipoma and do Hallel et al suggested that lipomatous proliferation of the synovial membrane would be an appropriate term.[8] The term arborescens comes from the word Arbor (Latin for tree) and describes macroscopic tree like morphology of lipomatous villous proliferation [4].

There are two aetiological types of lipoma arborescens primary and secondary depending on age of onset and underlying pathology. The more common secondary type is associated with underlying chronic irritation such as degenerative disease, trauma, meniscal injury and seen in old people. [3, 9] The less common primary type is idiopathic and occurs in patient of younger age group between second and third decade[3].

Lipoma arborescens should be considered in the differential diagnosis of monoarthritis with effusion and synovial thickening, such as progressive villonodular synovitis, synovial lipoma, synovial osteochondromatosis, tubercular arthritis, rheumatoid arthritis and gouty arthropathy [3, 6].

Sometimes chronic inflammatory conditions are itself associated with lipoma arborescens.[10].

The diagnosis of Lipoma Arborescens is based on typical findings on MRI and is considered as the gold standard. [3,11] Other test like laboratory investigation, joint fluid aspirate, X- rays can be used to rule out other causes of monoarthritis with effusion. [4,8] The MRI features of lipoma arborescens has frond like mass arising from the synovium. Secondly the mass has fat equivalent signal on all pulse sequences. The Lipoma arborescens shows high signal intensity villous or nodular foci on both T1- and T2-weighted images that are suppressed on short tau inversion recovery (STIR) or fat saturation sequences similar to that of any subcutaneous fat. The remaining non-fatty component of hypertrophied synovium in the condition displays heterogeneous high signal intensity on T2 or STIR sequences and intermediate-to-low signal intensity on T1- weighted sequences. Thirdly there is no enhancement on contrast administration of the sub synovial tissue but synovial fluid and synovium shows enhancement. Fourth feature is of effusion of varying degree [3,4]. And finally, there is an absence of magnetic susceptibility effects from hemosiderin. Which helps it to differentiate from closely mimicking pigmented villo nodular synovitis.[12] Other features like synovial cyst, degenerative changes, meniscal lesion, bony erosions can be also noted.

The sub synovial fatty proliferation in lipoma arborescens usually attains one of three morphological patterns: (a) diffuse villous form, involving the entire hypertrophied synovium; (b) focal nodular frond-like form; or (c) a mixed form of the two

aforementioned patterns[13].

Our patient had diffuse villous form with early degenerative and meniscal lesion.

Broadly lipoma arborescens have to be distinguished from intra articular masses which are broadly classified as non-infectious synovial proliferative lesion, infectious granulomatous lesion, depositional joint disease, neoplastic lesion, vascular malformation[3].

Among these, synovial osteochondromatosis, PVNS, rheumatoid arthritis, tuberculous arthritis. gouty Arthropathy and intra articular lipoma are the most common differential diagnoses for this condition, which may pose a diagnostic dilemma, even on imaging[13].

Macroscopically, Lipoma Arborescens appears as a yellowish synovial proliferation, with broad villous projections of fatty tissue arranged in an arborescent pattern, usually filling the suprapatellar pouch and both gutters. Histologically, massive infiltration of the synovium by mature adipose cells is characteristic for Lipoma Arborescens. Enlarged hyperaemic capillaries and focal chronic inflammatory infiltration is usually observed [14].

Clinically our case had initially suspicion on Rheumatoid arthritis but the lab investigation where not in favour . The Xray did not show any any obvious multiple calcified loose body, so synovial chondromatoisis was ruled out. The patient did not have any clinically sign for tuberculous infection and also the lab reports were normal. MRI helped us to rule out pigmented villous nodular synovitis and any other intra articular tumour. Lipoma Arborescens was diagnosed on MRI with associated arthritic changes suggested of secondary Lipoma Arborescens. We wanted to highlight this condition to be kept in mind as differential diagnosis clinically also.

It has also been noted that osteoarthritic changes are secondary to the presence of lipoma arborescens. Natera even concludes in his retrospective review that progressive joint degeneration could be prevented or at least delayed, if prompt synovectomy is performed [15,16].

So even being a benign lesion it has to be addressed by open or arthroscopic synovectomy though intra articular steroids and conservative treatment can give temporary relief.[8] Arthroscopic synovectomy is preferred as is minimally invasive and able to facilitate early postoperative recovery.[3] Also complete synovectomy can be done with arthroscopy as compared to open as posterior compartment is also visualised. The reported outcomes of an arthroscopic resection have favourable results. Recurrence after synovectomy is very rare [16] except Alfonso

[17] in his paper showed recurrence at 1 year follow up. We didnot have recurrence till 8 months post operatively. The choice of one technique over the other mainly depends on the extent of involvement in the joint and on the personal experience of the surgeon[4].

Debrima to relive the complains and decrease the risk of osteoarthritis.

Conclusion

Lipoma Arborescens is one of the causes of knee swelling, though rare has to kept in mind for patient with knee swelling. Mostly diagnosed with exclusion and with MRI images. Once diagnosed it is better to treat the patient with Arthroscopic

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

Conflict of interest: Nil **Source of support:** None

References

1. H. W. Garner and J. M. Bestic, “Benign synovial tumors and proliferative processes,” Seminars in Musculoskeletal Radiology, vol. 17, no. 2, pp. 177–188, 2013.

2. Hallel T, Lew S. Bansal M. Villous lipomatous proliferation of the synovial membrane (lipoma arborescens). J Bone Joint Surg Am 1988; 70:264-70.

3. Sanat Kumar Sanamadra, Ken Oon Ong, CME Article Lipoma Arbroscence .Singapore Med J 2014;55(1):5-11.

4. M. De Vleeschhouwer,1 E. Van Den Steen et al, Case Report Lipoma Arborescens: Review of an Uncommon Cause for Swelling of the Knee. Case Reports in Orthopedics Volume 2016, Article ID 9538075, 5 pages

5. Shinji Minami, Yusuke Miyake et al, Case Report Lipoma arborescens arising in the extra-articular bursa of the knee joint. SICOT J 2016, 2, 28

6. Taissa Pinto de Souza1, Juliana Brandao Pinto Carneiro1, Monique Freire dos Reis2 et al, Case Report: Primary lipoma arborescens of the knee.European journal of rheumatology DOI: 10.5152/eurjrheum.2017.17014

7. A. Arzimanoglu, “Bilateral arborescent lipoma of the knee,” The Journal of Bone & Joint Surgery—American Volume, vol. 39, no.4, pp. 976–979, 1957.

8.T. Hallel, S. Lew, and M. Bansal, “Villous lipomatous proliferation of the synovial membrane (l ipoma a r b o r e s c e n s) ," T h e Jo u r n a l o f B o n e & Jo i n t Surgery—American Volume, vol. 70, no. 2, pp. 264–270, 1988.

