JAJS VOLUME 2 NUMBER 1 JANUARY–APRIL 2015 PAGES 1–54 ELSEVIER

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JOURNAL OF ARTHROSCOPY AND JOINT SURGERY

JAJS

Official Journal of the International Society for Knowledge for Surgeons on Arthroscopy and Arthroplasty (ISKSAA)

Volume 2 | Number 1 | January–April 2015

ISSN: 2214-9635

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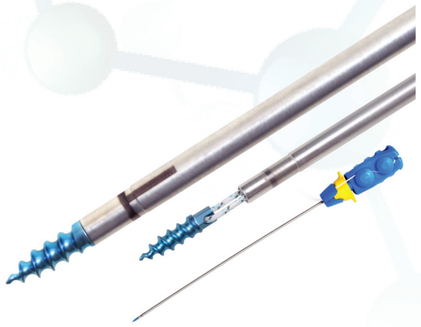

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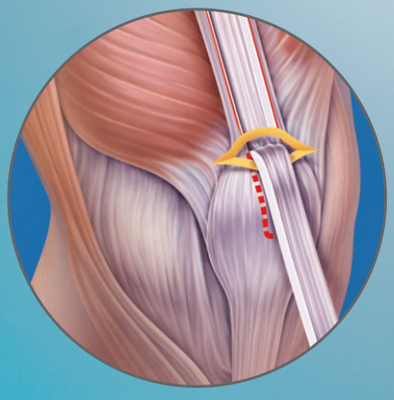

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Journal of Arthroscopy and Joint Surgery

An official publication of International Society for Knowledge for Surgeons on Arthroscopy and Arthroplasty

(ISSN: 2214–9635)

Volume 2, Number 1, January–April 2015

Aims and Scope

Journal of Arthroscopy and Joint Surgery (JAJS) is the official and peer-reviewed publication of *International Society for Knowledge for Surgeons on Arthroscopy and Arthroplasty* (ISKSAA). The Journal is committed to bring forth scientific manuscripts in the form of original research articles, current concept reviews, meta-analyses, case reports and letters to the editor. The focus of the Journal is to present wide-ranging, multi-disciplinary perspectives on the problems of the joints that are amenable with Arthroscopy and Arthroplasty. Though Arthroscopy and Arthroplasty entail surgical procedures, the Journal shall not restrict itself to these purely surgical procedures and will also encompass pharmacological, rehabilitative and physical measures that can prevent or postpone the execution of a surgical procedure. The Journal will also publish scientific research related to tissues other than joints that would ultimately have an effect on the joint function. The journal is published three times in a year (Jan-Apr, May-Aug, Sep-Dec) by Reed Elsevier India Pvt.Ltd. Contributors are invited to submit their manuscripts in English through the Online Manuscript Management System at **http://ees.elsevier.com/jajs**

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The *Journal of Arthroscopy and Joint Surgery* (ISSN: **2214-9635**) is published thrice a year. The annual price for **individual subscription** based in India is **INR 3600;** and for international subscribers, the annual price is **USD 60**. For **institutional subscription** within and outside India, please contact the Publishers office at journals.india@elsevier.com.

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Publishing Office: Elsevier, A division of Reed Elsevier India Pvt. Ltd., 14th Floor, Building No.10B, DLF Cyber City, Phase-II, Gurgaon-122002, Haryana, India. Email: journals.india@elsevier.com

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Published by Reed Elsevier India Pvt. Ltd.

Printed at EIH Limited-Unit Printing Press, IMT Manesar, Gurgaon

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Available online at www.sciencedirect.com

ScienceDirect

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Editorial

Journey to total hip arthoplasty

Hip joint is a mobile link between the trunk and the lower limb. It plays an important role in locomotion. Being a ball and socket joint it allows flexion extension, adduction, abduction, internal rotation and external rotation. These movements enable the person to adopt any posture for various activity of daily living, social occasions and at work and worship. Due to various causes like trauma, infection inflammation and degenerative processes etc., the hip joint may loose movements, become stiff, painful and deformed, severely jeopardizing its function. The patient may not be able to squat, sit cross legged or walk properly. These problems are as old as the history of man himself. The desire of the patient to have a mobile joint stimulated the surgeons to develop materials and methods to restore movement at ankylosed hip. Many attempts have been made to achieve movements with correction of deformity and relief of pain from time to time. Toward the end of 18th century attempt was made to replace femoral head with wooden block fixing it to the femur with plate and screws. Muscle flap, fascia, wall of the pig's bladder etc. were used for interposition between femoral head and acetabulum. The end result was failure and often disasterous.[1] The knowledge of biology, biomechanics, asepsis and compatability of the human tissues with these implanted materials was not known to the clinician.

John Rea Barton in 1927[2] reported his attempt to restore movements at the hip joint by creating a pseudoarthrosis in subtrochanteric region. Although this enabled the patient to sit properly in the chair yet the operation was unphysiological because main movers of the hip joint were inserted in the proximal fragment. The procedure has remained only of historical value. A better function was achieved by excising a bone segment from the neck of the femur. This was further improved by excision of the femoral head and neck by Girdle stone.[3] Bachelor[4] and Milch[5] tried to improve the stability after this procedure by doing osteotomy of the greater trochanter and fixing with the angled plate. Although good range of motion were restored at the hip, these produced shortening of the limb and appreciable limp.

Smith Peterson[6] initially prepared a mould of glass then of acrylic and resion and finally of vitallium which was given the name of Smith Peterson Cup. This cup covered the prepared head of femur and articulated with acetabulum. This produced quite satisfactory results lasting for few years. Ultimately the cup became loose and joint became painful requiring its removal. Judet[7] brothers designed a prosthesis which had a capital Part (head) segment and a stem. Capital component replaced the femoral head and the stem was fixed into the neck of the femur. It also met the same fate. Moore[8] and Thompson[9] designed intramedullary prosthesis consisting of a round head and a long intramedullary stem which was fitted into the medully canal of the femur. The head component articulated with the acetabulum. These were certainly better than the previous prostheses and are still in use in among patients of femoral neck fracture in geriatric patients. The problems often met with these were protrusio acetabuli and pain in the region of the hip and upper thigh requiring the removal of the prosthesis or substituting it with total hip arthroplasty. McKee Farrhar[10] & Phillip Wiles[11] designed a metallic cup and a stem somewhat similar to intramedullary stem of Thompson prosthesis. After preparation the cup was fixed to the acetabulum with screws or bone cement (methyl methacrelate) and stem in the medullary canal also with cement. The metallic joint produced sound during the movement and it became loose due to reaction of the local tissues to wear particles of metal.

Bipolar prosthesis was developed by Bateman[12,13] with the hope that it give would better results. The procedure of implantation is quite easy and taking short time. It is useful in patients with compromised health with life expectancy of <5 years. Though good results have been reported in >10 years followup.[13]

Charnley[14–16] designed non metallic cup first made of acrylic and later on of high density polyethylene and femoral component made of vitallium. Both the components were highly polished with the idea of decreasing the friction between the two and reducing the wear and tear of the implant. The results of this joint consisting of high density polyathelene cup and metallic stem were very good and the joint lasted for many years. Early complications were dislocation and infection which were improved by observing strict aseptic condition in the operation theatre and improvement in the operative technique. The delayed complications observed were aseptic loosening, osteolysis which required revision arthroplasty.[17–19]

Initially aseptic loosening was considered to be due to bone cement[20] and hence non cemented total hip was designed.

This consisted of a metallic shell with inner polyethylene lining. The metallic shell had granular outer surface and coated with hydroxyapatite for better corporation into the bone. The shell was fixed to the bone with screws and polyethylene lining was fitted into it. The femoral component was also designed in a way that the bone could grow into it. All these implants had monoblock femoral component. Further development produced modular type of femoral stem consisting of separate head component which could be fitted to the intramedullary stem. The size of the neck of the femoral component could be adjusted with the use of different sizes (length) of head which allowed adjustment of length the neck of the femur as well as the tension of the soft tissue. Even these types of non cemented joints had aseptic loosening. The blame now has shifted on the polyethylene cup or polyethylene lining. Wear particles of polyethylene cup produced reaction in the soft tissues leading to aseptic loosening and osteolysis on the acetabulars as well as the femoral side. In order to get rid of polyethylene from the total hip prosthesis, metal on metal and ceramic on ceramic joints were developed.[21,22] These had highly polished surfaces. Surface arthroplasty with coverage of femoral head with a metallic component articulating with metallic acetabular part was used in younger patients. These allowed vide a range of movements and the patients were able to squat and sit cross legged. The initial results were very encouraging. However, within few years, wear particles from the metallic cup and head started producing reaction in the soft tissues often leading to formation of tumour like lesions around the hip joint and metlosis. Revision arthroplasty had to be carried out in such cases and metal on metal joint has now gone out of market. Ceramic on ceramic joint are still in use. The problem faced with this prosthesis is squeaking sound and cracking of the cup resulting in pain in the region of hip. Now ceramic head on highly cross linked polyethylene cup and metallic head on cross linked polyethylene cup are latest to be used in total hip arthroplasty with improvement in the results reported. The cross linked polyethylene has very slow wearing property. Only time will show for how long these joints will last when implanted in young patients. Further research in these materials and development of new materials is still being carried out to design a joint which will last for the life of individual when planted in a young person.

Medical profession as well as the patients are anxiously waiting for the day when such a joint is made available to them.

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17 December 2014
Available online 30 January 2015

http://dx.doi.org/10.1016/j.jajs.2014.12.007

Available online at www.sciencedirect.com

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Original Article

Clinical examination, magnetic resonance imaging and arthroscopic correlations of ligament and menisci injuries of knee joint

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ARTICLE INFO

Article history:
Received 4 November 2014
Accepted 3 December 2014
Available online 26 December 2014

Keywords:
Knee
Arthroscopy
Clinical examination
Magnetic Resonance Imaging
Correlation

ABSTRACT

Purpose: Our study has been carried out due to ambiguity in results of different scientific publications. Data obtained sheds light on importance of history taking and clinical examination and verifies the importance of MRI.

Methods: Ours is a prospective cross sectional double blinded study. We reviewed 190 patients who underwent knee arthroscopy for suspected menisci and ligament injuries. Patients were divided into 2 groups on objective clinical assessment: Those who were positive for either menisci or cruciate ligament injury [group 1] and those having both menisci and ligament injury [group 2]. MRI was performed using a 1.5 T machine using standard protocol at our centre and reported by an experienced radiologist. Findings of clinical examination, MRI and arthroscopy were analysed by a single independent reviewer and arthroscopy was considered as gold standard.

Results: In medial meniscus injuries we observed that there was statistically significant difference between clinical versus arthroscopy and MRI versus arthroscopy group in sensitivity (91.39% Vs 76.59%, $p < 0.0001$) and negative predictive value (89.19% Vs 76.08%, $p = 0.0003$). In lateral meniscus injuries we observed that on comparison between the two groups only positive predictive value had a significant difference (82.92% Vs 71.73%, $p = 0.0086$). In injuries of anterior cruciate ligament on comparison between the two groups there was statistically significant difference in specificity (88.88% Vs 79.07%, $p = 0.0085$) and negative predictive value (100% Vs 91.89%, $p < 0.00001$) whereas in posterior cruciate ligament injuries on comparison between the two groups there was statistically significant difference in sensitivity (100% Vs 90.9%, $p = 0.0001$) and positive predictive value (91.66% Vs 83.33%, $p = 0.01$).

Conclusion: The strength of correlation between MRI and arthroscopic findings confirms the value of MRI in assessing internal knee structures. Whereas MRI can be invaluable in diagnosis, a competent and preferably repeated clinical examination surpasses it.

Level of evidence: Level I diagnostic study.

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http://dx.doi.org/10.1016/j.jajs.2014.12.003

1. Introduction

MRI has gained widespread acceptance in the evaluation of the ligaments and menisci injuries of the knee along with other pathologies, although one cannot rule out the importance of a thorough history and a good clinical examination. Many reports have stressed the importance of history taking and clinical examination and no statistical advantage of MRI in these cases.[1,2] On the other hand, other studies[3,4] emphasized the importance of MRI in increasing the accuracy of diagnosis. The aim of this study is to evaluate and compare the efficacy of clinical examination and radiological assessment using MRI with arthroscopic findings in ligament-menisci knee injuries. We hypothesized that MRI findings correlated with those of clinical examination and that of arthroscopy findings in case of tears of medial and lateral menisci and anterior and posterior cruciate ligament tears.

2. Materials and methods

Data from 260 consecutive knee arthroscopies performed by an experienced arthroscopy surgeon; between May 2011 and November 2013; for diagnostic arthroscopies, degenerative joint disorders, ligament injuries, loose body removals, and adhesiolysis were prospectively collected. From the above data, a subset of 190 patients who sequentially had clinical examination, MRI and arthroscopy for suspected meniscal and ligament injuries were considered for the present study and the data was reviewed. Patients with previous menisectomies, knee ligament repairs or reconstructions and osteochondral fractures on imaging were excluded from the study.

Clinical data including patient demographics, wait period between MRI and arthroscopy, suggestive symptoms including effusion, presence of a "pop", locking, mechanism of injury, clinical diagnosis, and operative details were documented and analysed. All patients were examined by one experienced arthroscopist. Findings of MRI were unknown to him.

Standard clinical tests were used for diagnosing pathologies. To diagnose menisci injuries joint line tenderness, Mcmurray's and Apley's tests were used, whereas for cruciate injuries, anterior and posterior drawer tests, Lachmann test, pivot and reverse pivot shift tests and posterior tibial sag were used.

MRI was requested for confirmation of clinical diagnosis and for obtaining additional information in those patients presenting to us for the first time and were allotted date of surgery with one to two weeks. In this study clinical and MRI findings were compared with arthroscopic findings considering later to be the gold standard. In this study all patients underwent MRI at the imaging centre in our institute. All magnetic resonance imaging studies were performed using a standard knee protocol on a 1.5-T MR scanner with a phased array knee coil. All of the patients had T1 and T2 weighted and proton dense sequence on coronal and sagittal plane images, without contrast. MR pulse sequences included fast spin echo (FSE) and fast recovery. All MRIs were reported by one senior radiologist at our institute. Radiologist, provided with only patient identifying data, and provisional diagnosis reported the MRI findings. Meniscal tears were radiologically graded from I to III. Grade I had only punctuate non-contiguous hyper intensities, while grade II had linear streak hyper intensity, both not extending to the articular surface, whereas grade III were hyper intensities extending to the articular surface and were considered as positive findings. Complete as well as partial lesions of the anterior and posterior cruciate ligaments were interpreted as ruptures. Any osteochondral fracture leading to instability picked up from MRI and missed in normal skiagrams was omitted from the study group.

Arthroscopies were performed in a standard manner under spinal anaesthesia. MRI findings were not known to the surgeon. Operative findings were documented in the operation theatre, which included the anatomical structure involved with the presence or absence of tear, its location, status of the articular cartilage and additional details when available. Findings of clinical examination, MRI and arthroscopy were analysed by a single independent reviewer and arthroscopy was considered as gold standard.

The composite data was tabulated on Microsoft excel spreadsheet and studied for correlation. There were two identified groups: Those who were clinically positive for either menisci or ligament injury [group A] and combined menisci and ligament injury [group B]. Sensitivity, specificity, positive predictive value and negative predictive value of clinical and MRI diagnosis for anterior cruciate ligament, posterior cruciate ligament, medial meniscus and lateral meniscus were calculated from the data procured using standard formulae. Full agreement was when the modalities correlated accurately. Any disparity between clinical examination and MRI at arthroscopy was considered no agreement. Partial agreement was when there was partial correlation between the modalities.

3. Results

The observations of the study group were prepared group wise for correlation. In group A the total population was 73 patients including 60 males and 13 females. Mean age of the group was 32 (Range; 9–58 years). Knees involved were 40 on the right side and 33 on the left side. Duration between injury and arthroscopy averaged to be 9.44 months (Range; 0.5–72 months). Duration between MRI and arthroscopy averaged to be 1.9 months (Range; 0.25–11). Mode of trauma was fall (including sports injuries) in 44 patients and two wheeler accidents in 29 patients.

On comparing the findings between clinical examination and arthroscopy medial menisci lesions showed full agreement in 19 patients (86.36%) and no agreement in 3 patients (13.63%). In case of all 6 patients with lateral meniscus lesions there was full agreement. 35 patients (87.5%) with anterior cruciate ligament (ACL) injury had full agreement and 5 (12.5%) had partial agreement denoting dilemma over complete versus partial tear. It has come to our notice that these patients had anterior cruciate stumps fibrosis attachment with posterior cruciate ligament giving pseudo firm end point on anterior drawer and lachmann tests, in only 1 patient diagnosed to have complete tear on clinical examination was there partial tear on arthroscopy in that only around 10% of

fibres were intact. All 6 patients with posterior cruciate ligament (PCL) injury had full agreement between clinical and arthroscopic findings. In addition 13 patients, who were diagnosed clinically to have cruciate injury, had additional menisci injury on arthroscopy. Among these 13 patients, 12 patients were diagnosed clinically to have isolated ACL tear, but on arthroscopy they had concomitant medial menisci tear in 4 patients, lateral menisci tear in 6 patients and tear in both medial and lateral menisci in 2 patients. One patient was diagnosed with isolated PCL injury on clinical examination also had lateral menisci tear on arthroscopy.