9. Al-Ismail K, Torreggiani WC, Al-Sheikh F, Keogh C, Munk PL. Bilateral lipoma arborescens associated with early osteoarthritis. Eur Radiol 2002; 12:2799-802.

10. Gozde Ercan Zeybek, et al. Progressive bilateral lipoma arborescens of the knee caused by uncontrolled juvenil idiopathic arthritis . North Clin Istanb 2020;7(5):512–515

11. Vilanova JC, Barceló J, Villalón M, et al. MR Imaging of Lipoma arborescens and the associated lesions. Skeletal Radiol 2003; 32:504-9.

12. J. F. Feller, M. Rishi, and E. C. Hughes, "Lipoma arborescens of the knee: MR demonstration," American Journal of Roentgenology,vol. 1994;163, no. 1, pp. 162–164.

13. Soler T, Rodríguez E, Bargiela A, Da Riba M. Lipoma arborescens of the knee: MR characteristics in 13 joints. J Comput Assist Tomogr 1998; 22:605-9.

14. Ioannis Tsifountoudis,1 Dimitrios Papoutsis , Case Report Lipoma Arborescens of the Knee: Report of Three Cases and Review of the Literature. Case Reports in Medicine Volume 2017, Article ID 3569512, 9 pages.

15. K. Ikushima, T. Ueda, I. Kudawara, and H. Yoshikawa, "Lipoma arborescens of the knee as a possible cause of osteoarthrosis," Orthopedics, vol. 24, no. 6, pp. 603–605, 2001.

16. L. Natera, P. E.Gelber, J. I. Erquicia, and J. C.Monllau, "Primary lipoma arborescens of the knee may involve the development of early osteoarthritis if prompt synovectomy is not performed,"Journal of Orthopaedics and Traumatology, vol. 16, no. 1, pp. 47– 53, 2015.

16. M. Franco, J. M. Puch,M. J. Carayon, D. Bortolotti, L. Albano,and A. Lallemand, "Lipoma arborescens of the knee: report of a case managed by arthroscopic synovectomy," JointBone Spine 2004; 71 (1): 73–75.

17. P.D. Afonso, Lipoma arborescens. Arthritis Rheum 2012;64 (6): 2054-2054.

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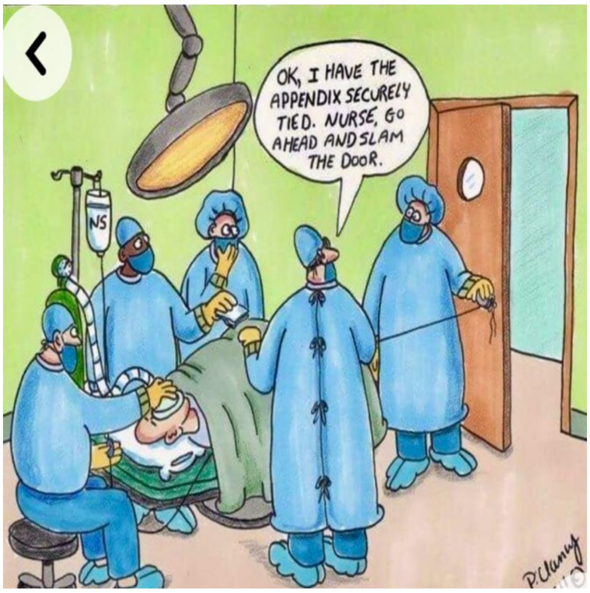

Sorry I'm late for your digital-rectal exam. I slammed my finger in my car door.

Chronic Irreducible Knee Dislocations: Outcomes following Open Reduction and Reconstructive Surgery

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Abstract

The management of unreduced knee dislocations who present late is challenging. The aim of this study was to determine the clinical, radiological, and functional outcomes following open reduction and reconstructive surgery for chronic irreducible knee dislocations. This retrospective study analyzed prospectively collected data of patients with an unreduced fixed anterior or posterior knee dislocation of 1 to 6 months' duration, treated with open reduction, hinged external fixator application, and ligament reconstruction who had a minimum 2-year follow-up. Patients were classified based on presence of prior periarticular surgery and direction of dislocation. Data on pre- and posttreatment clinical, radiological, and functional scores were analyzed. A total of 21 patients (age range: 19–43 years) fulfilled all inclusion criteria. These included 13 missed dislocations and 8 neglected postoperative dislocations. There were 18 posterior and 3 anterior dislocations. The mean follow-up was 6.9 years (range: 2.7–16.2 years). On final follow-up, all 21 patients were independently ambulatory with mean knee range of motion 127 degrees. No patient had symptomatic knee instability at final follow-up, despite four having isolated grade-III posterior cruciate ligament (PCL) laxity. Anatomical reduction was achieved in 19 patients, whereas 2 patients had incomplete joint reduction with a persistent grade-II fixed posterior subluxation. Scanograms revealed coronal alignment within 5 degrees of the opposite unaffected

limb in 17 patients. Mean functional scores improved from preoperative 9.4 ± 4.7 (range: 2–Keywords

- chronic knee dislocation
- multiple ligament deficient knee
- open reduction
- hinged external

fixator

- fixed posterior dislocation
19) to postoperative 75.9 ± 8.0 (range: 64–95) for Lysholm's and preoperative 10.7 ± 1.8
(range: 8.3–13.7) to postoperative 73.5 ± 6.7 (range: 66.7–88.7) for knee injury and osteoarthritis outcome score (KOOS) scores. Prior periarticular surgery was associated with significantly inferior Lysholm's scores ($p < 0.04$). Although 23.8% knees developed posttraumatic knee arthritis, no patient had undergone conversion to knee arthroplasty or

arthrodesis. The study concludes that open reduction and reconstructive surgery is an effective surgical treatment for chronic irreducible knee dislocations of up to 6 months duration. An individualized, often

stagedapproach that prioritizes joint reduction, early knee mobilization, and knee stability, ensures satisfactory clinical, radiological, and functional outcomes in the medium term. This is a clinical case series and reflects level of evidence IV.

received
February 1, 2021 accepted after revision April 26, 2022 article published online July 7, 2022

DOI https://doi.org/ 10.1055/s-0042-1750062. ISSN 1538-8506.

The management of chronic irreducible knee dislocations is extremely challenging. These cases are uncommon since most acute traumatic knee dislocations either relocate spontaneous- ly, or lend themselves to early diagnosis and immediate reduc- tion. Barring isolated case reports, there is sparse literature published on this disabling knee injury. Cases that have been reported have been described under two specific circumstan-

ces; either as a missed injury in a polytrauma patient[1–4] or as a neglected postoperative dislocation in a patient with multiple ligament knee injury having undergone periarticular surgery and immobilization in an inadvertent unreduced position.[5–8] There is no consensus on the treatment approach, and the limited cases reported have been treated with open arthrolysis with knee repositioning,[5] single stage open reduction with allograft ligament reconstruction and application ofa skeletally fixed knee hinge,[6] staged surgery with reduction and ligament reconstruction,[9] gradual reduction with the Ilizarov external fixator,[7] or a combination of these techniques.[2,4] Knee arthrod- esis[10] and arthroplasty[11,12] have also been reported as treatment options reserved for nonsalvageable and older

patients. The outcomes of these procedures remain largely unknown since all cases have reported short-term results.