On comparing the findings between MRI and arthroscopy medial meniscus lesions showed full agreement in 22 patients (73.33%) and in 8 patients (26.6%) there was none. In case of lateral menisci 11 patients (73.33%) showed full agreement and 4 patients (26.66%) there was no agreement. 33 patients (71.73%) with ACL tear had full agreement, 6 (13.04%) showed partial agreement and 7 (15.21%) had no agreement. 5 patients (83.33%) with PCL showed full agreement and 1 patient (16.6%) showed none.

In addition 7 patients who were diagnosed with isolated ACL injury on MRI had concomitant tear of medial menisci in 2 patients and tear of lateral menisci in 5 patients on arthroscopy. One patient diagnosed to have medial meniscus injury on MRI had only ACL tear (complete) on arthroscopy. Also in one patient was diagnosed to have PCL injury on MRI but it turned out to be ACL injury on arthroscopy. 3 patients had discoid lateral meniscus (incomplete) on arthroscopy.

Sensitivity, specificity, positive predictive value, negative predictive value of menisci and both cruciates in case of comparison between clinical examination and arthroscopy and between MRI and arthroscopy are represented in Table 1 and Table 2 in results respectively.

In group B there were total number of 117 patients with the age distribution of 15–52 years and average age of 29 years. There were 104 males and 13 females in the study group. Patients had derangement in right knees in 62 patients and left knees in 55 patients. Duration of injury ranged from 0.5 months to 120 months (average: 14.13 months). Duration of MRI from clinical examination and arthroscopy ranged from 0.25 months to 11 months and averaged at about 2.17 months. Mode of trauma included fall (including sports injuries) in 62 patients, two wheeler accidents in 54 patients and four wheeler accidents in 1 patient.

On comparing the clinical examination with the arthroscopy findings, in case of patients having combined medial and lateral menisci injury on clinical examination 3 (100%) partially agreed to clinical findings; in case of ACL with menisci injury 73 (68.86%) had full agreement, 32 (30.18%) had partial agreement, out of which 10 patients were diagnosed to have partial tear on clinical examination but had complete tear on arthroscopy and 1 (0.01%) patient had no agreement; in case of patients having posterior cruciate ligament injury along with menisci injury 1 (33.33%) patient had full agreement, 2 (66.66%) had partial agreement and finally in case of combined anterior and posterior cruciate ligament injury 2 (66.66%) had full agreement and 1 (33.33%) patient had partial agreement. This non agreement was due to sloppy anterior cruciate ligament with some non specific low hyperintensity on T2w image along with posterior cruciate ligament tear which was reported as both cruciate ligament tear on MR imaging by radiologist. In addition 18 patients having anterior cruciate ligament injury clinically had lateral meniscus injury and 2 patients had medial menisus injury.

On comparing MRI findings with arthroscopic findings, in case of patients having combined medial and lateral menisci injury on MRI 5 (71.42%) had full agreement and there was no agreement in 2 (28.57%) patients; in case of anterior cruciate ligament with menisci injury 72 (72%) patients had full agreement, 28 (28%) patients had partial agreement, out of which 8 patients were diagnosed to have partial tear on MRI but had complete tear on arthroscopy; in case of patients having posterior cruciate ligament injury along with menisci injury 1 (100%) patient had partial agreement and finally in case of combined anterior and posterior cruciate ligament injury 2 (40%) patients had full agreement and 3 (60%) patients had partial agreement.

In addition 25 patients having anterior cruciate ligament injury on MRI had concomitant lateral menisci injury along with anterior cruciate ligament injury in arthroscopy, similarly 18 patients having anterior cruciate ligament injury on MRI had concomitant medial menisci injury in arthroscopy. One patient who had medial meniscus tear reported in MRI actually had no meniscal injury but anterior cruciate ligament tear in arthroscopy. Similarly one patient having reported lateral meniscus tear on MRI had anterior cruciate ligament injury and no menisci injury in arthroscopy. One patient had no significant findings on MRI or arthroscopy but was clinically suspicious for partial anterior cruciate ligament injury along with medial meniscus injury, and was diagnosed with early arthritis. Two patients had both anterior cruciate and posterior cruciate ligament injury along with menisci injury in MRI and on clinical examination but on arthroscopic examination one patient had isolated posterior cruciate ligament

Table 1 – Clinical examination correlation (in percentage) with arthroscopic findings by type of injury among group A.

Test	Medial meniscus	Lateral meniscus	ACL	PCL
Sensitivity	75	37.5	100	100
Specificity	93.81	100	100	100
Positive predictive value	85.71	100	100	100
Negative predictive value	88.46	85.07	100	100

Here ACL stands for Anterior Cruciate Ligament and PCL for Posterior Cruciate Ligament.

Table 2 – MRI correlation (in percentage) with arthroscopic findings by type of injury among group A.

Test	Medial meniscus	Lateral meniscus	ACL	PCL
Sensitivity	91.66	68.75	97.50	83.33
Specificity	83.67	92.98	78.78	98.50
Positive predictive value	73.33	73.33	84.78	83.33
Negative predictive value	95.34	91.37	96.29	98.50

Here ACL stands for Anterior Cruciate Ligament and PCL for Posterior Cruciate Ligament.

and the other patient had posterior cruciate ligament along with both medial and lateral meniscus injury.

Sensitivity, specificity, positive predictive value, negative predictive value of menisci and both cruciates in case of comparison between clinical examination and arthroscopy and between MRI and arthroscopy are represented in Table 3 and Table 4 in results. Sensitivity, specificity, positive predictive value, negative predictive value of menisci and both cruciates in case of comparison between clinical examination and arthroscopy and between MRI and arthroscopy of the total population are represented in Table 5 and Table 6 in results respectively.

4. Discussion

MRI is a non invasive tool of imaging and causes no harm to the patient. It appears to be without risk and doesn't expose the patient to harmful radiation. Patients in whom meniscus tears are diagnosed on MRI but are not present arthroscopically can be due to misdiagnosed meniscal cysts, or mucoid degeneration or simply misinterpretation of normal anatomy or inadequate arthroscopic techniques.[5,6] Some lesions could have been missed due to large spacing for imaging. Li et al[7] report a medium risk of magic angle phenomenon for FSE (fast spin echo). The magic angle phenomenon has had an influence in our readings since our MRI centre use FSE. Overlooked MRI sheets can be a cause of the missing tears on the MRI.

Poor visualization of anterior cruciate ligament or posterior cruciate ligament injuries can be due to partial voluming, problem in imaging techniques which use contiguous slides, absence of anterior cruciate ligament or its rupture can be substantiated by the more than curled up appearance of posterior cruciate ligament.[5] MRI is also not able to diagnose bundle wise tear in anterior cruciate ligament as well as there is overlapping of partial and complete tears.[8]

The result of MRI are varied if the radiologist is a specialist in musculoskeletal radiology, and if it is more likely to pick up lesion when concomitant injuries are present as the radiologist may pay more attention to find out other lesions but in our study MRI showed better accuracy in group A than in group B.

MRI has superior sensitivity in detecting frank posterior horn tears and intra-substance meniscal tears, bone injuries with acute knee effusion and changes in hidden areas during arthroscopy, i.e., beneath the articular or in extra-articular spaces, deep chondral and sub-chondral lesions. Incidental findings on screening MRI facilitate preoperative planning.[9] Combined cruciate ligament and menisci injuries may affect the diagnosis of meniscus injuries, as there is a tendency to miss it clinically on examination, especially lateral ones.[3] It's our view that during the time interval between MRI and arthroscopic evaluation, patients due to altered biomechanics of the knee joint may develop new lesions. Such patients also develop increased quadriceps weakness and increased pressure on under surface of lower pole of patella and also chondral damage commonly to medial femoral condyle giving rise to anterior knee and mid joint line pain, and that they in absence of Mcmurray's test do not represent menisci pathology.

The differences between test modalities among the two groups were analysed using Z test for medial and lateral meniscus to determine the effect of concomitant injuries rather than single lesion on the diagnostic accuracy of MRI. In medial meniscus injuries we observed that there were

Table 3 – Clinical examination correlation (in percentage) with arthroscopic findings by type of injury among group B.

Test	Medial meniscus	Lateral meniscus	ACL	PCL
Sensitivity	97.1	59.6	100	100
Specificity	41.66	90	58.33	99.1
Positive predictive value	70.5	80	95.45	83.33
Negative predictive value	90.9	76.83	83.33	100

Here ACL stands for Anterior Cruciate Ligament and PCL for Posterior Cruciate Ligament.

Table 4 – MRI correlation (in percentage) with arthroscopic findings by type of injury among group B.

Test	Medial meniscus	Lateral meniscus	ACL	PCL
Sensitivity	71.4	50	98.13	100
Specificity	61.7	87.67	80	99.1
Positive predictive value	73.52	70.97	98.13	83.33
Negative predictive value	59.18	74.41	83.33	100

Here ACL stands for Anterior Cruciate Ligament and PCL for Posterior Cruciate Ligament.

Table 5 – Clinical examination correlation (in percentage) with arthroscopic findings by type of injury among 190 patients.

Test	Medial meniscus	Lateral meniscus	ACL	PCL
Sensitivity	91.39	53.96	100	100
Specificity	68.04	94.49	88.88	99.44
Positive predictive value	73.27	82.92	96.66	91.66
Negative predictive value	89.19	80.53	100	100

Here ACL stands for Anterior Cruciate Ligament and PCL for Posterior Cruciate Ligament.

Table 6 – MRI correlation (in percentage) with arthroscopic findings by type of injury among 190 patients.

Test	Medial meniscus	Lateral meniscus	ACL	PCL
Sensitivity	76.59	55	97.96	90.9
Specificity	72.91	90	79.07	98.88
Positive predictive value	73.47	71.73	94.12	83.33
Negative predictive value	76.08	81.25	91.89	99.43

Here ACL stands for Anterior Cruciate Ligament and PCL for Posterior Cruciate Ligament.

significant differences in case of sensitivity (91.66% Vs 71.4%, $p = 0.0001$), specificity (83.67% Vs 61.7%, $p = 0.0004$) and negative predictive value (95.34% Vs 59.18%, $p = 0.0001$) between the two groups whereas in case of positive predictive value (73.33% Vs 73.52%, $p > 0.05$) there was no statistical significant difference. In lateral meniscus injuries we observed that there were statistically significant difference in case of sensitivity (68.75% Vs 50%, $p = 0.0085$) and negative predictive values (91.37% Vs 74.41%, $p = 0.0012$) whereas in case of specificity (92.92% Vs 87.67%, $p = 0.05$) and positive predictive value (73.33% Vs 70.97%, $p > 0.05$) there was no statistical difference. These results show that MRI has better diagnostic value when there is single injuries to menisci and this value decreases when concomitant injuries are present. This is similar to other study by TR Madhusudhan[10] according to which MRI diagnostic value for menisci in group with concomitant injuries decreases.

The correlation between clinical versus arthroscopy and MRI versus arthroscopy findings of the total study group was evaluated using Z test. In medial meniscus injuries we observed that there was statistically significant difference between clinical examination and MRI findings regarding sensitivity (91.39% Vs 76.59%, $p < 0.0001$) and negative predictive value (89.19% Vs 76.08%, $p = 0.0003$) but with no statistical difference in specificity (68.04% Vs 72.91%, $p > 0.05$) and positive predictive value (73.27% Vs 73.47%, $p > 0.05$). In lateral meniscus injuries we observed that on comparison between the two groups only positive predictive value had a significant difference (82.92% Vs 71.73%, $p = 0.0086$) whereas no statistical significant difference in sensitivity (53.96% Vs 55%, $p > 0.05$), specificity (94.49% Vs 90%, $p > 0.05$) and negative predictive value (80.53% Vs 81.25%, $p > 0.05$). In injuries of anterior cruciate ligament on comparison between the two groups there was statistically significant difference in specificity (88.88% Vs 79.07%, $p = 0.0085$) and negative predictive value (100% Vs 91.89%, $p < 0.00001$) with no statistical difference between sensitivity (100% Vs 97.96%, $p = 0.46$) and positive predictive value (96.66% Vs 94.12%, $p > 0.05$). Finally in posterior cruciate ligament injuries on comparison between the two groups there was statistically significant difference in sensitivity (100% Vs 90.9%, $p = 0.0001$) and positive predictive value (91.66% Vs 83.33%, $p = 0.01$) with no statistically significant difference in specificity (99.44% Vs 98.99%, $p > 0.05$) and negative predictive value (100% Vs 99.43%, $p > 0.05$). So it would be reasonable to say that clinical examination appears to be superior when compared with MRI in diagnosing internal derangements of the knee especially in cases of concomitant injuries, however the role of MRI and its diagnostic value cannot be ruled out.[1,2,8,10–14] MRI has been proven to be more useful in our study when patient had concomitant injuries where some injuries might not be picked up even after thorough examination, and in doing so it gives additional information also helps in planning out and decreasing the time for arthroscopy.[9,10,15] One flaw in our study was the time interval between the MRI and finally arthroscopy examination (average of 2.05 months) because during this period patient might develop other injuries due to altered biomechanics and also due to repeated trauma, and it might have a role in determining the diagnostic value of this modality.

5. Limitations

The time interval between MRI and arthroscopy in our study was 1.9 months in case of group A patients and 2.17 months in case of group B patients. In the time between MRI and arthroscopy new lesions may develop because of the altered biomechanics of the knee joint and therefore reducing the sensitivity and specificity of imaging.

6. Conclusion

We conclude from our study that the strength of correlation between MRI and arthroscopic findings confirms the value of MRI in assessing internal knee structures. We also conclude that modern imaging techniques can be invaluable in diagnosis and pre operative planning but clinical examination outweighs the findings of MRI in case of medial menisci, lateral menisci, anterior cruciate and posterior cruciate ligaments. A normal MRI cannot be of sufficient evidence to deny arthroscopy where clinically knee injuries are suspected. In addition it may be wise to doubt magnetic resonance accuracy in case of combined injuries.

Conflicts of interest

All authors have none to declare.

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Original Article

Removal of a broken distal cannulated intramedullary femoral nail with solid reamer with closed methods and without using C-arm: A case report

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ARTICLE INFO

Article history:
Received 11 April 2014
Accepted 21 June 2014
Available online 18 December 2014

Keywords:
Broken nail
Distal nail
Cannulated nail
Implant removal

ABSTRACT

Intramedullary nailing of long bone fractures is an accepted technique with the advantages of not disturbing the fracture hematoma and the biomechanical superiority over plating.[1] However, problems with the nail are not infrequent, with broken nails and locking screws particularly posing a difficult problem for the orthopedic surgeon, especially when nail get broken due to cyclical stress of retrauma at site of distal screw placement as this the one of the weak part of intramedullary nail. Many techniques are described for extraction of the distal broken intramedullary nail that require special equipment like olive wires or laparoscopic grabbers.[1–3] There are many difficulties at times This equipment may not be always readily available which can make the process quite difficult. In remote parts of developing nation availability of C-arm is also an issue. We describe a simple reproducible method of extraction of the distal broken cannulated femoral nail fragment by antegrade approach without using C-arm and opening fracture site by using solid K-nail reamer. We have successfully used this technique to extract nail which is broken at D1 SCREW site, by using sequential K-nail reamer of size smaller than nail diameter in a young adult male patient.

1. Introduction

Intramedullary nailing of long bone fractures is an accepted technique with the advantages of not disturbing the fracture hematoma and the biomechanical superiority over plating.[1] However, problems with the nail are not infrequent, with broken nails and locking screws particularly posing a difficult problem for the orthopedic surgeon, especially when nail get broken due to cyclical stress of retrauma at site of distal screw placement as this the one of the weak part of intramedullary nail.

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http://dx.doi.org/10.1016/j.jajs.2014.06.007

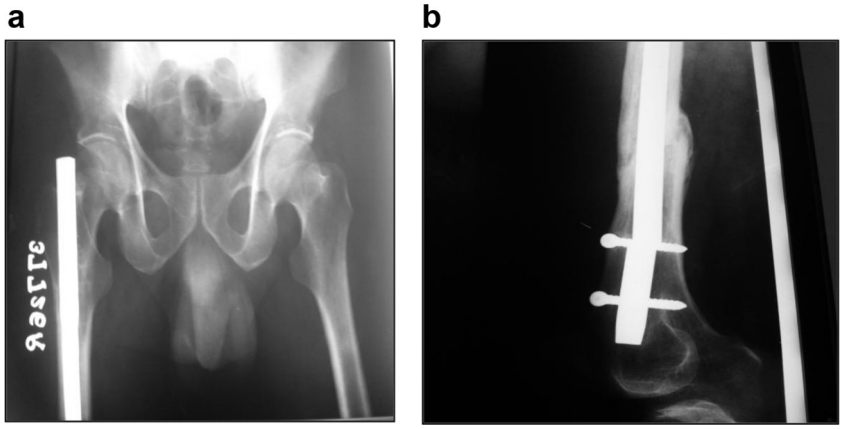

Fig. 1 – (a) and (b): X-ray of patient showing broken intramedullary cannulated nail broken at distal screw site.

Many techniques are described for extraction of the distal broken intramedullary nail that require special equipment like olive wires or laparoscopic grabbers.[1–3] There are many difficulties at times. This equipment may not be always readily available which can make the process quite difficult. In remote parts of developing nation availability of C-arm is also an issue.

We describe a simple reproducible method of extraction of the distal broken cannulated femoral nail fragment by antegrade approach without using C-arm and opening fracture site by using solid K-nail reamer. We have successfully used this technique to extract nail which is broken at D1 SCREW site, by using sequential K-nail reamer of size smaller than nail diameter in a young adult male patient.

2. Case report

2.1. *History*

A 35-year-old man underwent closed femoral nailing as a treatment of right femoral shaft fracture somewhere outside our hospital. Patient has history of second surgery 6 months later probably for dynamization of nail. 2 years later, he sustained another trauma due to fall along his strairs from first floor and start complaining pain at same thigh region.

2.2. *Radiograph*

A plain radiograph of involved thigh with AP/LATERAL views and X-ray pelvis with b/l hip region obtained showing no fresh fracture, intramedullary nail with united shaft fracture at distal 1/4th with broken nail at the level of D1 screw. Nail was not having P1 and P2 screws probably because of previous dynamization (Fig. 1(a) and (b)).

2.3. *Surgical technique*

Patient was taken in lateral position on standard operating table as C-arm was not functional at our institute. The proximal nail fragment was removed using a standard technique through the original entry point. It was found to be AO nail of size 10 mm × 36 mm. D1 and D2 screws were removed from incision on previous scar site.

Now in order to remove distal fragment of nail solid K-nail reamer were introduced with sequential graduation this allowed isthemic area to widen up and than solid reamer of size 10 was introduced which snuggly to fit in nail specially at distal tapering portion of nail and than nail fragment is removed by pulling and gradual twisting movement of reamer.

3. Result

At the end of surgery we were able to remove both portion of broken nail without opening fracture site and without use of C-arm Fig. 2(a) and (b).

Patient was followed up In routine opd for dressing and suture removal. At 2 months of follow up patient has no pain in thigh or knee with complete range of motion at both sites.

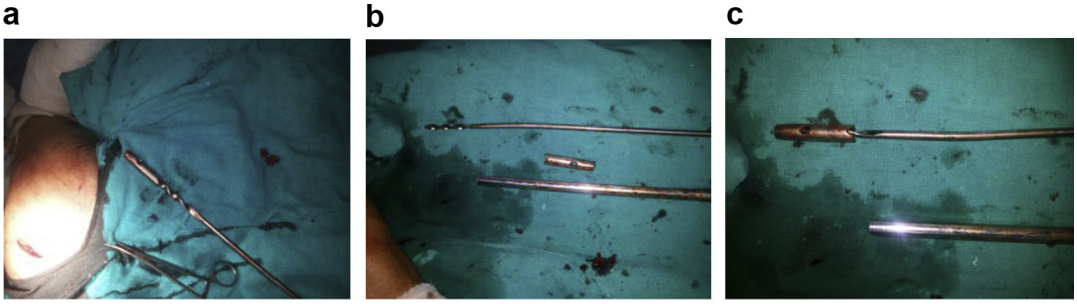

Fig. 2 – (a–c): Retrieved broken nail pieces with solid reamer.

4. Discussion

Broken femoral nail removal is not an uncommon procedure in orthopedic surgery for removing an intact nail various universal retractor are available, it is the broken nail which pose a surgical challenge especially when fracture site is united.

In general, the proximal portion of a broken nail is routinely removed without difficulty while challenge remains in the part of distal segment removal. For this instance, closed technique has been usually attempted as a primary procedure because of two reasons 1. Patient will have additional scar on his thigh which was not there from previous surgery. 2. Fracture is already united even after opening distal site we need to refracture that site in order to deliver distal fragment of nail.

For broken cannulated nails, the distal portion can be removed by antegrade and retrograde method each of them have their own advantages and shortcomings.

There are as many studies done in past to develop technique in order to deliver distal fragment[1–5] but in these techniques many instruments such as hook, femoral head cork screw, smaller nail, multiple guide wires, and guide wire with washer have been recommended to be used as an extractor.[1,6–11] in order to preserve the surrounding soft tissue.

Franklin et al[1] described their experience with the treatment of 60 broken femoral or tibial nails. In their series, 20 distal fragments were extracted without auxiliary surgical methods and 28 nail fragments were removed using long hooks. The hooks that were used have a profile that is similar to the profile of Ender pin extractors.

Brewster et al[2] and Hahn et al[12] also endorsed the removal of reamed nails with the use of long hooks. However, they mention that the hooks can slip several times at the tip of the nail, become stuck in the distal fragment, and bend (or even break) inside the nail.[13] These complications prolong the patient's surgery and exposure to the image intensifier, test the surgeon's patience, and increase the risk of postoperative complications.[14]

Giannoudis et al[15] described the extraction of fragments with special tools, such as long graspers and hooks. This technique involves the use of long trephines, hooks, and auxiliary pins. The technique is costly and labor-intensive, but it is a good alternative method, especially for fractures of rigid and unreamed tibial nail.

Levy et al[14] described yet a different surgical approach in which they impact a nail of smaller diameter than the original nail inside the distal fragment of a broken reamed femoral nail to facilitate local impaction and anterograde extraction.

Middleton et al[8] suggested filling the internal space of a cannulated nail with several guide wires to allow the anterograde extraction of the distal fragment.

Maini et al[16] proposed passing an olive guide wire through the distal fragment of cannulated femoral nail and then filling the nail with long Steinmann wires to facilitate its removal.

Marwan and Ibrahim[13] described a technique in which they pass a metallic wire through the middle of the fractured nail and through its distal hole. They then fasten this wire to the distal fragment through a small incision at the level of the distal hole.

Riansuwan et al[10] described a technique of retrograde impaction. Again in this technique knee arthrotomy is require which further pose complication like knee stiffness, infection, condylar fracture etc.

In our method of nail extraction we neither use any extra incision or pose patient to any risk of image intensifier by using simple traditional sequential K-nail reaming we were able to extract out distal cannulated broken segment of nail and have excellent outcome of patient on follow up.

Conflicts of interest

All authors have none to declare.

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Original Article

Polytetrafluoroethylene patches for massive rotator cuff tears: An update of current concepts

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ARTICLE INFO

Article history:
Received 10 June 2014
Accepted 15 July 2014
Available online 15 August 2014

Keywords:
PTFE
Massive rotator cuff tears
Arthroscopy
Rotator cuff surgery

ABSTRACT

Introduction: Rotator cuff tears are one of the most important causes of shoulder disability and are highly prevalent in most western populations. Massive rotator cuff tears present inherent challenges for the orthopaedic surgeon. Patch augmentation with polytetrafluoroethylene (PTFE) felt patches has become increasing popular over the last decade. The aim of this review is to summarize the available literature on PTFE patches in massive rotator cuff tears.

Method: A search of MEDLINE and EMBASE was performed. The authors further searched available literature using Google Scholar and the reference lists of selected articles. A total of eleven studies (four animal and seven clinical) were found.

Results and discussion: Animal and clinical studies have shown that PTFE patches are biomechanically and biologically sound, and have established optimal patch dimensions. Complications with the use of the patch have been minimal, although the outcome of biologic reaction at the patch-bone interface requires further work.

Conclusion: Longer-term clinical studies and randomized controlled clinical trials are needed. Further work is needed to better understand the biologics of the patch and its incorporation into the graft-host tissue interface.

1. Introduction

Rotator cuff tears are one of the most important cause of shoulder disability, accounting for 4500,000 specialist visits and over 250,000 surgical procedures performed in the USA every year.[1] Despite recent surgical advancements in their management, recurrence/re-tear rates range from 40 to over 90%.[2,3] Failure is often due to suture pull out at the suture-tendon interface,[4] with age as a negative factor.

The definition of massive rotator cuff tears remains controversial. Although most surgeons currently define a tear as massive when there is detachment of at least two complete tendons, some continue to use the older Cofield definition of a tear greater than 5 cm in size.[5,6] In contrast to small or large rotator cuff tears where techniques for surgical management

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http://dx.doi.org/10.1016/j.jajs.2014.07.003

have yielded satisfactory results, there is no consensus on the best way to manage massive tears with a wide variety of treatment options at the disposal of the orthopaedic surgeon.[5,6]

The optimal goal of any rotator cuff repair is restoration of original biology and biomechanics. In chronic massive rotator cuff tears, the low elasticity of the tendon due to its replacement by biomechanically inferior scar tissue leads to reduced tissue mobility and impairs our ability to directly suture-tendon to bone. If left untreated, massive rotator cuff tears will lead to persistent defects, weakness, and poor outcomes, and can cause uncoupling of forces across the glenohumeral joint, with resulting unstable shoulder kinematics and ultimately, osteoarthritis.[5,7]

Tendon reconstruction, a method popular in the past for large and massive tears, involves relatively large-scale surgeries and is an unrealistic option due to the high prevalence rates of rotator cuff tears in the community. To this effect, a synthetic material may be inserted between tendon and bone for repair. Studies have shown that augmentation of rotator cuff repair with a scaffold can reduce pain and lead to higher satisfaction and function compared to non-augmented repairs.[8–10]

The rationale for using a scaffold device for rotator cuff repair may include mechanical augmentation by "off-loading" the repair at time zero and for some period of post-operative healing, or biologic augmentation by improving the rate or quality of healing, or both.[11] It is hypothesized that to achieve any biomechanical benefit, scaffold devices should have robust mechanical and suture-retention properties and be applied in a surgically appropriate manner.[12] Synthetic devices may have little impact on the biology of repair healing; however their ability to maintain mechanical properties over time may function to mechanically stabilize the repair construct until host tissue healing can occur.[11]

Cardiothoracic, vascular and general surgeons have been using non-absorbable synthetic materials for many years for the reconstruction of large vessels, the heart and abdominal wall. These materials have had low infection rates, few adhesions, and good mechanical strength and suture-retention. There is no consensus or clear guidelines as to what is the safest or most efficacious augmentation. Polytetrafluoroethylene (PTFE), a synthetic fluoropolymer of tetrafluoroethylene, offers one such possibility.

PTFE is a high-molecular-weight, hydrophobic, inert, thermoplastic compound of fluorocarbon. PTFE, an accidental discovery, was famously used in the Manhattan project for tubing of uranium, and was later popularized as a coating for kitchen appliances under the brand Teflon (DuPont, USA). PTFE has a Young's modulus of 0.5 GPa, a yield strength of 23 MPa, a melting point of 600 K, and a coefficient of friction of 0.05–0.10. Gore-Tex (a popularized brand name) is PTFE with incorporated micropore technology.

PTFE is a non-degradable polymer. It works, like other synthetic materials, on the premise that supporting a cuff repair mechanically, and permanently, similar to a hernia repair, would enable biologic healing. PTFE patches are characterized by their strong tensile strength, good tissue compatibility and excellent handling properties.[13] PTFE patches have been studied in both animal models and human patients for rotator cuff tear repairs. Both biomechanical and histocompatibility (tissue affinity and tissue integrity) properties of these patches have been studied.

Some concerns with the use of such non-degradable materials includes persistent infections often requiring revision operation to remove the implant, and loss of integrity in the long-term leading to degradation, inflammation and revision surgery.[13] There is a lack of long-term studies into patch augmentation modalities. A sound understanding of surgical technique is necessary.

2. Surgical technique

Although various methods of patch augmentation are used worldwide, there is little published literature on patch augmentation techniques in rotator cuff surgery, perhaps due to the novel nature of the technique. In his paper, Labbe (2006) describes one such method. The patient is placed in a lateral position and the cuff tear is addressed using standard techniques, with a lateral viewing portal. Two mattress sutures are placed in the anterior and posterior portions of the cuff and then two double-stranded suture anchors are placed into the lateral aspect of the greater tuberosity. The patch is sized using a ruled probe or similar device placed into the subacromial space. The patch is appropriately prepared, scope inserted into posterior portal and a large cannula into the lateral portal. All sutures are brought out through the cannula and the corresponding ends of each suture are held by clamps. Sutures are passed through the graft into their respective anatomical positions, using a mattress method. The graft is then grasped using a small locking grasper on its medial edge and passed through the cannula into the subacromial space. A smaller (5 mm) cannula is then passed through one of the anchor incisions into the subacromial space and the medial two sutures are retrieved through the small cannula and tied. This is then repeated for the lateral two sutures. Post-operative rehabilitation is essential.[14] We suggest the use of pre-operative MRI to help with patch sizing. There is a need to incorporate patch augmentation methods into basic shoulder courses and workshops to facilitate uptake of this novel technique.

3. Method

A search of MEDLINE (1946 – present) (search terms: "massive rotator cuff tear" AND "polytetrafluoroethylene"; "massive rotator cuff tear" AND "GORE-TEX" OR "PTFE") and EMBASE (1988 – present) (search terms: "massive rotator cuff tear" AND "polytetrafluoroethylene"; "massive rotator cuff tear" AND "GORE-TEX" OR "PTFE") was performed. The authors further searched available literature using Google Scholar (search terms: "massive rotator cuff tear/s" AND "polytetrafluoroethylene/PTFE/GORE-TEX") and the reference lists of selected articles were reviewed for additional relevant articles. Studies were included in this review if they assessed PTFE use for the treatment of massive rotator cuff tears in vivo or in vitro. A total of eleven studies (four animal and seven clinical) were found.

4. Results and discussion

4.1. Animal studies

Kimura et al (2003) reconstructed infraspinatus tendon defects of 31 beagle dog shoulders using PTFE felt grafts. Healing of tendon was achieved in 30 of the cases, with one case of infection.[15] The tensile strength of the tendons increased five fold from 60.84 N immediately after surgery to 306.51 N at 12 weeks post-operatively. The stiffness of specimens at PTFE felt-bone interface increased 14 fold from 9.61 kN/m immediately after surgery to 135.09 kN/m at 12 weeks.[15] Histological analysis of tendons showed ingrowth of fibrous tissue between the PTFE fibres, suggesting that PTFE becomes incorporated into host tissue. However, foreign body reactions were found at the margin of PTFE-bone interface between 12 and 24 weeks.[15] These results are similar to a previous study of PTFE grafts in 60 rat shoulders.[16] These studies suggest that PTFE augmentation increases tensile strength and stiffness post-operatively and becomes incorporated into host tissue.

The method for securing the patch in the host has also been studied in animals. In a biomechanical study of 2 mm PTFE patch in 12 ovine shoulder with artificially created massive rotator cuff tears, Shepherd et al (2011), found that inverted mattress tension band repairs provide significantly higher footprint contact pressures than vertical mattress suture method.[17] Tension band repairs also had significantly higher pull out strength (220 N) compared with mattress repairs (188 N).[17] Further, Ronquillo et al (2013) compared multiple mattress suture technique to weave suture technique for 44 ovine massive infraspinatus tendon tears. The found that the multiple mattress suture technique had significantly higher failure loads (327 N) compared with weave technique (265 N), however, no difference in repair stiffness, peak energy to failure, and total energy to failure were found.[18] The exact technique for patch augmentation is still evolving, and further work is needed in this field to better address the question of optimal technique.

4.2. Clinical studies

In the earliest clinical study, Ozaki et al (1986) studied 25 patients with massive rotator cuff tears repaired using PTFE patch and found 90% to achieve satisfactory functional results with an optimal patch thickness of 3–5 mm.[16] Patch dimensions were further studied by Hirooka et al (2002) who divided their cohort of 28 patients with massive rotator cuff tears (average follow up period of 44 months post-operatively) into two groups: small patch size (less than 2 cm anteroposterior dimension; 12 shoulders) and large patch size (greater than 2 cm anteroposterior dimension; 16 shoulders). They found a significant improvement in average Japanese Orthopaedic Association (JOA) scores from 57.7 pre-operatively to 88.7 post-operatively for all patients, with no significant difference between the small and large patch size groups.[19] However, the small patch group had a significantly higher abduction strength (6.2 kg at 90° abduction) versus the large patch group (1.5 kg). Thus, smaller (less than 2 cm anteroposterior dimension) patches with thickness 3–5 mm may offer the best clinical outcomes.

In a clinical study of 30 patients with irreparable massive rotator cuff tears over a 5 year period (mean follow up of 38 months post-operatively), Kimura et al (2000) found significant improvement in pain scores (9.5 pre-operatively and 23.2 post-operatively), and mean total shoulder score (JOA score; 57 pre-operatively and 82 post-operatively).[20] There were no new osteoarthritic changes of the shoulder joint. Only one patient had a subacromial bursal infection at 6 months post-operatively. However, enlargement of the bone gutter of the greater tuberosity was seen in 30% of cases post-operatively, and the authors attribute this to biological reaction against PTFE.[20] However there was no correlation between this bone absorption and clinical outcomes. These medium term clinical results were similar to those reported earlier.[21] The bone resorption phenomenon needs to be studied in the long-term as the medium term return of tendon mechanics may be offset by repair loosening in the long-term.