The main challenges in treating this paradox of a stiff unstable joint include obtaining and maintaining a reduction, concurrently regaining range of motion, and ultimately ensur- ing a stable functional joint. To what extent these severely dysfunctional knee deformities can regain a reduced, pain-free, stable joint, with functional range of motion following surgery is unclear. Moreover, there is no information on how these knees progress with respect to joint congruity, alignment, and secondary posttraumatic arthritis in the long term.

Chronic irreducible knee dislocations continue to be sporadically encountered, especially in countries with limit- ed trauma services in remote and rural regions.[13–16] The approach of our knee preservation service has been to perform open reduction with ligament reconstructive sur- gery for chronic irreducible knee dislocations of less than 6 months' duration, and we reserve gradual distraction with correction using either the Ilizarov external fixator or Taylor spatial frame for chronic dislocations beyond 6 months. The aim of this study was to determine the clinical, radiological, and functional outcomes following open reduction and reconstructive surgery for chronic irreducible knee disloca- tions of up to 6 months' duration. The study hypothesis was that a surgical approach involving open reduction, hinged external fixator application, and ligament reconstruction for a chronic irreducible knee dislocation, can convert a painful

deformed knee which is both stiff and unstable, to a reduced joint with functional range and stability having satisfactory medium-term outcomes.

Methods

Study Design and Patient Selection

This retrospective study analyses prospectively collected data of patients with a chronic irreducible knee dislocation of minimum 1 month and maximum 6 months' duration, treated at our knee preservation service from January 2002 through December 2017. The study was approved by the institutional review board (IRB) of our hospital (IRB number: KDAH IEC-A Code: 038/2020). The inclusion criteria were patients' diag- nosed with a chronic irreducible traumatic knee dislocation of minimum 1 month and maximum 6 months' duration, who underwent surgical treatment for the same, and had a mini- mum 2-year follow-up. Exclusion criteria included patients with chronic knee dislocations of over 6 months' duration who were corrected with gradual distraction using an external fixator, nonsalvageable open or infected chronic knee disloca- tions which underwent arthrodesis, chronic knee dislocations with significant osteochondral loss or secondary degeneration deemed inappropriate for joint salvage, pathological knee dislocations of nontraumatic origin, and patients who had incomplete preoperative data or follow-up less than 2 years.

Data Collection

Preoperative

The demographic data, duration, and treatment taken since injury, and detailed preoperative clinical examination findings for all patients were noted. Each patient's radiological images including radiographs, magnetic resonance imaging (MRI), and vascular studies were analyzed. Based on the direction of dislocation, and history of prior intra-articular, extra-artic- ular, or periarticular knee procedure performed, patients were classified into types 1 and 2 as described in Table 1. Preop- erative functional scores, such as Lysholm's knee scoring scale and knee injury and osteoarthritis outcome score (KOOS), of patients were retrieved.

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Treatment

All surgeries were performed by a single surgeon and the detailed surgical notes for each case were reviewed. Although an individualized treatment plan was utilized for each patient, the surgical rationale was similar and included joint reduction,

Table 1 Classification of chronic irreducible knee dislocations and distribution of cases in this series

ÇяБŇ	tДŇИŇüdŇ of prior knee surgery	{нĎТяБŇ	5üДŇdŤĆü of dislocation	bнï ĎŇД of cases
ÇяБŇ 1	Chronic knee dislocation detected in a knee having undergone no prior periarticular surgical procedure	1a	Anterior	2
		1b	Posterior	11
Type 2	Chronic knee dislocation detected in a knee having undergone an intra-articular, extra-articular, or periar- ticular surgical procedure	2a	Anterior	1
		2b	Posterior	7

hinged external fixator application, ligament reconstruction, and prolonged rehabilitation. In three patients, surgery was performed in a single stage, whereas 18 patients had under- gone this process in stages. Reduction of the chronically dislocated knee warranted circumferential capsular release and extensive scar tissue excision. In all patients, except one, this was performed as an open procedure. Prevention of postoperative arthrofibrosis was facilitated with early mobili- zation using a hinged external fixator that maintained the reduction, while reestablishing stable anatomic range of motion. Ligament reconstruction was either performed in the same stage or at a subsequent stage based on the individual needs of the case.

Follow-up and Outcomes

All patients' serial postoperative evaluations were analyzed and the following clinical outcome measures at latest follow- up were noted: ambulatory status and need of orthotic devices and aids for walking, visual inspection of gait for lurch or limp, clinical testing of knee stability, and goniometer assessment of knee range of motion. Knee stability was clinical graded into I (<5 mm), II (5–10 mm), and III (>10 mm) based on the extent of translation or joint opening assessed on the following commonly used tests: Lachman's test for anterior cruciate ligament (ACL), posterior drawer test for posterior cruciate ligament (PCL), valgus stress test at 30 degrees for medial collateral ligament (MCL), and varus stress test at 30 degrees for lateral collateral ligament (LCL). Posterolateral complex (PLC) laxity was determined to be present or absent using the dial test. Each patient had undergone serial radiographic evaluation and these were studied for adequacy of initial joint reduction, loss of reduction with time, and secondary degen- erative changes as graded by the Kellgren and Lawrence (KL) classification system. Patients with grade-III knee joint laxity on follow-up had undergone stress radiography confirmation. An alignment scanogram was performed at the minimum 2-year follow-up, and all patients had an assessment of limb alignment in the coronal plane. Selected patients also had lateral scanograms performed to assess standing alignment in the sagittal plane. Each patient's functional status with Lysholm's and KOOS scores at final follow-up was determined.

Data Analysis

The data collected contained a combination of numerical and categorical variables. Statistical analysis was per- formed for the numerical data of Lysholm's and KOOS scores using Python. Numerical data were first assessed for normality using the Shapiro–Wilk test. Data that met the null hypothesis were assessed for statistical signifi- cance using the independent t-test. Data that rejected the null hypothesis were tested using the Mann–Whitney U-test for statistical significance. A p-value of <0.05 was considered to be statistically significant. Preoperative scores were compared with postoperative scores to deter- mine functional improvement following surgery. Further, postoperative functional scores of types 1 and 2 were compared with determine differences in results amongst the two groups.