Kanbe et al (2012) undertook arthroscopic repair of a massive rotator cuff tear using PTFE patch, and a second look arthroscopic surgery one year later to evaluate patch-bone and patch-tendon interface. They found a tight connection between PTFE patch and bone, and smooth attachment to cuff tissue without proliferation of inflammatory cells in the synovium.[22] Further they found improvement of American Shoulder and Elbow Surgeon scores of 24 pre-operatively to 75 post-operatively.[22] These clinical outcomes were similar to a 10 year follow up study of 5 patients with massive rotator cuff tears repaired using PTFE patch,[23] however the small sample sizes in both studies makes any conclusion difficult. Longer-term and larger clinical studies are needed.

In a Japanese study, Toshiro et al (2001) compared lattisimus dorsi transfer (14 shoulders) with PTFE felt patch (20 shoulders) for massive rotator cuff tears for mean follow up of 43.7 and 32.6 months, respectively. They found that both techniques significantly improved JOA and UCLA shoulder scores, but that average post-operative pain was lower and average post-operative strength higher in the muscle transfer group.[24] There was no significant difference in function between the two groups. PTFE combined with better pain control may allow for comparable outcomes to muscle transfer. Further work is needed to compare PTFE augmentation with other repair or augmentation techniques.

5. Conclusion

Overall, animal model studies have showed good biomechanical and biological characteristics for PTFE patches in rotator cuff surgery. However, a significant finding was the high incidence of foreign body reactions which may, in the long-term, lead to material failure. Further, tension band repair was shown to be biomechanically superior method to vertical mattress repair, and weave suture technique was biomechanically similar to multiple mattress technique. Clinical studies have confirmed the biomechanically sound principles of PTFE patches but have not allayed the fears of foreign body reactions found in animal studies, although mid-term results show low infection rates and no clinical correlations with bone

resorption phenomenon. Optimal patch dimensions have also been described. However, most clinical studies have follow up periods of less than 4 years and it is essential to assess longer-term follow ups. Additionally, clinical outcomes of patch repairs need to be compared with other commonly used techniques such as tendon grafting and other augmentation methods through randomized controlled trials.

Conflicts of interest

All authors have none to declare.

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Original Article

Implant survivorship and clinical outcomes of the Bigliani-Flatow shoulder prosthesis at a mean of five years: A post-marketing surveillance study from three centres☆

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ARTICLE INFO

Article history:
Received 9 November 2014
Accepted 26 November 2014
Available online 21 January 2015

Keywords:
Bigliani-Flatow
Shoulder hemiarthroplasty
Total shoulder arthroplasty

ABSTRACT

Background: This is the first study to report survivorship and clinical outcomes of a third generation shoulder prosthesis [Bigliani-Flatow (BF)], comparing BF total shoulder arthroplasty (TSA) versus hemiarthroplasty (HA); and cemented versus uncemented implantation.

Methods: Prospectively collected data including Constant-Murley (CM) and Oxford Shoulder Scores (OSS) were analysed for clinical outcome and survivorship of 164 arthroplasties (164 patients) performed in three established shoulder arthroplasty centres. The mean follow-up was 65 months (range 46–111; SD 13.3).

Results: One hundred and five of 164 patients followed up at a mean of 5 years demonstrated implant survivorship of 96.6% (95% CI: 93.4%–99.9%). There was no significant difference between cemented and uncemented stems in implant survivorship [97.9% (CI: 93.9%–100%) v/s 95% (CI: 91.3%–100%)], or in final CM and OSS. Intra-operative blood loss was significantly less in uncemented stems ($p = 0.016$), and also in HA compared to TSA ($p = 0.004$). There were no significant differences between TSA and HA in functional outcomes and implant survivorship.

Discussion: The first outcome study of the BF prosthesis shows satisfactory survivorship and comparable functional outcomes at five years. Loss to follow up of surviving patients despite active, structured post-marketing surveillance underscores the need for mandatory joint registries.

☆ Presented as a free paper at the 13th 37 EFORT Congress at Berlin, May 2012 and 38 The British Elbow and Shoulder Society, Newcastle upon Tyne, UK, June 2011.

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http://dx.doi.org/10.1016/j.jajs.2014.11.001

1. Introduction

The first shoulder arthroplasty was performed on a patient with glenohumeral joint destruction due to tuberculosis. However, almost 60 years passed before an implant with reproducible long-term function and pain relief was developed for widespread use.[1] Charles Neer devised an unconstrained shoulder implant for the treatment of proximal humeral fractures in 1951, starting a new era of shoulder arthroplasty.[2] Encouraged by the advances in hip arthroplasty, Neer redesigned his humeral component and added a polyethylene glenoid component.[3] A multitude of shoulder implants have been introduced since, and analysis of failure modes has led to further improvements in implant technology.[3–5] Understanding of potential factors that influence survivorship, long-term function and associated complications has led to changes in patient selection, implant geometry and cementing technique.[2,6,7] Monitoring of newly introduced implants is essential to aid this process and ensure safe clinical use.

The Bigliani-Flatow (BF) shoulder implant was introduced in 1999; it may be inserted as a hemiarthroplasty (HA) or as a total shoulder arthroplasty (TSA), with stem implantation being either cemented or uncemented. Results of the BF arthroplasty have not been previously published in literature. Our aim was to analyse the medium-term survivorship of the BF shoulder prosthesis from prospective post-marketing surveillance data. We also compared clinical outcomes of cemented versus uncemented humeral stems in a consecutive series of TSA and HA performed at three established shoulder arthroplasty centres.

2. Materials and methods

Between January 2001 and December 2005, 164 patients (164 shoulders) underwent shoulder arthroplasty with the Bigliani-Flatow prosthesis (Bigliani/Flatow Total Shoulder Solution; Zimmer, Warsaw, IN, USA) at three different centres in Europe (Fig. 1). Research regulatory approvals were obtained at all three centres for prospective data collection for this structured post-marketing surveillance study. Individual surgical preferences dictated the use of HA or TSA and the choice of cemented or uncemented stem. All included patients provided written informed consent for participation in the study. Data collected included patient demographics, body mass index (BMI), indications for surgery, type of operation (TSA or HA), method of fixation of humeral stem (cemented or uncemented), duration of surgery and intra-operative blood loss.

Two validated functional scores were selected for pre- and post-operative functional assessment.[8] Patients were asked to fill in the 12-item Oxford Shoulder Score (pre-revision) questionnaire when listed for surgery. Physiotherapists recorded the Constant-Murley score pre-operatively and at follow up, independent of the treating surgeons.[9,10] The range of motion was entered as a mean of two values recorded by two physiotherapists. Strength measurement was standardised using a calibrated load cell myometer. All post-operative Oxford Shoulder Scores were recorded when patients attended physiotherapy clinics.

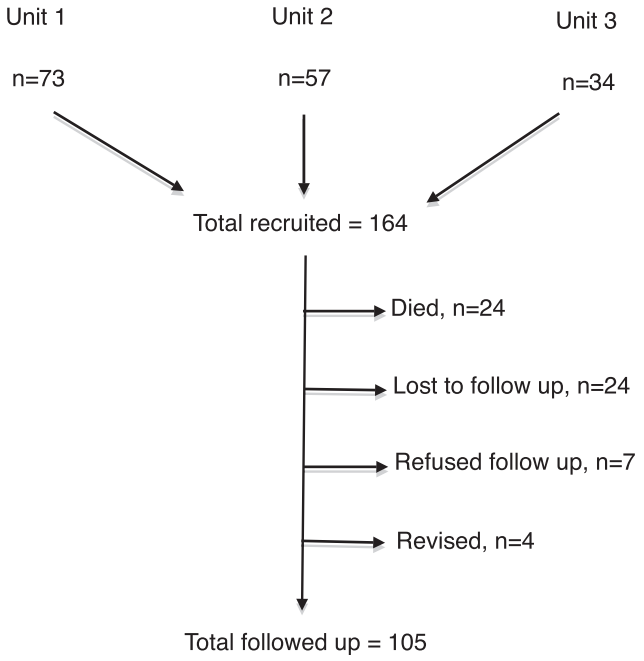

Fig. 1 – Recruitment and loss to follow up.

Differences between treatment groups (cemented versus uncemented; TSA versus HA) were assessed using the Mann–Whitney U-test for continuous variables. Nominal data were compared using either the Pearson's Chi square test (for variables with three or more expressions) or the Chi square test (for variables with two expressions). All tests were performed two-sided. Cumulative survival estimates of the BF prosthesis were assessed using the Kaplan–Meier method with 95% confidence intervals; the endpoint was defined as a revision or removal of any component. Differences of survival distribution between groups were assessed using the log rank test (Mantel–Cox). Results were stratified for cemented/uncemented and TSA/HA. Statistical analysis was performed with SPSS (version 19, SPSS Inc, Chicago, IL).

3. Results

The original cohort consisted of 51 men and 113 women, with mean age at the time of surgery being 67.3 years (range 28–92). Table 1 compares cemented and uncemented procedures, and TSA and HA in terms of distribution of gender, age, BMI and indications for surgery. The indications for surgery included osteoarthritis (OA; 45.1%), rheumatoid arthritis (RA; 21.9%), post-traumatic arthritis (12.2%), acute fracture (10.4%), avascular necrosis (6.1%) and psoriatic arthritis (1.8%). Sixty (36.6%) prostheses were implanted with cement. Thirty-one (18.9%) patients received a total shoulder arthroplasty. There were no significant differences between the three units in the primary indications for surgery, gender distribution, and in the proportions of cemented/uncemented and TSA/HA. Patients receiving cemented stems tended to be older overall ($p = 0.042$), but there were no significant differences in gender distribution or mean BMI between the treatment groups.

Table 1 – Overview of patient and implant selection.

Parameter		Type of *stem fixation* (n = 164)		Difference	Type of *implant* (n = 164)		Difference
		Cemented (60)	Uncemented (104)	p = 0.465	TSA (31)	HA (133)	p = 0.058
Gender	Female:Male	46:14	67:37	p = 0.117	18:13	95:38	p = 0.273
Age (years)	Mean (Range)	69.8 (42–88)	65.9 (28–92)	p = 0.042	69.3 (28–92)	66.8 (31–88)	p = 0.164
BMI (kg/m^2)	Mean	27.8	29.5	p = 0.099	28.9	28.7	p = 0.799
Indications	Osteoarthritis	18	56	p = 0.005	20	54	p = 0.027
	Rheumatoid arthritis	17	19	p = 0.441	4	32	p = 0.267
	Post-traumatic arthritis	9	11	p = 0.558	4	16	p = 0.894
	Psoriatic arthritis	1	1	p = 0.692	0	2	p = 0.492
	Acute fracture	14	3	p = 0.0001	2	15	p = 0.641
	Avascular necrosis	0	10	p = 0.032	1	9	p = 0.745
	Others	1	1	p = 0.692	0	2	p = 0.492
	Unknown	0	3	p = 0.469	0	3	p = 0.921
Implants revised (rate)		1 (1.6%)	3 (2.9%)	p = 0.626	0 (0%)	4 (3%)	p = 0.741

Although there was no significant difference in duration of surgery between cemented and uncemented procedures (1.63 vs. 1.50 h, p = 0.397), TSAs tended to take more time than HA (1.49 vs. 1.84 h, p = 0.002). There was significantly less blood loss in uncemented compared to cemented stems (311 vs. 242 ml, p = 0.016), and significantly less blood loss in HA compared to TSA (257 vs. 320 ml, p = 0.004).

Fifty-nine patients were lost to follow up (Fig. 1), due to death, geographical restraints or lack of response from the patient. The mean follow up time for the remaining 105 patients was 65 months (range 46–111; SD 13.3). Comparison of abduction, flexion, internal rotation and hand positioning on top and behind the head showed no significant difference between groups at pre- and post-operative assessment (Table 2). There were no significant differences between HA and TSA patients with regards to Constant-Murley and Oxford Shoulder Scores. There were also no significant differences in functional scores between patients with cemented and uncemented stems (Table 2).

Four hemiarthroplasties were revised (2 osteoarthritis, 2 fractures) for complications. These included the shoulders of: two males who had uncemented revisions for stiffness; one female with uncemented revision for aseptic stem loosening and painful glenoid erosion; and one female who had a cemented revision for infection. Overall implant survivorship of patients followed up at a mean of 60 months was 96.6% (95% CI: 93.4%–99.9%) (Fig. 2). Implant survivorship was 97.9% (95% CI: 93.9%–100%) for cemented stems and 95.9% (95% CI: 91.3%–100%) for uncemented stems (Fig. 3). Survivorship of TSA was 100% while that of HA was 95.7% (95% CI: 92.0%–99.9%) (Fig. 4). The differences in distribution of the survival functions were not significant between cemented and uncemented humeral stems (p = 0.652), or between HAs and TSAs (p = 0.359). The proportion of patients with ability to perform sporting activities for cemented versus uncemented stems and TSA versus HA are shown in Figs. 5 and 6.

4. Discussion

Survivorship and clinical outcome following shoulder arthroplasty are fundamental concerns for both patients and clinicians. Over 70 different shoulder implants have been in use since Neer's report of his initial series of shoulder arthroplasties.[3,11] The importance of monitoring performance of newly introduced implants cannot be overstated. Post-marketing surveillance studies for such new implants play an important role in monitoring performance where National Joint Registries do not exist. This is to our knowledge the first post-marketing surveillance study of the Bigliani-Flatow shoulder prosthesis (BF). This study shows medium-term outcomes of the BF prosthesis to be comparable to other shoulder implants on the market. Overall survivorship of implants in our patients at 5 years compares favourably with the literature[7] as do the results with regards to pain relief compared to studies of hemiarthroplasty (HA)[12–14] and in total shoulder arthroplasty (TSA).[15,16] Function as assessed by Constant-Murley score and Oxford Shoulder Score showed a close correlation between preoperative and post-operative range of movement (ROM) with no significant differences between the groups (Table 2).

Traditionally primary diagnosis has been thought to influence results of shoulder arthroplasty surgery with OA outperforming patient's conditions such as post-traumatic arthritis.[17–19] Here the failure of the BF was not higher in patients with either RA or post-traumatic arthritis, though results might be different at a later follow up date. Increasingly there appears a trend amongst orthopaedic surgeons to use uncemented humeral stems in arthroplasty, despite cemented stems being considered the gold standard.[20] In this study there were almost twice as many uncemented as cemented stems inserted, the choice of stem being the individual surgeon's preference. There was no survival or functional outcome differences between cemented and uncemented stems, although interestingly uncemented stems resulted in less blood loss at the time of surgery. It is worth noting that mechanical failure of humeral stems is rare[21] and frequently humeral stem removal is to aid access to the glenoid.[22] This makes differences between cemented and uncemented stems difficult to demonstrate. Sanchez-Sotelo et al have shown cemented stems to give superior radiographic results to uncemented stems.[20] Though the measured outcomes between stems were similar in this study, radiographic analysis may have revealed differences.

It is not clear whether TSA or HA is the best choice for joint replacement in the diseased shoulder. Potential advantages of

Table 2 – Pre- and post-operative shoulder function and scoring.

Parameters analysed (means)	*Cemented stem*		*Uncemented stem*		p-value follow-up	TSA		HA		p-value follow up
	Preop[d]	Final 5 yr	Preop[d]	Final 5 yr		Preop[d]	Final 5 yr	Preop[d]	Final 5 yr	
Abduction [°][a,f]	37.29	65.83	49.03	75.87	0.472	48.33	81.32	44.29	70.47	0.568
Flexion [°][a,f]	42.43	77.50	65.00	87.17	0.415	61.67	93.95	56.51	81.63	0.430
Internal rotation (points)[b,f]	1.54	3.72	2.26	3.30	0.587	1.78	4.32	2.07	3.26	0.052
Full elevation from top of head[c]	0	22	1	32	0.366	0	32	1	28	0.782
Hand on top of head with elbow back[c]	0	19	9	39	0.049	0	42	7	30	0.417
Hand on top of head with elbow forward[c,f]	9	42	25	42	1.000	22	47	19	41	0.616
Hand behind head with elbow back[c]	6	33	13	44	0.402	0	63	13	35	0.037
Hand behind head with elbow forward[c]	26	64	45	54	0.407	44	58	37	57	1.000
Unaffected sleep[c]	26	36	30	48	0.303	28	47	29	43	0.801
Full recreation or sport activities[c]	9	31	17	35	0.828	28	47	12	30	0.182
Full work activities[c]	17	50	16	49	1.000	39	68	12	45	0.081
No activities[c]	46	11	38	13	1.000	44	11	40	13	1.000
Constant and Murley Score & subcategory scores: means (N)										
Pain	1.09	11.17	1.69	9.83	0.229	1.39	11.67	1.51	9.93	0.134
ADL[f]	5.50	11.60	7.82	12.14	0.667	7.67	12.71	6.95	11.77	0.479
ROM[f]	6.19	18.07	9.82	19.12	0.741	8.44	21.06	8.71	18.20	0.403
Shoulder power	0.39	3.40	2.20	5.54	0.094	0.975	4.09	1.73	5.12	0.792
Total Constant & Murley[e,f]	13.05 (N = 32)	42.53 (N = 30)	20.73 (N = 68)	45.07 (N = 57)	0.827	18.15	47.94	18.30	43.29	0.392
Oxford Shoulder Score	13.67	32.09	17.44	32.37	0.826	14.87	36.53	16.68	31.30	0.053

[a] Means of categories (e.g. category 0–30° = 15°).
[b] Mean of category points for Constant & Murley Score: Back of hand to lateral thigh or unable to move shoulder (0), Back of hand to buttock (2), Back of hand to lumbosacral junction (4), Back of hand to waist (6), Back of hand to T12 vertebra (8), Back of hand to interscapular region (10).
[c] Proportion of patients with ability to perform action (e.g. 21.2 = 21.2%).
[d] Only preoperative patients with 5 year follow-up performed.
[e] Patients with missing Shoulder Power were included and Shoulder Power Score was considered as zero.
[f] Preoperative difference between groups is statistically significant ($p < 0.05$).

HA include a simpler, quicker procedure, avoidance of risks associated with glenoid loosening, reduced blood loss, and its feasibility in the setting of inadequate glenoid bone stock.[15,17] The disadvantages of HA are suboptimal pain relief in OA and potential need for revision due to painful glenoid erosion.[22,23] Alternatively the TSA may lead to better pain relief,[24,25] better ROM and better function in patients with primary OA.[15]

In our study there was no significant difference in shoulder scores, pain relief or ROM between HA and TSA. There was a trend in our study suggesting HA was more likely to be revised in the first five years, but the numbers were small, making it difficult to draw clear conclusions. Lo et al found no difference between HA and TSA in a prospective, randomized study.[16] In contrast, a meta-analysis of TSA versus hemiarthroplasty reported by Radney et al found significantly better pain relief, forward elevation, gain in external rotation and patient satisfaction with total shoulder replacement.[23] When only objective post-operative shoulder measurements were used however, several studies revealed TSA showed no superiority when compared to HA.[25,26] Whilst we had more HAs revised than TSAs, this was not statistically significant. The decision between using TSA and HA remains a matter of debate, although like Edwards et al (2003), in our study HA operations were quicker and resulted in less blood loss.[15]

Glenoid loosening is a reported problem of TSA.[17,27] In our study, no TSA glenoid components required revision. In agreement with other authors we feel this may reflect improvements in glenoid design, improved cementing technique[28,29] and avoiding uncemented glenoids which may lead to early loosening.[28,30–36] Cil et al have shown better survivorship in HA compared to TSA to be negated if all polyethylene glenoids were cemented at surgery.[22] Some studies have focused on post-operative radiographic evidence of potential loosening around the implant, particularly radiolucent lines around the glenoid on follow up radiographs.[7,30,37] The significance of this is not entirely clear though it may be a sign of loosening.[37] We did not analyse post-operative radiographs systematically across the three units. We did not comment on radiolucent lines around the glenoid or humeral stem in this study partly because of difficulties with reproducibility and the potential for inter-observer error with interpretation of radiographs across three units in three different countries. We feel that any significant glenoid loosening, which would have been indicated by radiolucent lines, would have been reflected

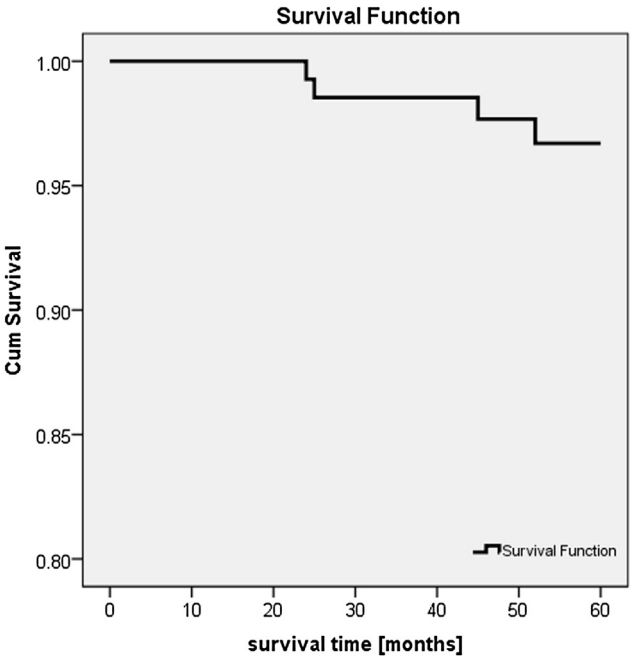

Fig. 2 – Overall survival function.

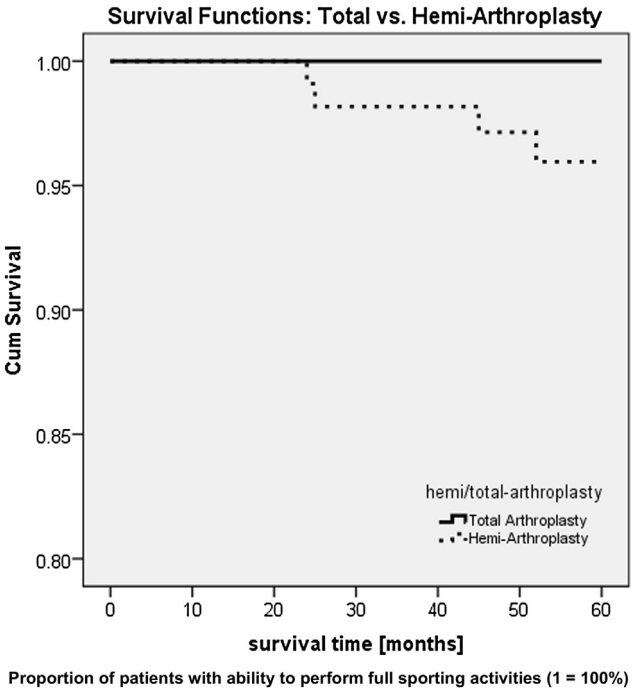

Fig. 4 – Survival function total arthroplasty versus hemiarthroplasty.

in the post-operative shoulder scores and patients presenting for revision. Kasten et al reported excellent results with cemented glenoids and a survivorship of 98% despite radiographic signs of loosening of 9% at 5 years but without the need for revision.[7] Clearly a longer follow up study will help determine the incidence of late glenoid loosening with the BF prosthesis requiring revision.

A recognised factor leading to revision of HA is the onset of painful erosion of the glenoid,[17,27] with or without associated rotator cuff tear. In keeping with these findings, our study shows stiffness, pain and rotator cuff rupture to be the indication for revision in two of four HA and destruction of the glenoid with loosening of the uncemented stem in one HA. As revision rate was the end point of this study and a thorough cross unit radiographic analysis was not performed, we

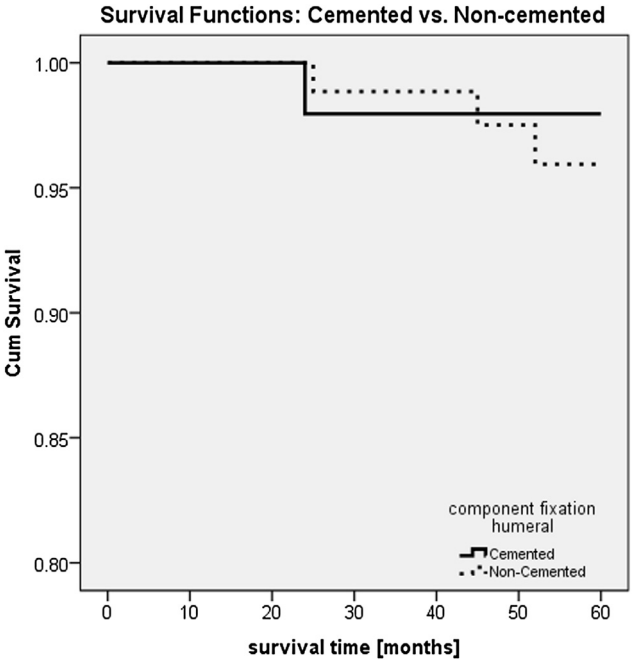

Fig. 3 – Survival function cemented versus non-cemented humeral stem.

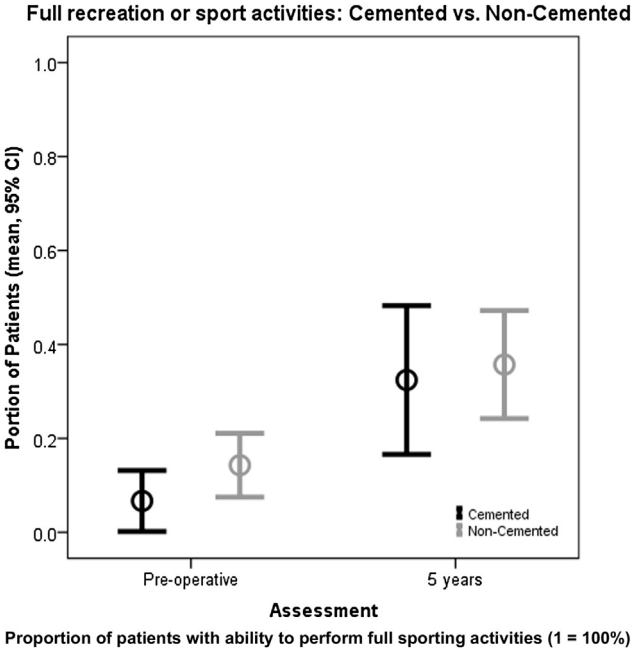

Fig. 5 – Full recreation or sport activities: cemented versus non-cemented.

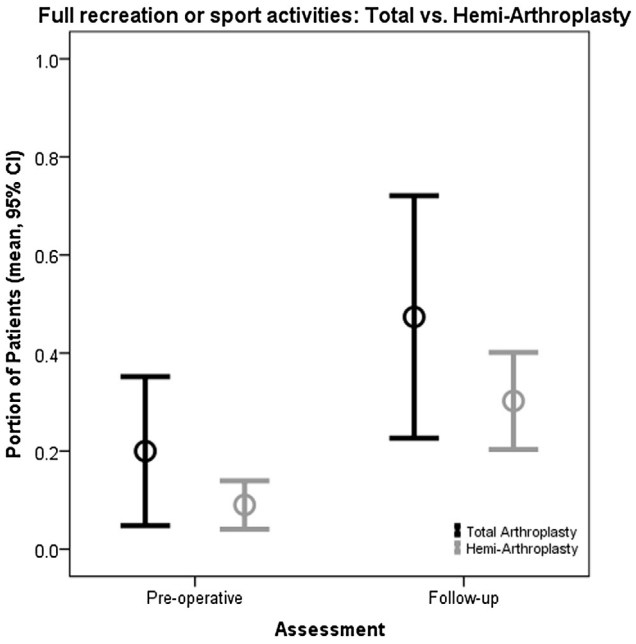

Fig. 6 – Full recreation or sport activities: total arthroplasty versus hemiarthroplasty.

cannot comment on radiographic evidence of glenoid erosion following HA. Further long-term follow up will help demonstrate if HAs require revision due to glenoid erosion and/or rotator cuff tear.

The strength of this study lies in it being the first report of outcomes following use of the BF shoulder implant. Even declaring patients who were lost to follow up as "failures", it shows a relatively low revision rate at five years for this implant. Our study is also enhanced by being a multi-national, prospective design, involving three European centres, with different indications for joint replacement. The three units in this trial are tertiary referral centres and the surgery was performed by senior specialist shoulder surgeons with over fifteen years' experience.

We acknowledge the study's potential weaknesses, e.g. the number of patients lost to follow-up. It is worth noting that of the 59 patients lost to follow up, 24 (40%) had died and hence some data loss was inevitable. We calculated the worst-case scenario at 60 months, considering all patients lost to follow-up as failure. In this case, the overall implant survivorship would be 81.7% (95% CI: 75.6%–87.8%) and therefore far lower than reported in other studies.[7,22] Other reported studies have also had similar issues with loss to follow up. Cil et al monitoring 1584 shoulder arthroplasties until failure or until death reviewed only 601 with less than 5 year follow-up, 322 with 5–10 years, 220 at 15–20 years and only 35 at more than 20 years follow-up.[22] Thus follow up attrition is to be expected given the average age of the study population and associated comorbidities. We acknowledge that unless implants can be tracked to the point of failure, loss to follow up of surviving patients may potentially weaken survivorship analyses. This is a strong argument for the use of mandatory National Joint Registries to reliably track implant performance.

5. Conclusions

Our results show good overall survivorship at 5 years for the Bigliani-Flatow shoulder replacement prosthesis. There was no difference in survivorship between TSA and HA. We also found comparable survivorship and clinical outcomes for cemented and uncemented humeral stems at 5 years. Blood loss was less in the uncemented group. The level of loss to follow up in our study in spite of well-structured post-marketing surveillance highlights the importance of mandatory Joint Registries in monitoring implant performance.

Funding sources

This study was a post marketing surveillance kindly supported by Zimmer Clinical Affairs. The authors confirm no additional funding was received from any source in the design of this study, data collection and analysis, or in the preparation of the manuscript.

Conflicts of interest

All authors have none to declare.

Acknowledgements

The authors would like to express their gratitude to Dr Katy Elizabeth Baldwin for her invaluable help in editing this manuscript and the staff at the Rodney Cove-Smith Library, The James Cook University Hospital.

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Review Article

Constrained condylar knee systems: A review of five commonly used brands

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ARTICLE INFO

Article history:
Received 17 July 2014
Accepted 5 December 2014
Available online 10 January 2015

Keywords:
Revision
Arthroplasty
Replacement
Prosthesis
Constrained condylar

ABSTRACT

Purpose: Constrained condylar knee (CCK) implants are commonly used in a revision setting. They are designed to fix the prosthesis to the host bone at epiphysis and diaphysis to provide good construct stability and provide flexibility to balance the knee in the coronal and sagittal planes. There are many knee revision systems available which makes it difficult for knee surgeons to choose the ideal implant that is suitable to an individual patient's needs. The study of failed knee revision systems and recent developments in technology and biomaterials has considerably improved our understanding of implant design. Although the CCK systems follow similar principles in design, they are crucially very different and based on contrasting philosophies. Some of these systems are very versatile and user friendly while others are very complex making the procedure and the task of the orthopaedic surgeon difficult.

Scope: In this review article we consider five of the most commonly used CCK revision systems and provide a detailed discussion of the design features of each system, their potential advantages and limitations and their reported outcomes in the relevant literature.

Conclusions: There are many differences between the five CCK systems. There are limited outcome data to support the use of any particular CCK system. The newer systems may offer versatility but surgeon's skills and experience may still be the determining factor in the success of revision surgery.

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http://dx.doi.org/10.1016/j.jajs.2014.12.001

1. Introduction

Total knee arthroplasty (TKA) is a common procedure providing pain relief, improved function and quality of life, with excellent results.[1–3] Despite excellent long term implant survivorship,[4,5] TKA revision will be necessary.[2]

A total of 77,545 and 81,979 knee replacement procedures were entered into the NJR for England and Wales during 2009 and 2010 respectively, of which, 4565 and 5109 were revision procedures.[6,7] It is predicted that there will be a 601% increase in revision knee cases from 2005 to 2030.[8] The expectation is that the number of revision TKA performed in the US will grow from 38,000 in 2005 to 270,000 by the year 2030.[8] Revision knee arthroplasty is a technically challenging and economically demanding procedure,[9,10] the success of which depends on identifying the cause of failure, thorough preoperative planning, adherence to revision knee arthroplasty principles, precise surgical technique, and correct reconstruction of the leg axis. Good component design and availability of diverse implant options to facilitate the surgeon are essential.[11]

The primary goal of revision knee surgery is to restore knee alignment and stability through a full range of movement, with well-fixed implants that re-establish the native joint line.[12] Recreation of the joint line near anatomic position optimizes knee kinematics.[13] Appropriate soft tissue balancing ensures stability, and meticulous surgical technique avoids intra-operative extensor mechanism complications.[14]

With an increasing number of revision knee arthroplasty systems now available, matching the correct implant to individual patient needs is an ever increasing challenge for the arthroplasty surgeon. The choice of revision implants is primarily based on soft tissue integrity and bone stock. Some implant types are more versatile in helping the surgeon to achieve their goal of a well fixed and balanced revision knee replacement. In this review the most commonly used constrained condylar knee (CCK) revision systems are considered. Potential advantages and limitations of each design are highlighted to assist surgeons in selecting the most suitable system for their individual patients.