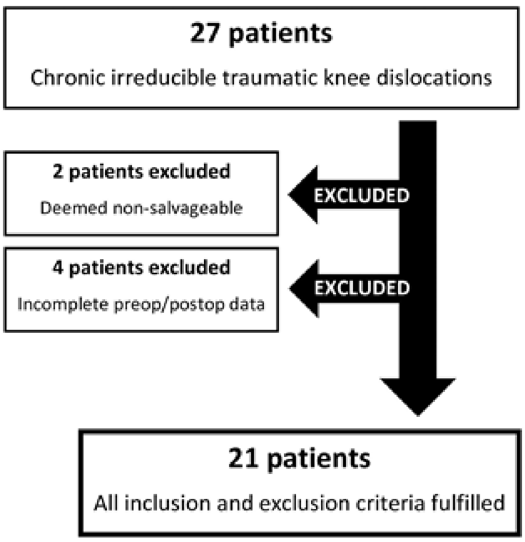


Fig. 1 Flow chart summarizing the number of patients included in the study. Postop, postoperative; preop, preoperative.

Results

A total of 27 patients with chronic irreducible traumatic knee dislocations of duration between 1 to 6 months underwent surgery during the 16-year study period. Two patients were deemed nonsalvageable and underwent knee arthrodesis, whereas four patients had to be excluded due to incomplete preoperative or postoperative data. Overall, 21 patients fulfilled all the inclusion and exclusion criteria and formed the basis of this study (Fig. 1). The patients included 17 males and 4 females, with an age range of 19 to 43 years (mean ¼ 29 years). The mean follow-up was 6 years and

9 months and ranged from 2 years 7 months to 16 years 2 months.

Injury Characteristics In 13 patients, the chronic knee dislocation was secondary to a missed injury, often in patients who had either sustained polytrauma or an ipsilateral limb fracture. Eight patients had a neglected postoperative dislocation, and this typically occurred in a patient with an acute multiple ligament knee injury having undergone surgery and immobilization in an inadvertent unreduced position (Fig. 2). Also, 19 patients had a history of significant trauma at the onset of symptoms; in two obese patients, the mechanism of injury was low energy. The mean duration from injury to presentation at our knee service was 11 weeks and ranged from 4 to 22 weeks.

Salient Preoperative Features

All patients were significantly disabled and unable to ambu- late without a walking aid. The mean preoperative knee range of motion was 48 degrees. The mean maximum extension was 32 degrees fixed flexion deformity, and ranged from 15 degrees hyperextension to 65 degrees fixed

Fig. 2 Type-2 chronic irreducible posterior dislocation of left knee.
(A) This young female with a BMI of 47 kg/m^2 sustained a multiple ligament knee injury with popliteal artery injury following an ultra-low velocity knee injury. The trivial mechanism of injury probably misled the primary surgeon and resulted in underdiagnosis and undertreat- ment of the knee instability. (B) She presented 10 weeks following her injury and had undergone an acute repair of her posterolateral corner, followed by immobilization in a cast for 4 weeks. (C) MRI revealed a fixed posterior dislocation with a contracted intact ACL. (D) Angio- gram on presentation revealed a missed popliteal artery injury with collateral circulation formation. ACL, anterior cruciate ligament; BMI, body mass index; MRI, magnetic resonance imaging.

flexion deformity. Maximum preoperative flexion ranged from 35 to 110 degrees, with a mean of 80 degrees. Four patients had sustained an arterial insult during the index injury. Of these, two had undergone successful vascular surgery for the same, whereas two patients had a missed partial or transient vascular injury with adequate collateral circulation formation noted on presentation (Fig. 2). One patient had a persistent peroneal nerve complete palsy, whereas four patients had a transient partial palsy that had largely recovered prior to presentation. In 18 patients, the direction of dislocation was primarily posterior, whereas 3 patients had an anterior unreduced dislocation. No patient had a medial–lateral dislocation or complex rotatory dislo- cation. In the absence of joint reduction, it was not possible to classify these patients as per Schenk's anatomic knee dislocation (KD) classification system. The distribution of cases based on the classification we proposed is described in Table 1. The mean preoperative Lysholm's knee score was 9.4 and ranged from 2 to 19 points. The mean preopera- tive KOOS score was 10.7 and ranged from 8.3 to 13.7.

Surgical Details All patients underwent surgical reduction following extensive arthrolysis that involved circumferential capsular release and extensor compartment suprapatellar and infrapatellar scar excision. In 20 patients, this was performed as an open procedure and in 1 patient, this was performed primarily as an arthroscopic procedure with some extra-articular posterior

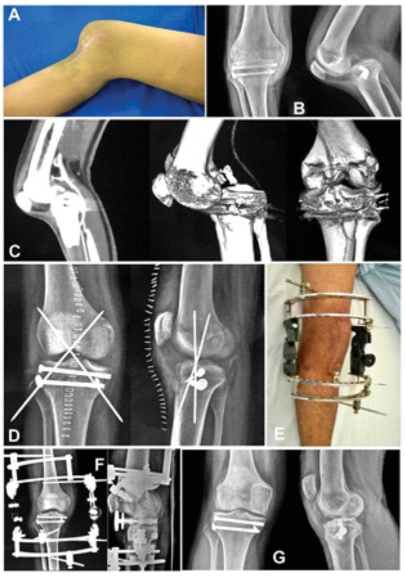


Fig. 3 Type-2b chronic irreducible knee dislocation of 3 months duration in a young male.
(A) Clinical image during presentation revealed a deformity pathognomonic of this unusual clinical scenario.
(B) He sustained a right knee fracture-dislocation 3 months prior to presentation and had undergone a tibial plateau fracture fixation with possibly open MCL repair immediately following the injury. He was thereafter immobilized for 6 weeks in a cast. (C) CT angiogram on presentation confirmed the absence of vascular injury and delineated the course of the popliteal artery. (D) He underwent open reduction and was immobilized for 2 weeks in a reduced position. (E) Range of motion exercises were initiated after 2 weeks of the surgery and maintenance of reduction was facilitated with a hinged external fixator. (F) Serial radiographs during mobilization were performed to
confirm no loss of anatomical reduction. (G) At 7-year follow-up, he has normal function (Lysholm's score ¼ 84, KOOS score ¼ 78.8) with full range of active movements and an asymptomatic grade-2 laxity of
PCL. His alignment is normal, and his weight-bearing radiograph reveals early medial compartment degenerative changes. CT, com- puted tomography; KOOS, knee injury and osteoarthritis outcome score; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

and lateral release performed prior to PLC ligament recon- struction. All 21 patients underwent early range of motion exercises facilitated with a hinged external fixator. From 2002 to 2008, this constituted the hinged Ilizarov frame, whereas from 2008 onward, this was achieved with a Compass Univer- sal Hinge (Smith & Nephew, Memphis, TN) with external frame.[6] Immobilization for 2 weeks in full extension to stabi- lize the reduction prior to knee range exercises in a Compass hinge was used for patients with long duration dislocations in whom concurrent ligament reconstruction was not performed (Fig. 3). Overall, 17 of the 21 patients underwent some

Table 2 Ligament reconstructive surgeries performed in 21 cases

Ligaments reconstructed	No. of cases
No ligament reconstruction: only open reduction	4
MCL þ MPFL	1
PCL	3
PCL þ PLC	2
PCL þ PLC þ MCL	6
PCL þ PLC þ MCL þ ACL	5

Abbreviations: ACL, anterior cruciate ligament; MCL, medial collateral ligament complex including posterior oblique ligament; MPFL, medial patellofemoral ligament; PCL, posterior cruciate ligament; PLC, pos- terolateral ligament complex including lateral collateral ligament.

ligament reconstructive surgery, the combinations of which are detailed in Table 2. Standard ligament reconstructive surgical techniques were employed and included singlebundle anatomic ACL reconstruction, single-bundle PCL reconstruc- tion, double-bundled medial patellofemoral ligament (MPFL) reconstruction, and anatomic medial ligament reconstruction which included superficial MCL and posterior oblique liga- ment. Of the 13 PLC reconstructions performed, 9 included anatomic reconstruction of LCL, popliteus, and popliteofibular ligament, whereas 4 cases had undergone split biceps tenod- esis. In 15 patients, ligament reconstruction was performed with ipsilateral and/or contralateral autografts, whereas in 2

patients this was performed with cadaveric allografts. Three patients underwent a single-stage surgery, whereas in 18 patients, a minimum of two stages were performed to com- plete the procedure. The mean duration between open reduc- tion and staged ligament reconstruction was 22 weeks, and ranged from 10 weeks to 16 months. No major intraoperative complication, neurovascular deficit, or infection occurred following surgery. Three patients developed persistent signif- icant stiffness that warranted an arthroscopic arthrolysis.

Ambulatory Status

On final follow-up, all 21 patients were independently ambu- latory. Also, 20 were not using any walking aid, whereas 1 patient with a body mass index (BMI) of 47 kg/m^2 was regularly using a walking stick for outdoor activities. She was 7 years following surgery and had posttraumatic knee arthritis of KL grade 4. Two patients walked with a clinically discernable limp when ambulating without an orthotic sup- port and included the above-mentioned patient, and another patient with complete peroneal nerve palsy with foot drop having undergone a foot tendon transfer surgery.

Joint Stability on Clinical Testing

No patient had symptomatic knee instability at final follow- up. Four patients had an asymptomatic isolated grade-III PCL laxity confirmed on stress radiography (Fig. 4). Of these, three had undergone only open reduction with hinged knee fixator application, and had refused subsequent ligament

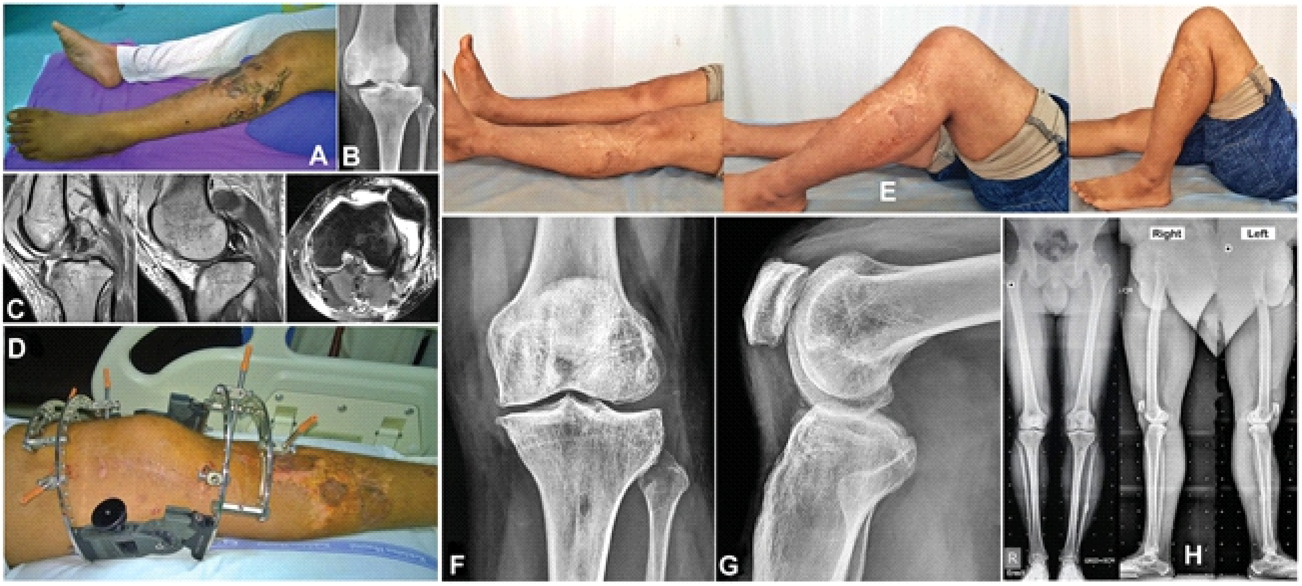


Fig. 4 Left knee type-1b chronic knee dislocation of 10 weeks duration in a patient with polytrauma. (A) Clinical image and (B) radiograph at presentation. (C) MRI revealed a knee dislocation with tears of the ACL, PCL, and MCL along with an unreduced lateral patellar dislocation. He had no neurovascular injury. (D) He underwent single-stage open reduction, hinged fixator application, and MCL with MPFL reconstruction. The plan was to perform a second stage arthroscopic bicruciate reconstruction once range had been achieved. This, however, was not performed, as per the patient's request, since he had no symptomatic knee instability despite a grade 3 PCL laxity. (E) 10 years following surgery he has a normal gait, full knee range, and functional scores of Lysholm's score of 88 points and KOOS score of 88.7 points. (F) Standing AP radiograph at 10 years follow-up reveals Kellgren–Lawrence grade-2 degenerative joint disease. (G) Stress radiography confirmed isolated grade 3 PCL laxity which is still asymptomatic. (H) Coronal and sagittal scanograms revealed normal limb alignment. ACL, anterior cruciate ligament; AP, anteroposterior; KOOS, knee injury and osteoarthritis outcome score; MCL, medial collateral ligament; MPFL, medial patellofemoral ligament; MRI, magnetic resonance imaging; PCL, posterior cruciate ligament.rendered them asymptomatic. Besides these four patients, another six patients had residual grade-I or -II laxity of the ACL, PCL, or MCL which was asymptomatic in all cases.

Final Range of Motion

The mean knee range of motion was 127 degrees at final follow-up. The mean extension was 2-degree hyperexten- sion, and ranged from 7-degree hyperextension to 5-degree fixed flexion deformity. Flexion regained after surgery ranged from 95 to 140 degrees with a mean of 123 degrees.