2. Background

Patients with painful knee arthroplasty should be thoroughly assessed prior to revision surgery to determine the cause/causes of failure.[15] Aseptic loosening, instability, polyethylene wear/osteolysis, infection, periprosthetic fracture, malalignment and dysfunction of the extensor mechanism are some of the common reasons for revision.[7,16,17]

A systematic pre-operative evaluation including clinical history, physical examination, laboratory results, radiologic investigations and joint aspirations will identify the cause of failure in the majority of the cases.[15] Anatomic variation, implant fixation, potential bone loss, extensor mechanism integrity, patellar and joint line height, tibial or femoral bowing, narrow intramedullary canal, ipsilateral hip prosthesis are some of the many parameters to be considered.[15]

The focus of revision surgery is to preserve all viable host bone. Reconstructive options include modular TKA systems with optional stems, wedges, metal augments and more recently sleeves or cones. Constrained condylar knees with a stem extension are commonly used in revision surgery to off load the poorly vascularised and deficient epiphyseal bone.[18] Controversy surrounding the length of stem and decision to use cemented, uncemented or hybrid components remains.[12]

3. Constrained condylar knee revision systems

The ideal TKA revision system should increase both accuracy and simplicity of the procedure, provide a wide variety of component sizes and length to suit each individual case and have easy to use tools with a relatively small number of trays. The system should confer optimum implant fixation and construct stability at the epiphyseal, diaphyseal and metaphyseal interface (if the latter is required). In order to achieve that there may be a need for metal augments, component offset, stem extension offset, asymmetric tibial base plate, short smooth cemented stems and long slotted, possibly fluted, uncemented stems.

Currently there are many CCK revision systems available. Some provide instruments that make implantation easier to perform, however they all have specific advantages and disadvantages when compared to each other. Commonly used TKA revision systems are NexGen (Zimmer), Triathlon TS (Stryker), Legion (Smith & Nephew), Vanguard SSK (Biomet), PFC Sigma TC3 (DePuy) and Endo-model rotational and hinge (Endo, Waldermar Link) (Fig. 1).[6,7] The latter is not directly comparable to the main five systems as it is a hinged implant.

4. Materials

Table 1 presents the specifications of each system. Most implants are either made of Cobalt Chrome (CoCr) or Titanium alloy (Ti–6Al–4V). Titanium has lower wear resistance and shear strength than CoCr.[19] However, its Young's Modulus is lower (deforms more for the same load). The fatigue strength of the two materials is similar.[20]

Some patients are known to develop metal sensitivities following total joint replacement.[21,22] These responses have been linked to asceptic loosening, dermatological reactions and other local and systemic metal-induced toxicity throughout the body.[23,24] In the case of patients that have dermatological reactions, revision surgery may be required to replace components containing Nickel using either a titanium alloy or ceramic (e.g. Oxinium) prosthesis.[25] Only the Legion system has Oxinium as an option for the femur. All the remaining implants use CoCr since wear rates are lower.[26,27]

All companies use high density polyethylene for the tibial insert, with the Legion using an ethylene oxide sterilisation method which may reduce late oxidation in the polyethylene.[28] The triathlon TS is available with a more highly cross-linked polyethylene treated with 9 MRad and a triple annealing process. Annealing is used following irradiation to reduce free radicals that can lead to oxidation of the polyethylene.[29] Annealing involves heating the polyethylene at temperatures below their melting point, and has been shown

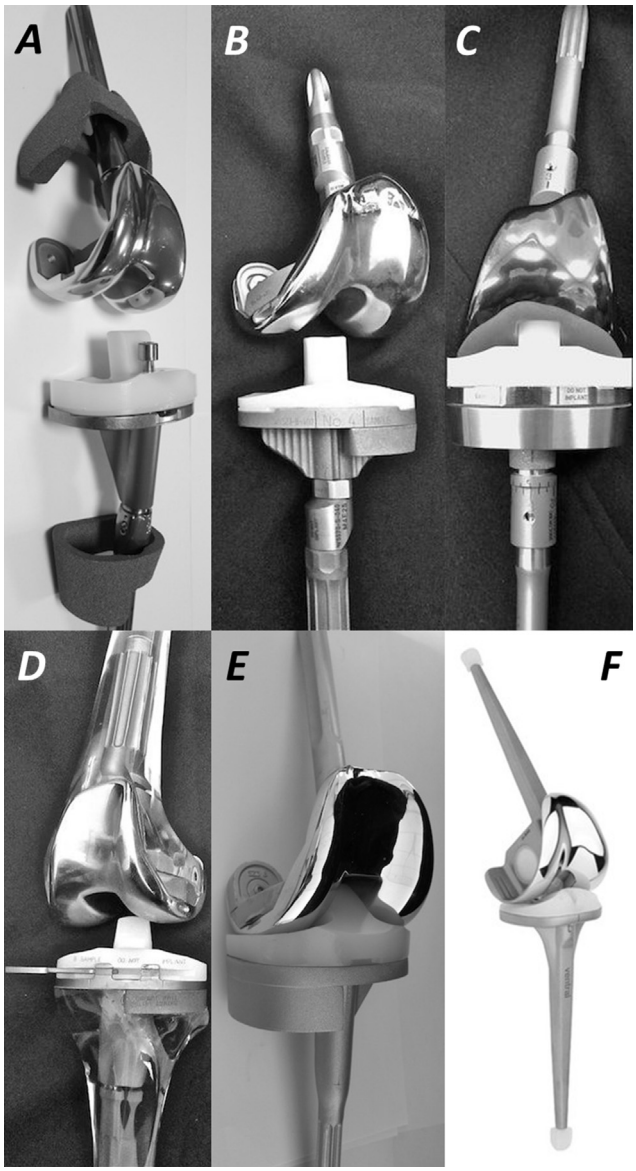

Fig. 1 – Images of six of the most commonly used TKA revision systems. A – NexGen, B – Triathlon TS, C – Legion, D – Vanguard SSK, E – PFC Sigma TC3, F – Endomodel.

to retain better mechanical properties of the material when compared to re-melting.[30]

5. Stem design

Nexgen, Legion and Vanguard use a taper locking mechanism with additional side screws to connect the stem and femoral component. The Sigma TC3, however, uses a bolt which may lead to a weak connection and failure.[31] The Triathlon system uses a cam locking technique which can be technically demanding to use and has yet to be proven in the clinical setting. The Legion system offers true press fit stems with distal slots avoiding potential stem tip pain,[32] which are also found in the Vanguard and Sigma TC3. All the systems have cutting blocks that can be locked to the reamers making it easier to use, with the exception of the TC3. The stems are interchangeable between femur and tibia in the NexGen, Vanguard and Legion. One-millimetre increments in stem diameter are available in Triathlon and Legion but only two millimetres increments are available in Vanguard and Sigma TC3. Jazrawi et al observed that proximal tibial stress reduced as stem diameter increased, and micromotion of the tibial tray in press fit tibial stems reduced as the diameter increased to 14 mm.[33]

6. Offsets and augments

Hicks et al reported large malalignments (up to 15 mm) between the centre of the diaphyseal canal of the tibia and the centre of the tibial plateau.[34] Stem offsets are often required in revision surgery to ensure good alignment within the intramedullary canal and to overcome these anatomical malalignments.[35] Without using stem offsets, overhang of the tibial tray will often be seen.[36] Offsets allow improved stability in flexion, ligament balancing, and optimal bone coverage to reduce bone-implant stress.[37] Femoral and tibial component offsets options are limited in Sigma TC3 and are not available for the femur in Vangard which can be a significant limitation when using uncemented stems. 360° offsets can be found in Triathlon, NexGen and Legion. The NexGen offset is achieved via stem extension which provides femoral and tibial stem offsets of up to 4.5 mm, but it can only be used with certain stem lengths. Stem extension offset is a good idea in principle but the offset can be too distal to the base plate thereby limiting their use in small patients on the tibial side. Offsets in Sigma TC3 are built into the base plate, which means a larger inventory. Triathlon and Legion offsets are through a proximal bushing.

Augments are used to substitute for bone loss and limit the use of allograft or cement.[38] Augments can be either rectangular or wedge shaped, solid or porous, and can be used where the implant is unsupported by up to 40% of the host bone.[37]

7. Implant design

7.1. *Femoral component*

The sagittal radius of the femoral component is multi-radius in all but the Triathlon system, which has a single radius design. Multi-radius femoral components have been implicated in mid-flexion instability due to slackening of the ligamentous structures of the knee.[39] Single radius designs have been proposed to ensure a more constant ligament tension through the full flexion range of motion, although Stoddard et al were unable to demonstrate improved kinematics or stability in the single radius knee.[40]

Gender differences are known to exist at the knee. Patellofemoral contact areas are reduced in women at high flexion which could increase contact pressure,[41] and increase valgus deformity has been observed in female knees.[42] Implant manufacturers have developed gender specific components to

Table 1 – Specifications of commonly used total knee revision systems.

Parameters	Models				
	Triathlon	Sigma TC3	NexGen LCCK	Legion	Vanguard
Implant Material	Femur: Co–Cr Tibia: Co–Cr	Femur: Co–Cr Tibia: Co–Cr	Femur: Co–Cr Tibia: Titanium alloy	Femur: Co–Cr or Oxinium Tibia: Titanium alloy	Femur: Co–Cr Tibia: Titanium alloy
Stem Material	Cementless: Titanium alloy Cemented: Co–Cr	Cementless: Titanium alloy Cemented: Titanium alloy	Cementless: Titanium alloy	Cementless: Titanium alloy Cemented: Co–Cr	Cementless: Titanium alloy Cemented: Co–Cr
Sagittal Radius Femoral Design	Single radius	J-Curved Multi radius	J-Curved Multi radius	Multi radius	Multi radius
Tibial Base Plate	Symmetric Unpolished Posterior pin No Holes Anti-rotation island Peripheral locking wire Dovetail locking	Symmetric Unpolished Posterior pin Holes for wedge attachment i2 locking mechanism and containment rail	Symmetric Unpolished Locking screw Holes for wedge attachment Double dovetail locking mechanism with containment rail	Asymmetric Highly-Polished None No holes Dovetail locking mechanism	Symmetric Unpolished Screw Holes Compressively loaded tibial locking mechanism with anterior locking pin
Polyethylene Insert	Conventional or highly cross linked X3 poly. PS or TS constraint options	GUR 402 grade UHMWPE with titanium reinforcing pin that is part of the tibial spine. PS or TC3 constraint options PS or TC3 constraint options	Net shape compression moulded polyethylene. Long or short post constraint options	Conventional or moderately cross linked poly. PS or PS HF (high flexed) & VVC constrained options	Arcom direct compression moulded polyethylene. PS and constrained bearings options
Tibial Offset Options	2 mm 4 mm 6 mm 8 mm 360° offset	4 mm Mediolateral direction only	4.5 mm 360° offset but about 45 mm distal to the tray	2 mm 4 mm 6 mm 360° offset using deferent bushing for each offset	0 mm 2.5 mm 5 mm 360° offset
Gender Differences	No	No	Yes (NexGen only)	No	No
Femoral Box Resection	Range 21–23 mm	Fixed size of 22 mm	Range of sizes available from 22.1 mm to 25.8 mm	Variable size starting at 16.5 mm	Fixed size more than 22 mm
Femoral Offset Options	2 mm 4 mm 360° offset using the same bushing but complex	2 mm 0 mm −2 mm AP direction only	Up to 4.5 mm 360° offset	2 mm 4 mm 6 mm 360° offset using deferent bushing for each	Offset not available
Component Sizes	Femur: 8 sizes Tibia: 8 sizes	Femur: 7 sizes Tibia: 7 sizes	Femur: 4 sizes Tibia: 6 sizes	Femur: 8 sizes Tibia: 8 sizes	Femur: 6 sizes Tibia: 9 sizes
Stem Diameter	1 mm increment from 10 mm to 25 mm (cementless) 9 mm, 12 mm or 15 mm (three lengths available) (cemented)	2 mm increment from 10 mm to 24 mm	1 mm increments from 10 mm to 22 mm	1 mm increments from 9 mm to 16 mm 2 mm increment from 16 mm to 24 mm	2 mm increments from 10 mm to 24 mm (cementless) 2 mm increments from 10 mm to 16 mm (cemented)

Stem Options	Slotted and tapered tip with stem extenders size 25, 50 mm to optimise placement with the canal	Non interchangeable Solid stem. Recent introduction of universal slotted stems to tibia and femur in lengths of 75, 115 and 150 mm	Interchangeable femoral and tibial stems Four stem lengths of 30, 100, 155 and 200 mm	Interchangeable Slotted 160, 220, 280 Titanium Co–Cr for cemented implants less cement cracking	Interchangeable Splinned cementless slotted Two cemented options smooth and grit blasted
Stem Locking Mechanism	Cam locking technique	Bolt lock for femur Tibial stem attaches directly into tray.	Double Morse type taper with 2 side set screws for femur and top screw through the tibia	Simple Taper locking with side screws	Simple morse taper locking with screw
Advanced Bearing Options	Yes: X3 poly	No	No	Yes: Oxinium femur	No
Metal Sensitive Option Femur	No	No	No	Yes: Oxinium femur	No
Augment Options	Femur: Distal 5 mm, 10 mm and 15 mm, Posterior 5 mm and 10 mm Tibia: Medial and lateral 5 mm and 10 mm half blocks	Femur: Distal 4 mm, 8 mm, 12 mm and 16 mm blocks, Posterior 4 mm and 8 mm blocks Tibia: 15° and 20° full and hemi wedge blocks, 10 mm and 20 mm step wedge blocks	Femur: Cone augments and shapes Tibia: Cone augments, shapes, wedges and blocks Trabecular metal femoral and tibial cone augments Trabecular metal femoral and tibial shapes Tibial Wedges Tibial Blocks Femoral Augments	Femur: Distal 5 mm, 10 mm and 15 mm, Posterior 5 mm and 10 mm (L Combination wedges) Tibia: Medial and lateral 5 mm and 10 mm half blocks or wedge	Femur: Distal 5 mm, 10 mm and 15 mm blocks. Posterior 5 mm and 10 mm blocks Tibia: 6 mm, 10 mm and 16 mm half blocks. Regenerex cone augments for tibia
Patellofemoral Tracking	Deep and lateralised track	The trochlea design changed recently	Deeper trochlear groove and lateral angulation by 3°	Extended and lateralized trochlea groove	Deeper and extended trochlear groove
Reamers	Instruments lock to reamers	Instruments do not lock to reamers	Instruments lock to reamers	Instruments lock to reamers	Instruments do not lock to reamers
Kit	10 trays, only need to open 5 to begin each case.	11–12 very large trays	5 core trays	11–12 trays	10 trays
Hinge Conversion	Use different system Modular rotating hinge (MRH)	Use different system Noiles	Easy conversion, simply change trial trays and can add 3 more trays for complete limb salvage products	Recently launched Also have RT Hinge	Separate option for hinge (RHK) and Orthopaedic Salvage System (OSS)

address these differences (e.g. NexGen LCCK). However, the use of gender specific implants appears unnecessary[43] as gender differences have not previously been observed following total knee replacement in terms of pain,[44] survivorship,[45] or joint stiffness,[46] and minimal reductions in flexion (1–2°) in women following both primary[47] and revision[48] total knee replacement.

The femoral box cut can potentially sacrifice a large amount of host bone (up to 23 × 21 mm) with all the systems that have a fixed box size. The Legion has a smaller box cut that can be varied in size proportional to the femoral component size. It is important to note, however, previous reports of periprosthetic fracture as a result of insufficient size of the box cut.[49] Surgeons should make sure that the box cut, if using the Legion, is appropriately adjusted to ensure that fracture is avoided.

The Vanguard includes a deep trochlear groove. Although this could improve patellofemoral congruence and reduce the potential of the patella to sublux, it is hypothesised to lead to increased shear forces.[50] Petersilge et al,[51] however, demonstrated in cadaveric knees that a femoral component with deeper trochlear groove can reduce mediolateral patellofemoral shear forces. Although superior–inferior shear forces were increased with the deeper trochlear groove, the total shear force was found to be 5% lower with a deeper groove over the full range of extension. Compressive force within the patellofemoral joint were also reduced with a deeper trochlear groove, most notably at flexion angles above 70°.[51]

7.2. *Tibial component*

Due to the asymmetrical anatomy of the tibial plateau and intramedullary canal,[35] the design of the tibial tray and its alignment with the stem are important considerations. An asymmetrical tibial tray should improve prosthesis fit to the tibia, improve bone coverage, and reduce overhang.[52] Despite the apparent benefits of using an asymmetrical tibial tray, all systems, with the exception of the Legion, have symmetrical tibial base plates. A polished tibial tray has been shown to reduce wear,[19] although it has been associated with increased micromotion when compared to blasted tibial trays.[53] A polished tray is only available in the Legion. Restoration of range of motion following knee arthroplasty is an important factor in terms of functional outcome.[54] Following surgery, however, patients' range of motion often appears limited.[55] This limitation to flexion has been attributed to impingement between the posterior tibial tray and the femoral component which limits anteroposterior translation of the femoral component during high flexion.[56]

8. Constraint level

Most companies provide a comprehensive array of implant options for cases that require varying levels of constraint. However, few have an integrated system that facilitates conversion to higher level of constraint in the same platform. Zimmer offers surgeons a progressive integrated cross system capability, while Biomet, Smith & Nephew and Stryker have a separate hinge system. There is cross over between some of the components in the Sigma TC3 when changing from a sleeved to hinged revision.

The majority of the systems use the same femoral component whether a normal PS or constrained insert is used. This makes switching between the two when trialling the implants straightforward. The Sigma TC3 can be used with either a standard PS femur, still with the option to use stems and augments; but to use a constrained insert, the box resection must be repeated to accommodate the larger box housing for a TC3 femoral component.