Joint Reduction

Radiologically confirmed complete joint reduction was achieved in 19 patients, whereas 2 patients had incomplete joint reduction with a persistent grade-II fixed posterior subluxation in the immediate postoperative radiographs. Three patients had loss of initial correction on serial radio- graphs; however, no patient had a complete recurrence of joint subluxation or dislocation noted.

Limb Alignment

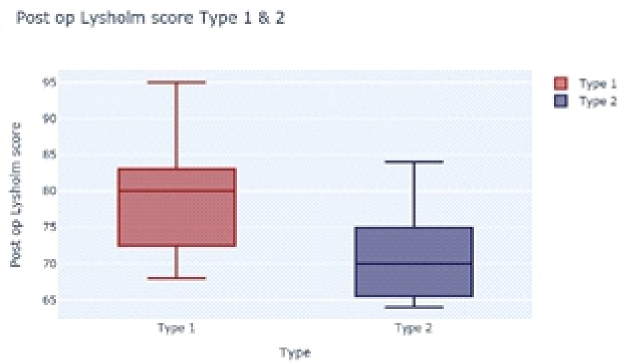
Scanograms at final follow-up revealed coronal alignment within 5 degrees of the opposite unaffected limb in 17 patients, whereas in 4 patients, there was a varus malalignment exceed- ing 5-degree difference (range: 7–10 degrees). In three of these four patients, this varus malalignment was associated with KL grade-4 radiographic tricompartmental osteoarthritis.

Secondary Posttraumatic Knee Arthritis

No patient had degenerative changes in their knee prior to injury, and all patients were graded as KL grade 0 on their immediate postoperative radiographs. No patient with less than 5-year follow-up demonstrated secondary degenera- tive radiographic changes. Of the 13 patients with more than 5-year follow-up, there were 2 KL grade-0, 4 KL grade-1, 2 KL grade-2, 1 KL grade-3, and 4 KL grade-4 patients. All five patients with KL grade-3 or KL-grade 4 radiographic features of knee degenerative joint disease had either incomplete joint reduction with a persistent grade-2 fixed posterior subluxation in the immediate postoperative radiographs or duration of follow-up exceeding 12 years.

Functional Outcomes

Final mean functional scores for each type of chronic knee dislocation are detailed in Table 3. The mean postoperative



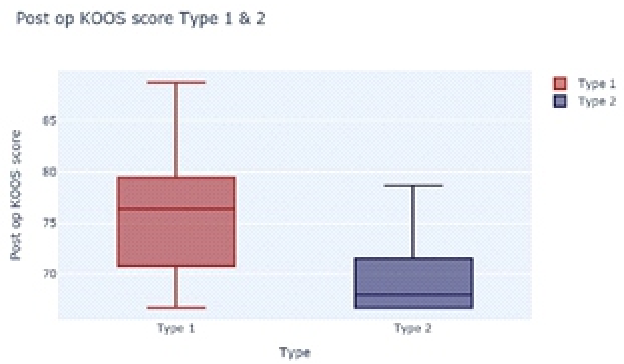


Fig. 5 Comparative analysis of maximum, minimum and median values for postoperative Lysholm's and KOOS scores of type-1 and -2 chronic knee dislocations. KOOS, knee injury and osteoarthritis outcome score; Post op, postoperative.

Lysholm's knee score was 75.9 ± 8.0 and ranged from 64 to 95 points. Type-1 patients showed a maximum postoperative Lysholm's score of 95, whereas type-2 patients showed a maximum postoperative Lysholm's score of 84 (Fig. 5). Type-1 patients had a significantly higher mean postopera- tive Lysholm's score of 79 ± 7.5 as compared with mean postoperative Lysholm's score of type 2 of 71 ± 6.4. Statistical significance was noted on comparison of postoperative Lysholm's score between the two groups ($p < 0.04$). No statistical significance was noted between preoperative Lysholm's scores of both groups (*p* ¼ 0.854). The mean post- operative KOOS score was 73.5 ± 6.7 and ranged from 66.7 to 88.7. Type-1 patients showed a maximum postoperative KOOS score of 89 whereas type-2 patients showed maximum postoperative KOOS score of 79. Type-1 patients had a higher

Table 3 Preoperative and postoperative mean Lysholm's and KOOS scores for each type of chronic knee dislocation

ÇяБŇ	bЄƵ of cases	t ДŇЄБŇД ŤůŇ Lysholm's score Mean ± SD	t ЄИTЄБŇД ŤůŇ Lysholm's score Mean ± SD	t ДŇЄБŇД ŤůŇ KOOS score Mean ± SD	t ЄИTЄБŇД ŤůŇ KOOS score Mean ± SD
Ҍş	2	6.5 ± 0.5	74.5 ± 6.5	9.9 ± 1.3	72.5 ± 5.8
1b	11	10.1 ± 5.0	79.5 ± 7.4	10.5 ± 1.6	76.5 ± 7.0
2a	1	16.0	77.0	13.6	72.4
2b	7	8.1 ± 4.0	70.3 ± 6.4	10.8 ± 1.9	69.4 ± 4.1
	21	9.4 ± 4.7	75.9 ± 8.0	10.7 ± 1.8	73.5 ± 6.7

Abbreviations: KOOS, knee injury and osteoarthritis outcome score; SD, standard deviation.

mean postoperative KOOS score of 76 ± 7.0 as compared with type-2 mean postoperative KOOS score of 70 ± 4.0. Preoper- ative KOOS score of both groups showed no statistical significance (p ¼ 0.409). Postoperative KOOS data were assessed for statistical significance by applying the Mann–Whitney U-test. This showed no statistical significance between the groups (p ¼ 0.052).

Conversion to Arthroplasty

Despite a follow-up that extended up to 16 years 2 months, no patient in this series had undergone knee arthroplasty or arthrodesis for failed surgery or secondary to posttraumatic knee arthritis.

Discussion

The principal finding of this study is that open reduction and joint reconstruction can effectively treat a chronic irreduc- ible knee dislocation and convert it from a painful deformed joint which is both stiff and unstable to a reduced joint with functional range and stability having satisfactory functional outcomes in the medium term. Additionally, type-2 chronic dislocations with prior periarticular surgery are associated with significantly inferior Lysholm's scores ($p < 0.04$) as compared with type-1 chronic knee dislocations.

Although failure to detect a knee dislocation following an injury may seem inconceivable in the present era, these can sometimes be missed, especially in patients with polytrauma or concomitant ipsilateral limb fractures, and in obese patients who sustain ultra-low velocity knee dislocations. Our series had predominantly missed posterior dislocations and three anterior dislocations. There were no medial–lateral or complex rotatory dislocations presumably because the external deformity caused in these injuries is overtly apparent and impossible to miss. Our series also had a significantly large number of patients (38%) who had post- operatively missed knee dislocations (type 2), and this is a common phenomenon in the prior reported cases too.[5–8]

Special attention should be paid to radiographically "nor- mal" multiple ligament knee injuries which are notorious for being missed spontaneously reduced knee dislocations. An inexperienced surgeon may underestimate the complexity of the primary injury with resultant underdiagnosis or under-treatment of the knee instability. In most of these missed postoperative dislocations, the knee instability was inade- quately addressed, and all had undergone a period of post- operative knee immobilization in an inadvertent dislocated position. These were often obese patients or patients within a cast where the postoperative dislocation was probably not clinically overt and hence was missed. The primary surgeries performed on the patients ranged from popliteal artery repair with no ligament reconstructive surgery, to isolated PLC or capsular repair in acute highly unstable multiple ligament knee injuries, to a bicruciate reconstruction in an acute posterior knee dislocation (Fig. 6). Early recognition with adequate physical examination and serial postoperative radiographs are critical to avoid overlooking this complication.

Each case of chronic irreducible knee dislocation is unique and warrants appreciation of the altered anatomy of the knee, along with a detailed preoperative assessment that includes a vascular study, followed by an individualized operative and rehabilitation plan. The surgical priority in such cases is first joint reduction, followed by regaining functional range of motion, and finally return of optimal stability. Open reduction of a chronic knee dislocation is predictably achievable up to 6 months, and requires circum- ferential excision of adherent capsular and scar tissue. The significant distortion of anatomy, including that of the neurovascular bundle, especially in prior operated cases, is to be anticipated and addressed with care. For both anterior and posterior chronic knee dislocations, our sequence of release was first anteriorly, so as to have a completely free extensor apparatus, thereafter femoral notch clearance, followed by medial and lateral suprameniscal capsular release, and finally posterior subperiosteal soft tissue release. We encountered the maximum resistance to reduc- tion in the region of the posterolateral corner in posterior dislocations, and in the entire posterior aspect of femur and tibia in anterior dislocations. An intact contracted ACL was

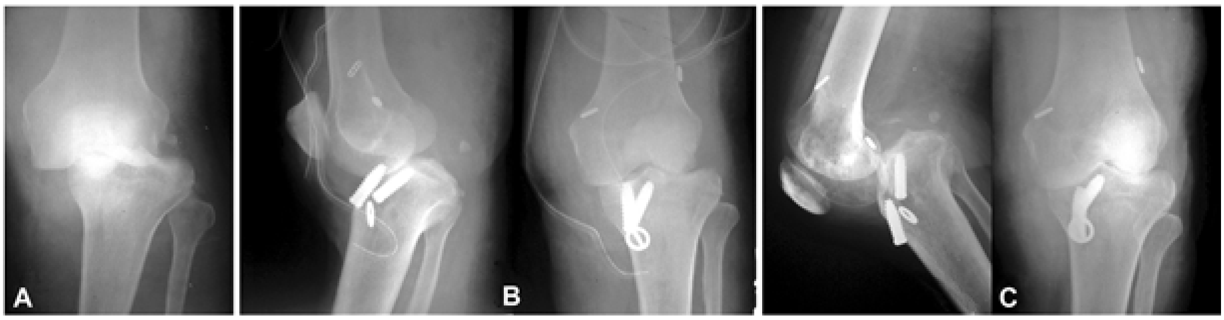


Fig. 6 The leading cause of type-2 chronic irreducible knee dislocations is inappropriate primary treatment. Inability to appreciate the complexity of the injury often leads to underdiagnosis and undertreatment of the knee instability. Adequate expertise to manage these injuries, along with early recognition of loss of reduction are critical to avoid overlooking this disastrous complication. (A) Acute posterolateral left knee dislocation in a 29-year-old male. (B) He underwent an inappropriately performed bicruciate reconstruction for his multiple ligament knee injury. His immediate postoperative radiographs revealed a persistently dislocated postsurgical knee. He was subsequently immobilized in this position. (C) Radiographs on presentation to our service 5 months following his primary surgery reveal a Type-2b chronic irreducible left knee dislocation.

Fig. 7 (A) Left knee type 1b chronic knee dislocation of 9 weeks' duration with a fixed posterior subluxation. (B) Radiographs 1 year following a single-stage reduction, hinged fixator application, and multiple ligament reconstruction (PCL þ PLC þ MCL, intact ACL not released) reveal a persistent grade-2 fixed posterior subluxation. (C) 14 years following surgery, his radiographs reveal Kellgren–Lawrence grade-4 posttraumatic arthritis, with a persistent grade-2 fixed pos- terior subluxation, and patellofemoral degenerative joint disease. (D) His knee range extends from -5-degree hyperextension to 115- degree flexion. (E) Scanogram reveals left varus alignment 5 degrees more than the right lower limb. (F) Clinical alignment in coronal plane appears within normal limits, although 5 degrees of hyperextension is noted in the sagittal plane. After 14 years of surgery, he has a normal gait, with functional scores of Lysholm's score of 64 points and KOOS score of 66.7 points. ACL, anterior cruciate ligament; KOOS, knee injury and osteoarthritis outcome score; MCL, medial collateral liga- ment; PCL, posterior cruciate ligament; PLC, posterolateral complex.

noted in many posterior dislocations, and this often necessi- tated excision to facilitate reduction (Fig. 2). We suspect failure to do so was one of the causes for incomplete joint reduction in one of our early cases in the series.

The extensive release necessitated to reduce the joint anatomically, renders the knee not only extremely unstable but also prone for arthrofibrosis.[6] Early resumption of range while maintaining joint reduction is mandatory and can be best achieved with a hinged external fixator. Moreover, if ligament reconstruction is planned at the same stage, a hinged external fixator is critical to prevent increased stress on the grafts.[6] Concurrent multiple ligament reconstruction, especially with ipsilateral autografts, adds to the surgical insult and complexity of the case and should be performed with caution. In case of any doubt, especially with disloca-tions beyond 3 months, it may be prudent to perform ligament reconstruction on a need basis depending on the resultant instability, once knee range has been regained. This is also applicable for type-2 chronic dislocations with prior failed intra-articular or extra-articular ligament surgery. In this series, only 3 patients underwent a single-stage surgery, whereas in 18 patients with a minimum of two stages were performed to complete the procedure.

A 2-week period of immobilization in reduced extended knee position for chronic posterior knee dislocations, prior to initiation of knee range exercises, helps maintain the reduc- tion. This is especially applicable for dislocations for over 3 months' duration in whom ligament reconstructive surgery is often staged. A loss of reduction was noted in three of our earlier cases in whom knee range exercises were initiated in the immediate postoperative period. This possibly occurred due the contracted posterior musculature which needed a period of sustained stretching following joint reduction to regain its normal length. Moreover, we observed that hinged external fixators predictably maintain coronal plane and rotatory reduction but are sometimes vulnerable to sus-tained posterior translatory forces at the joint.