9. Metaphyseal bone loss

The majority of CCK implants that rely on epiphyseal and diaphyseal contact can be utilised successfully in revision surgery when there is type 1 Anderson Orthopaedic Research Institute (AORI) metaphyseal bone defect.[15] However, when there is a severe metaphyseal bone deficiency that compromises a major portion of either femoral condyle or the tibial plateau, an additional fixation at the metaphysis should be considered to achieve construct stability. In order to address a large defect one can either use structural allograft,[57] metaphyseal filling highly porous tantalum trabecular metal full/stepped cones (Zimmer) or stepped porous coated metaphyseal sleeves (DePuy).[15] The differences between the two manufactured metaphyseal fillings implants are primarily in their compatibility to other products and the way they interface with the stemmed component and the host bone. The trabecular metal comes in variety of shapes and sizes so that it can be shaped intraoperatively to the defect with the stem passing through the cone and cemented to it at the metaphyseal area. The metaphyseal sleeve engages with the stem using a "morse" taper and has a coated surface to enable bone ongrowth. The advantage of the sleeve is that its insertion is instrumented allowing a perfect fit, and it acts as one unit with the stem to compressively load the adjacent metaphyseal bone. Furthermore, it can be used with a mobile bearing platform to diffuse loosening forces above the tibial tray.[58] However the metaphyseal sleeve can only be used with DePuy products. The tibial sleeves are dispatched in five sizes while uncemented femoral sleeves come in four sizes. Occasionally even the largest femoral sleeve may fail to fill the distal femoral cavity, which may necessitate using linked implants in order to prevent extension gap laxity. Both implants are gaining rapid popularity and have had encouraging early results.[59,60]

10. Follow-up data

Only a small number of studies have reported long term results of revision TKA systems (Table 2).[61–69] By contrast, the literature is focussed more on the outcome for specific groups of patients undergoing knee revision (e.g. uncontained metaphyseal defects, strategies for eradication of infection, etc.). A wide variety of knee revision systems have been employed and it is often considered that the "condylar" designs are very similar.[70] This is unfortunate, since in primary knee replacement it would never be assumed that implants from two

Table 2 – Revision knee replacement outcomes.

First author	Year of publication	Implant	No. cases	Case mix	Mean follow up (range)	% Survival	Reason for failure	Scoring system	Pre-op scores	Post-op scores
Hossain[61]	2010	PFC/TC3 also 3 different designs of RH	349	Infection (32.7%), loosening (14.9%), wear (12.3%). Includes conversion of UKA. 112 cases were not stemmed.	57 months (12–120)	90.6% survival at 10 years	Infection (2.9%) Instability (1.7%) Loosening (1.4%)	KSS	33.8	87.9
Rodriguez[62]	2003	TC3	44	Loosening (15) Instability (10) Osteolysis (8) Infection (7)	5.5 years	N/A	1 recurrent sepsis, 1 subsided femoral component	KSCS	60	89
Mabry[63]	2007	PFC	70	Loosening (42) Wear (13) Instability (7) (No infections)	10.2 years (median)	92% survival at 10 years	5 cases aseptic loosening 2 deep infections	KSS	58	85
Lonner[64]	2002	PFC	17	All had cancellous grafting with mesh for uncontained defects. No infections	(6–40)	100% survival	1 infection treated with debridement and suppression	KSCS	47	95
Kim[65]	2009	Legacy CCK	114	Aseptic loosening (54%) Polyethylene wear (22%) Infection (12%) Instability (8%)	6.1 years (0–24 years)	96% (aseptic loosening) survival at 10 years	4 cases aseptic loosening, 1 broken tibial post, 2 cases recurrent infection	HSS	31	83
Chiu[66]	2009	Nexgen	183	N/A	89 months (36–156)		6 cases deep infection	HSS	46	85
Lonner[67]	2007	IB2 or Nexgen (CCK in 41)	102	Aseptic loosening (39) Mal-alignment (17) Instability (13) Wear (4)	12 months (1–38)	N/A		KSCS	52	71
Wood[69]	2009	Legion	135	Instability (34%) Infection (25%) Aseptic loosening (21%) Osteolysis (19%)	5 years (2–12)	98% survival at 12 years (aseptic loosening) 82% survival at 12 years (all cause revision or radiographic loosening)	2 Infection 2 Loosening 2 MCL rupture	KSCRS	69	135
Utting[68]	2004	Endo 21 rotating 9 fixed	30	Periprosthetic fractures (with or without aseptic loosening) 22 Aseptic osteolyses 5 deep infections 3	3 years (0.5–9.3)	N/A	Infection 6 Disarticulation 2	AKS OKS WOMAC		69.8 34 30.5

KSS – Knee Society Score, KSCS – Knee Society Clinical Score, HSS – Hospital for Special Surgery knee score, KSCRS – Knee Society Clinical Rating System, OKS – Oxford Knee Score, AKS – American Knee Society Score, WOMAC – Western Ontario and McMaster Universities Arthritis Index.

different companies were equivalent in terms of long-term survival. The implant with by far the most literature on long-term survival is with the Sigma TC3, although there is also good long term outcome published for the Nexgen and Legion. The majority of studies report good survivorship at follow up durations of 10–12 years. The Sigma TC3 has demonstrated 91–100% survivorship at 10 years[61,63,64] and the Legacy CCK has a reported 10 year survivorship of 96%.[65] The Legion has a 98% survivorship at 12 years follow up.[69]

There is considerable difficulty in comparing outcomes for revision knee replacement systems since the patients undergoing surgery are a much more heterogenous group than those undergoing primary TKA. As an example, Hossain et al included patients undergoing conversion from a unicondylar knee replacement and included almost a third of the patients not having a stemmed revision.[61] This is hard to compare to patients undergoing a two stage revision for infection or having substantial bone loss. It may be that in the future registry data may be able to provide meaningful survival data for knee revision systems and will have sufficient numbers to exclude patients with more limited revisions.

11. Advantages and disadvantages of each system

11.1. *Triathlon*

Advantages. The Triathlon system provides the largest range of 360° tibial offset. It has a variable femoral box size depending on the size of the femoral component and has a 360° femoral offset.

Disadvantages. The Triathlon system uses a symmetric and unpolished tibial tray. It does not include a metal sensitive option. Whilst the system has a variable femoral box cut size, this range is small and all available sizes are relatively large.

11.2. *Sigma TC3*

Advantages. The system also has a metaphyseal sleeve option. Despite the system historically having a solid stem, a slotted stem has recently been introduced in both the tibial and femoral components. It has the greatest volume of literature supporting its use.

Disadvantages. The Sigma TC3 system has only a limited offset available in both the tibial and femoral components. It requires a relatively large femoral box cut and has shown increased risk of patella clunk. It has a symmetric tibial tray which is unpolished and uses one of the larger number of surgical instrument trays. The Sigma TC3 system includes holes for wedge attachment which may allow tracking of wear debris beneath the tibial tray. It also does not provide a metal sensitive option.

11.3. *NexGen*

Advantages. The NexGen system provides 360° offsets in both the tibial and femoral components. It has the lowest number of surgical instrument trays of all the systems.

Disadvantages. The NexGen system has a symmetric and unpolished tibial tray. Once again it has holes in the tibial tray for attaching wedges. It has the smallest number of sizes available in both the femoral and tibial components, and does not provide a metal sensitive option.

11.4. *Legion*

Advantages. The Legion system includes a metal sensitive option and an asymmetric tibial tray. It uses the smallest femoral box cut size and includes 2, 4 and 6 mm 360° tibial and femoral offsets. It also has a highly polished tibial tray, and provides a metal sensitive option. The system has good follow-up data available.

Disadvantages. The Legion system uses one of the higher number of surgical instrument trays.

11.5. *Vanguard*

Advantages. The Vanguard system includes a range of 360° offsets in the tibial component. It has the highest number of tibial component sizes available.

Disadvantages. The Vanguard system does not provide offsets in the femoral component. It has a symmetric and unpolished tibial tray which does not have holes for the attachment of wedges. It has a large femoral box cut size. It does not have a metal sensitive option.

12. Conclusions

In summary, five CCK revision systems have been reviewed in relation to their features. Whilst each system has its own advantages, there are not sufficient follow up data available to be able to determine whether any one system shows better overall results than the others. The newer systems tend to have greater versatility, but the overriding factor that affects the long term success of a revision procedure could still be the skills and experience of the operating surgeon. Further research is needed to examine the long term outcomes of patients following knee revision surgery using these CCK revision systems.

Conflicts of interest

All authors have none to declare.

Acknowledgements

The authors received no funding for the conduct of this study. The manufacturers of each of the five implants reviewed in this article were contacted to obtain detailed information about the implants. This information was provided by Richard Brown (Zimmer, Ltd), Derrick Malpass (Biomet UK Ltd), Tom Steele (Stryker), Mark Whitelock (Smith & Nephew Orthopaedics Ltd) and Nathan Woodhouse (DePuy UK).

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Review Article

Over half of badminton players suffer from shoulder pain: Is impingement to blame?

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ARTICLE INFO

Article history:
Received 20 May 2014
Accepted 17 December 2014
Available online 5 January 2015

Keywords:
Badminton
Badminton players
Shoulder injury
Shoulder pain
Shoulder kinematics

ABSTRACT

Background/objectives: Badminton is one of the most widely played sports in the world and is considered a relatively safe sport. Despite this many badminton players report shoulder pain. The aim of this review is to summarize the available literature on current state of understanding for shoulder pain among badminton players.

Method/materials: MEDLINE and EMBASE (Search terms: "badminton" AND "shoulder injuries"; "badminton" AND "rotator cuff tears"; "badminton" AND "impingement"; and associated synonyms) were performed in March 2014. The authors further canvassed the reference list of selected articles and online search engines such as Google Scholar. Inclusion criteria were studies that assessed shoulder injuries among badminton players. A total of 4 studies were identified on primary search, and later expanded to 10 studies.

Results/discussion: Shoulder pain affects or had affected over 50% of recreational and elite badminton players, with 20% reporting ongoing shoulder pain. There was no difference for shoulder pain prevalence between males and females. Most continue to play through the pain but report an impact on training, competition and activities of daily living. Shoulder kinematics were different for dominant and non-dominant shoulders, however the direction of difference is controversial.

Conclusion: Over half of recreational and elite badminton players report previous or current shoulder pain, most likely the result of subacromial impingement, instability or scapulothoracic dyskinesia. There appears to be no difference for shoulder pain prevalence or shoulder kinematics between male and female players. Further work is needed to better define shoulder kinematics and study the underlying pathophysiology of shoulder pain among badminton players.

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http://dx.doi.org/10.1016/j.jajs.2014.12.006

1. Background

Badminton is one of the most widely played sports in the world. The Badminton World Federation estimated that about 150 million people play the game worldwide and that more than 2000 players participate in international competitions. Badminton, a non-contact sport, has been considered a very safe sport.[1] Despite its global following, studies into medical problems among badminton players are sparse. This review explores our current state of understanding of shoulder pain in badminton players.

2. Method/materials

MEDLINE and EMBASE (Search terms: "badminton" AND "shoulder injuries"; "badminton" AND "rotator cuff tears"; "badminton" AND "impingement"; and associated synonyms) were performed in March 2014. The authors further canvassed the reference list of selected articles and online search engines such as Google Scholar. Inclusion criteria were studies that assessed shoulder injuries among badminton players. A total of 4 studies were identified on primary search, and later expanded to 10 studies.

2.1. *Injuries among badminton players*

Although badminton is widely accepted as a safe sport, it does carry injury burden. Previous studies, mostly in Europe, have demonstrated risk of injury in badminton to be 1.6–2.9 injuries per 1000 h of play.[2,3]

In their review conducted in 1990, Jorgensen and Winge showed that most injuries in badminton were localized to the foot and ankle.[4] The most frequent injuries were Achilles tendinitis and tennis elbow. They also showed that men have higher injury risk than women, and that recreational players are more prone to injury than elite players.[4] A more recent Scandinavian study found that the lower extremity is the site of injury in over 90% of players, with Achilles tendon ruptures and ankle sprains/fractures the two most common acute injury patterns.[5]

Recently, epidemiological studies outside of Europe have contradicted this finding. A retrospective survey of Malaysian badminton players over a two and a half year period found that the majority of injuries occur in the knee and are categorized as mild overuse injuries. The majority of injuries were diagnosed in younger players and occurred during training/practice sessions. There was no difference between male and female players.[6] A retrospective study of 44 Hong Kong elite badminton players found that incidence rate of injuries was 5.04 per 1000 h of play, and the back was the most frequently affected location, followed by the shoulder, thigh and knee.[7]

This suggests that injuries sustained by badminton players are different in different geographical locations and perhaps the underlying mechanism of injury may also be different.

Of note, a large proportion of badminton players continue to play despite being injured. 17–28% of badminton players play with an ongoing injury, but in 92% of cases the injury does not prevent the player from playing but may adversely affect the quality of their performance.[2] The effect of playing with injury on long term performance and worsening of injury among badminton players needs to be studied.

2.2. *The shoulder problem*

Badminton is a sport that requires a lot of overhead shoulder motion, with the shoulder in abduction and external rotation. Overhead shots are estimated to constitute 30% of shots played by badminton players (unpublished study data from International Badminton Federation), with female players having a higher percentage of overhead shots compared to their male counterparts.

In the normal population, shoulder pain is a musculoskeletal problem with a prevalence of 12% in the age group 16–44 years and 19% in the age group 45–64 years.[8] Shoulder injuries accounted for 19% of all injuries in a study of 44 elite Hong Kong badminton players.[7]

According to a survey study of 188 international elite badminton players (mean age = 24) during the World Mixed Team Championship in 2003, previous or current shoulder pain on the dominant side was reported by 52% of players, with 37% of players reporting previous shoulder pain and 20% ongoing pain.[9] There was no difference between male and female players and the majority of shoulder pain was of insidious onset. There was a common association with stiffness, and impact on training and competition, as well as activities of daily living.

A Swedish study of 99 recreational badminton players (mean age = 43) found that 52% of them had previous or present pain in the dominant shoulder with 16% having ongoing pain.[10] The majority of players reported that the pain affected their training habits, but they continued to play through the symptoms.

Thus, over half of badminton players, both recreational and elite, have a previous or current painful shoulder but many continue to play despite it. At any given point in time roughly 1 in 5 players have ongoing shoulder pain, comparable to norms in the general population. There appears to be no difference in shoulder pain prevalence between male and female players, despite female players having more overhead shots than their male colleagues. This may suggest that the painful shoulder in these players is not directly related to badminton, however, the large burden load among badminton players points to the contrary.

2.3. *The cause of the painful shoulder?*

During the overhead throwing/hitting motion the shoulder complex functions as a regulator of forces generated by the legs and the trunk.[11] It is this regulating function as well as the high velocities that accompany the hitting motion that places large forces across the glenohumeral joint.[12] These forces as well as the frequent repetition of the overhead hitting action produce severe stresses on the muscles, bones and joints of the upper extremity.[13]

Shoulder pain and impingement of the rotator cuff caused by anterior instability of the shoulder are frequent problems for athletes engaged in overhead sports.[11,14–16]

Previous studies of overhead athletes in other sports have found that those with shoulder injuries have higher training loads,[17,18] have altered scapula kinetmatic,[19] altered muscular strength patterns[20] and greater internal rotation (IR) to external rotation (ER) range of motion in the dominant shoulder.[20]

Repetitive overhead activities likely lead to adaptation to the pillars that constitute the shoulder joint – the bones (including the scapula), the cuff and the muscle stabilizers. Whether the subsequent change in shoulder kinematics is adaptive[20–22] or the result of pathology[14,23,24] remains an area of debate.

In the Swedish study, dominant shoulders of the players with shoulder pain had decreased active pain-free shoulder abduction range, however isometric shoulder strength was no different when compared with pain-free shoulders. Clinical diagnosis in most patients was primary subacromial impingement or anterior instability.[9] Interestingly, a diagnostic picture of scapulothoracic dysfunction was found in some cases of shoulder pain.

A Dutch study kinetic study of the rotator cuff in badminton players found that the dominant arm was stronger than the non-dominant arm, and that concentric internal rotation strength is greater than external rotation strength, and that eccentric external rotation strength is greater than concentric external rotation strength.[25] Interestingly, for female players the eccentric external rotation strength was greater than the concentric internal rotation strength, whereas for male players then concentric internal rotation strength was greater than the eccentric external rotation strength.

In contrast, a Hong Kong based study of 25 male badminton players found that the eccentric internal rotation (antagonist) to concentric external rotation (agonist) ratios were different between the dominant and non-dominant shoulders.[26] This was for both the cocking and the deceleration phase of a forehand overhead smash.

Overall, there appears to be a gender difference to shoulder kinematics. Regardless of gender, dominant shoulders of badminton players have decreased range of motion for pain-free abduction with no significant change to the range of motion otherwise. This is in contrast to other sports where ER typically increases and IR decreases with repetitive overhead hitting.

Further, strength, overall, tends to be different for dominant versus non-dominant shoulders, however which muscles tend to get stronger and which weaker is controversial. Further kinematic studies are essential to define this antagonist–agonist relationship.