Reduction and alignment are chondroprotective and essential for a good long-term outcome. Sixteen patients had no or minimal secondary degenerative changes (KL grades 0–2). All of these patients had a well reduced joint with acceptable limb alignment, though some had terminal flexion range restrictions and asymptomatic joint laxity. All five patients with KL grade-3 or -4 degenerative joint disease had either a persistent grade-2 fixed posterior subluxation in the immediate postoperative radiographs (Fig. 7), or a loss of reduction, or developed a varus malalignment over time (follow-up exceeding 12 years). This reconfirms that malre- duction and malalignment have a poor prognosis and should be prevented or treated early. On the other hand, asymp- tomatic joint laxity and loss of terminal flexion range do not cause degenerative joint disease in the medium term. It would also appear that patients tolerate residual ligament laxity better than loss of range and reduction. Despite almost half of the patients demonstrating some residual knee liga- ment laxity on clinical examination at final follow-up, no patient in this series complained of symptomatic knee instability and three patients declined second-stage liga- ment reconstructive surgery since they were already satis- fied with their functional outcome.

Significant increases in functional scores from preopera- tive to postoperative were noted in this case series. Mean scores improved from preoperative 9.4 ± 4.7 (range: 2–19) to postoperative 75.9 ± 8.0 (range: 64–95) for Lysholm's score and preoperative 10.7 ± 1.8 (range 8.3–13.7) to postopera- tive 73.5 ± 6.7 (range: 66.7–88.7) for KOOS score. These encouraging results support open reduction and reconstruc- tive surgery for this complex condition despite the often staged and lengthy treatment and rehabilitation. These out- comes also stress the need for early diagnosis and reduction of knee dislocations since the results following early and appropriate treatment of knee dislocations is superior to that achieved in the chronic setting.[17–19]

The following limitations should be considered when inter- preting the results of this study. First, this study is a retro- spective analysis of prospectively collected data of a single surgeon's experience with an uncommon condition. This introduces the possibility of an inherent selection bias and observer bias which may possibly have had an influence on the results. Second, there is marked heterogeneity among this group of patients which necessitated much variability with regard to surgical execution and rehabilitation. More- over, since the study period extended 16 years, there were variations in the ligament reconstruction techniques employed, especially for posterolateral corner reconstruc- tion. This may limit the generalizability of the findings. Lastly, there may be possible concerns with external validity that may not transfer to other populations. Many patients in this study had either low physical demands preinjury or had modified their physical activities, so as to adapt to their knee capabilities, and this may have had a bearing on the medium- term subjective patient-reported outcomes.

Conclusion

Open reduction and reconstructive surgery is an effective surgical treatment for chronic irreducible knee dislocations of up to 6 months' duration. An individualized, often staged approach that prioritizes joint reduction, early knee mobili- zation, and knee stability ensures satisfactory clinical, radio- logical, and functional outcomes in the medium term. Type-2 chronic dislocations with prior periarticular surgery are associated with significantly inferior Lysholm's scores ($p < 0.04$) than type-1 chronic knee dislocations.

Conflict of Interest

None declared.

References

1 Richter M, Lobenhoffer P. Chronic posterior knee dislocation: treatment with arthrolysis, posterior cruciate ligament recon- struction and hinged external fixation device. Injury 1998;29 (07):546–549

2 Polyzois VD, Stathopoulos IP, Benetos IS, Pneumaticos SG. A two- stage procedure for the treatment of a neglected posterolateral knee dislocation: gradual reduction with an Ilizarov external fixator followed by arthroscopic anterior and posterior cruciate ligament reconstruction. Knee 2016;23(01):181–184

3 Van Thiel GS, Baker CL III, Bush-Joseph C. A chronic posterolateral knee and patella dislocation: case report. J Orthop Trauma 2009; 23(07):541–545

4 Khamaisy S, Haleem AM, Williams RJ, Rozbruch SR. Neglected rotatory knee dislocation: a case report. Knee 2014;21(05):975–978

5 Henshaw RM, Shapiro MS, Oppenheim WL. Delayed reduction of traumatic knee dislocation. A case report and literature review. Clin Orthop Relat Res 1996;(330):152–156

6 Simonian PT, Wickiewicz TL, Hotchkiss RN, Warren RF. Chronic knee dislocation: reduction, reconstruction, and application of a skeletally fixed knee hinge. A report of two cases. Am J Sports Med 1998;26(04):591–596

7 Watanabe K, Yamada Y, Kura H, et al. Chronic knee fracture dislocation treated by the Ilizarov technique: case report. J Trauma 2001;50(01):151–154

8 Pardiwala DN, Subbiah K, Rao N, Jain V. Complications of multiple ligament knee injury surgery: prevention and salvage. Asian Journal of Arthroscopy 2020;5(01):58–65

9 Said HG, Learmonth DJ. Chronic irreducible posterolateral knee dislocation: two-stage surgical approach. Arthroscopy 2007;23 (05):564.e1–564.e4

10 Vicente-Guillen P, Figa-Mataró J, Coloma-Bellver J. Long-standing unreduced dislocation of the knee. A case report. Int Orthop 1998; 22(04):275–276

11 Petrie RS, Trousdale RT, Cabanela ME. Total knee arthroplasty for chronic posterior knee dislocation: report of 2 cases with techni- cal considerations. J Arthroplasty 2000;15(03):380–386

12 Chen H, Chiu F. Chronic knee dislocation treated with arthro- plasty. Inj Extra 2007;38:258–261

13 Saini R, Mootha AK, Goni VG, Dhillon MS. Neglected irreducible posterolateral knee dislocation. Indian J Orthop 2010;44(04): 468–470

14 Karn N, Khanal G, Singh D. Long-standing unreduced anterior dislocation of the knee - a case report. Internet Journal of Medical Update 2010;5(01):51–53

15 Matthai T, Bhowmick K, Boopalan PR, George JC. Neglected anterior dislocation of the knee with common peroneal palsy. Case Rep Orthop 2015;2015:174965

16 Kapil Mani KC, Dirgha Raj RC, Parimal A, Ram PB. Open reduction of neglected knee dislocation: case report of a rare injury. Malays Orthop J 2016;10(03):56–57

17 Moatshe G, Chahla J, LaPrade RF, Engebretsen L. Diagnosis and treatment of multiligament knee injury: state of the art. J ISAKOS 2017;2(03):152–161

18 Peskun CJ, Whelan DB. Outcomes of operative and nonoperative treatment of multiligament knee injuries: an evidence-based review. Sports Med Arthrosc Rev 2011;19(02):167–173

19 Bagherifard A, Jabalameli M, Ghaffari S, et al. Short to mid-term outcomes of single-stage reconstruction of multiligament knee injury. Arch Bone Jt Surg 2019;7(04):346–353