3. Conclusion

Over 50% of recreational and elite badminton players report previous or current shoulder pain, most likely the result of subacromial impingement, anterior instability or scapulothoracic dyskinesia. Most players continue to play through the pain, but report that the pain affects their play and non-play related activities. There appears to be no difference for shoulder pain prevalence or shoulder kinematics between male and female players. Further work is needed to better define shoulder kinematics and study the underlying pathophysiology of shoulder pain among badminton players.

Conflict of interest

All authors have none to declare.

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Case Report

Hoffa fracture associated with avulsion fracture of cruciate ligaments: Two case reports

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ARTICLE INFO

Article history:
Received 29 October 2014
Accepted 3 December 2014
Available online 22 January 2015

Keywords:
Hoffa fracture
Avulsion fracture
Cruciate ligaments tear

ABSTRACT

Hoffa fracture designated as intraarticular coronal plane femoral condyle fracture are the uncommon injury in orthopaedics. Hoffa fracture associated with cruciate ligament avulsion fracture are rather rare injuries reported. We encountered 2 cases of Hoffa fracture with cruciate ligament avulsion fracture in our hospital. These cases were managed by open reduction and internal fixation of femoral condyle with 2 lag screws and screw fixation of avulsion fracture of cruciate ligament. Patients were followed up for 18 months. KOOS functional knee score was used to evaluate the outcome. Excellent result in one and good result was observed in second case regarding postoperative knee movement, weight bearing, pain and bony union.

1. Introduction

Unicondylar fractures of the lower end of the femur are uncommon injuries that usually occur in the sagittal plane.[1] Coronal (tangential) plane fractures, first described by Hoffa in 1904, are unusual.[1–4] According to AO classification Hoffa fractures comes under type B3. When they do occur, the cause is often direct anteroposterior force applied to a flexed knee in a high-energy accident. In this report an unusual trauma pattern of a Hoffa fracture associated with avulsion fracture of cruciate ligament is presented.

2. Case 1

A 32-year-old woman with history of motor vehicle accident reported in emergency with knee pain and non-weight bearing. Physical examination revealed gross swelling and tenderness of the left knee. Anterior drawer and Lachmann test were positive during examination. Plain radiography showed a lateral condylar Hoffa fracture. MRI imaging revealed lateral Hoffa fracture with avulsion fracture of ACL. Treatment comprised a left knee lateral parapatellar incision with open reduction and internal fixation achieved visually and fixed with two antero-posterior lag screws to achieve appropriate compression. ACL avulsion on femoral site was evaluated but fragment found to be very small to fix. Lateral condyle was drilled in the same ligament direction and ACL was transfixed at its attachment site with Ethibond through the drill hole and screw with washer on opposite side. Postoperatively knee brace was used for 3 weeks. Physiotherapy including controlled knee movement was started 3 weeks postoperatively. Radiological fracture union was achieved at 3 months. Functional evaluation was done with KOOS

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http://dx.doi.org/10.1016/j.jajs.2014.12.002

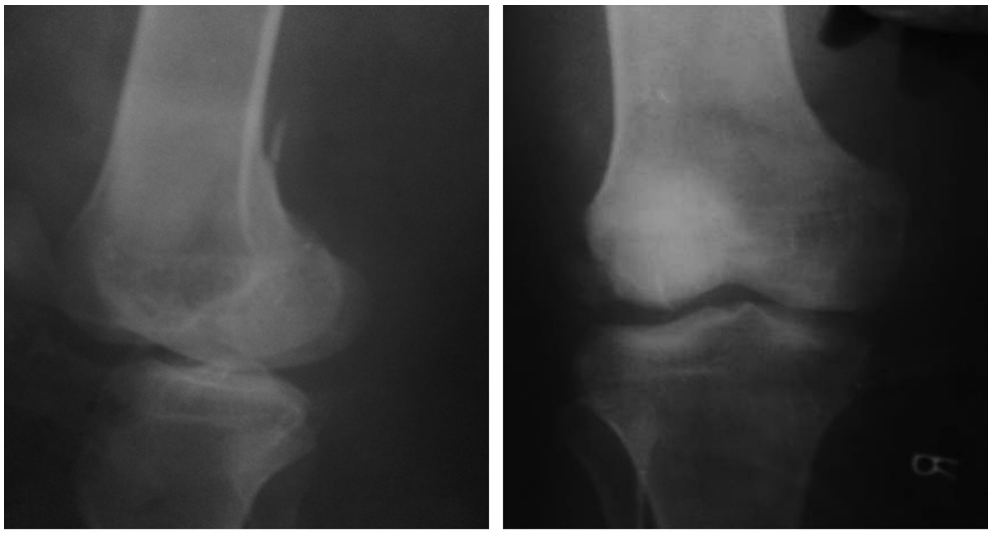

Fig. 1 – (A) AP View and (B) Lateral view of lateral femoral condylar with Hoffa fracture.

functional outcome score. Excellent score was reported in the case (Figs. 1–6).

3. Case 2

A 37-year-old male patient had a road side accident presented to casualty within 2 h. Physical examination revealed deformity (sagging of tibia), swelling and tenderness of the right knee. Radiographs showed a unicondylar coronal plane fracture of the lateral femoral condyle. CT and MR imaging, indicated by the anteroposterior laxity of the knee detected during physical examination, revealed Hoffa fracture combined with bony avulsion of the PCL. No other morbidity was found. Treatment comprised a right knee lateral parapatellar incision with open reduction and internal fixation achieved visually and fixed with two antero-posterior lag screws. The heads of the screws were countersunk. The bony fragment of tibia to which PCL was attached fixed with cortical screw. Knee brace applied for 3 weeks. Physiotherapy including controlled knee movement was started 3 weeks postoperatively, and in the 6th postoperative week partial weight bearing was allowed after observing early sigh of union. At 4 months postoperatively, radiological fracture union was achieved. KOO's functional sore was used to evaluate outcome. Good result was observed (Figs. 7–9).

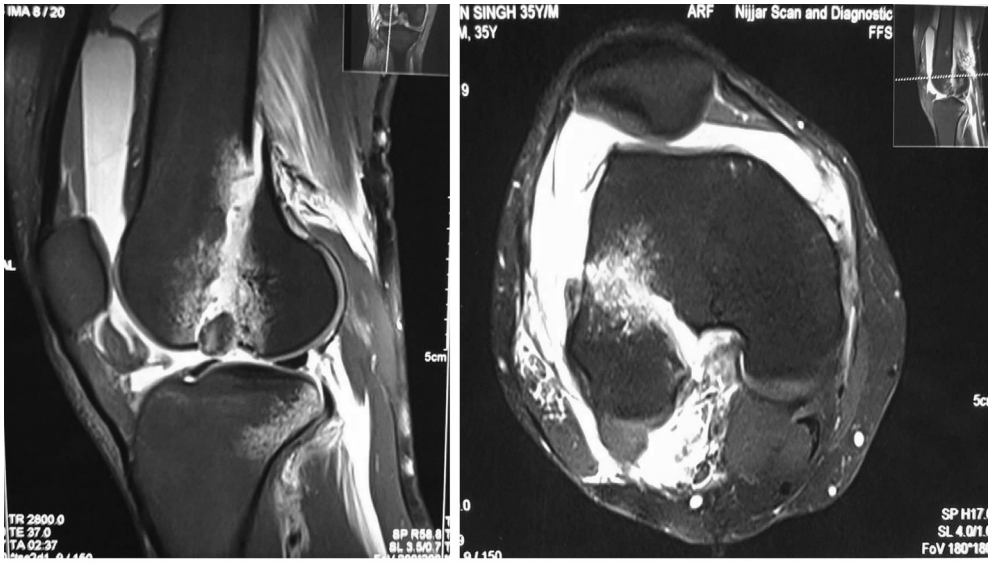

Fig. 2 – MRI images of the same case showing Hoffa fracture and associated injuries.

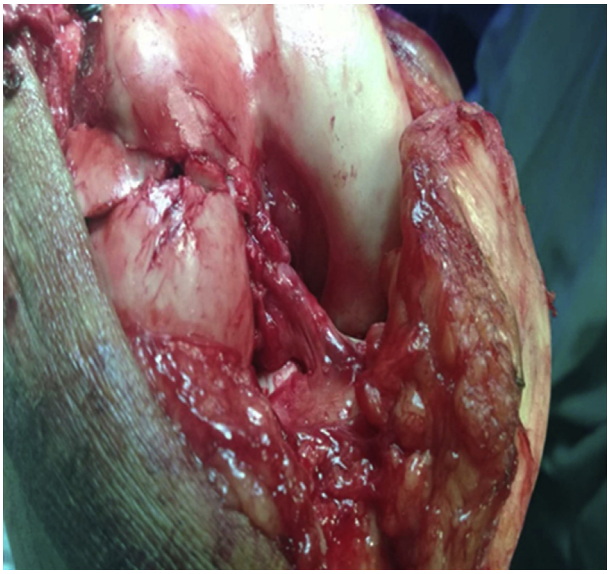

Fig. 3 – Intraoperative photographs of the case showing Hoffa fracture and Avulsed ACL.

4. Discussion

The Hoffa fracture is an intra-articular fracture of the knee analogous to the capitellum fracture of the elbow. The injury is the result of violent force and generally occurs in young adults.[4] The fracture results from a combination of forces: direct trauma, possibly with an element of abduction.[4] The ground reaction is transmitted through the tibial plateau. Axial compression on a flexed knee concentrates the force in the posterior half of the femoral condyles. In flexion the lateral condyle is the leading part of the knee to receive the impact.[4] Although the Hoffa fracture may be of either condyle,[4–6] the preponderance of lateral condylar fractures suggests an anatomic-biomechanical vulnerability due to the physiological valgus. Our one patient had an ACL injury associated with lateral Hoffa fracture and other had a PCL injury with lateral Hoffa fracture which is rather rare orthopaedic injury. In any such unusual pattern of injuries, the diagnosis of additional bone and soft-tissue trauma is important in planning treatment and achieving functionally satisfying results. Coronal fractures when undisplaced can be overlooked easily and tend to displace with conservative

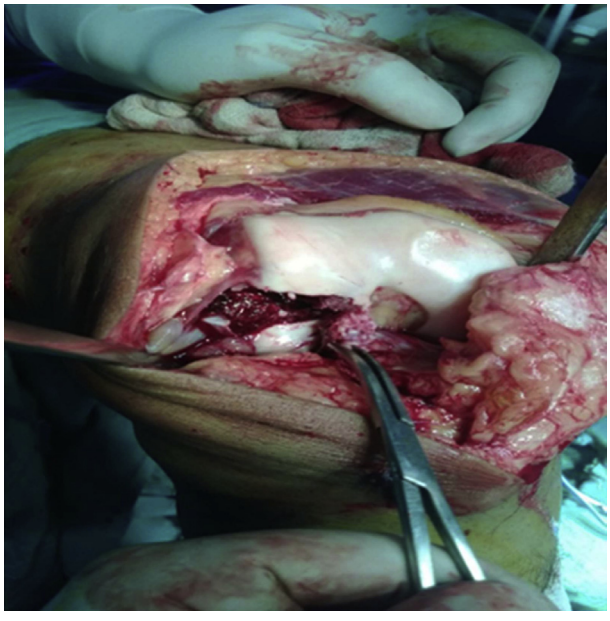

Fig. 4 – Intraoperative photographs of the case showing Hoffa fracture and Avulsed ACL.

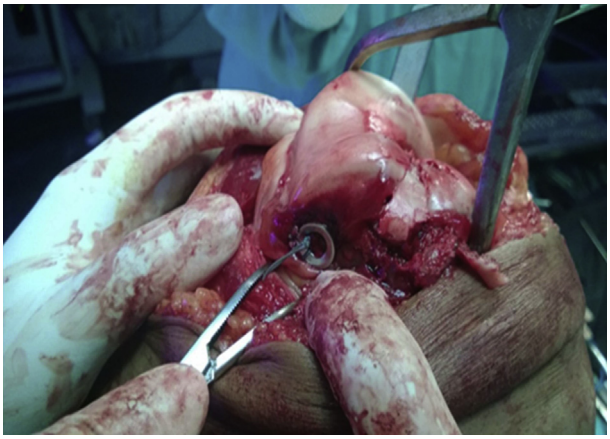

Fig. 5 – Intraoperative photograph showing fixation of Hoffa and Avulsed ACL.

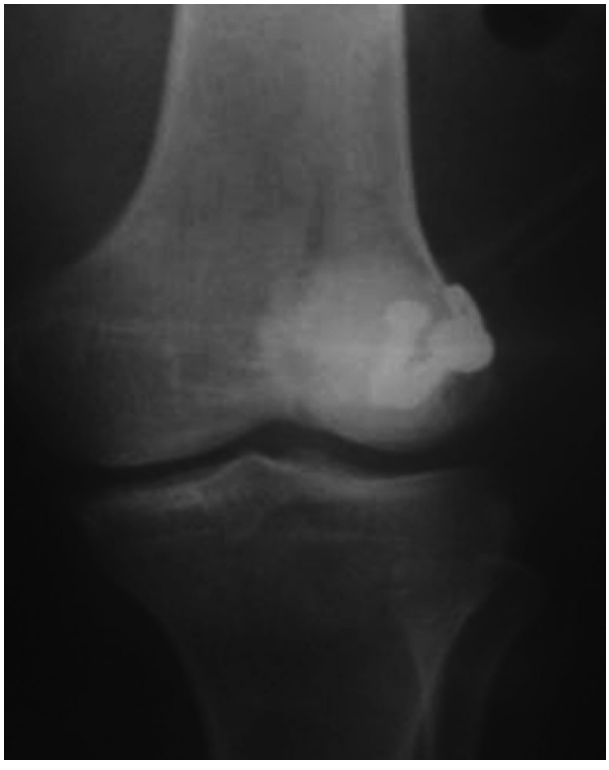

Fig. 6 – Postoperative X-ray AP view after fixation of Hoffa fracture and Avulsed ACL.

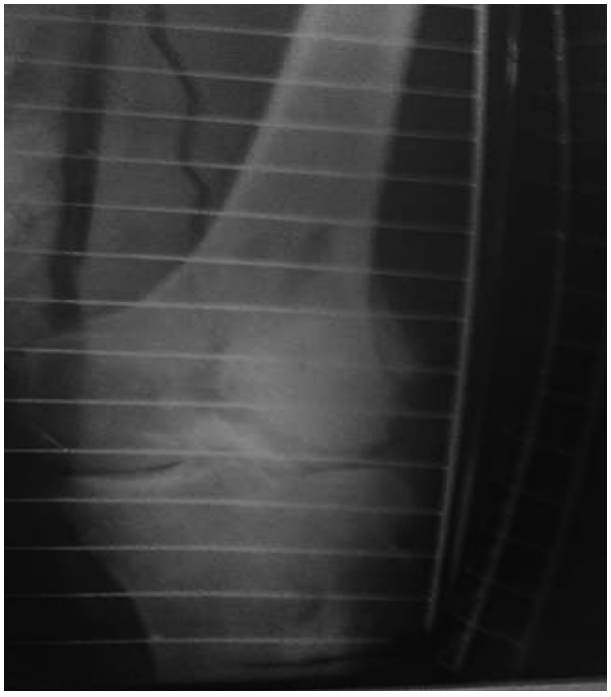

Fig. 7 – Case 2 – X-ray Rt knee AP view of lateral femoral condylar with Hoffa fracture.

treatment.[2,4,7] The operative approach was lateral. As was reported by Holmes et al[8] visualisation was best attained by the parapatellar approach; this facilitates the diagnosis of intraarticular injuries as well as their treatment. In lateral approach vastus lateralis was reflected off the lateral intramuscular septum and the knee joint opened. Maintaining the

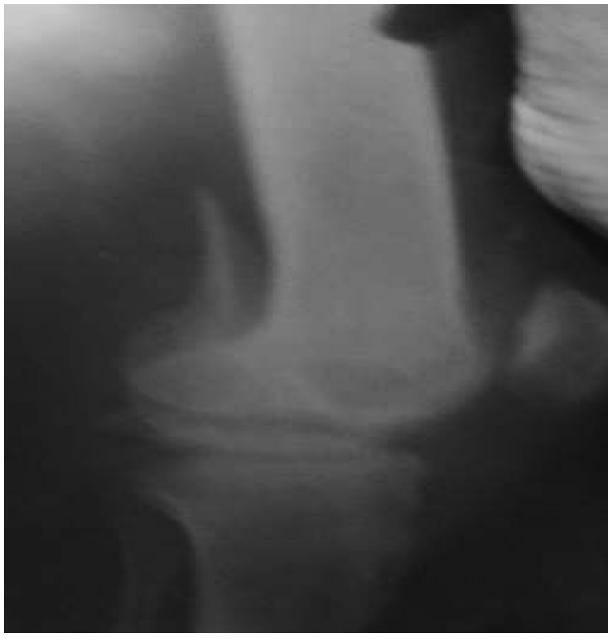

Fig. 8 – Case 2 – X ray Rt knee lateral view of lateral femoral condylar with Hoffa fracture.

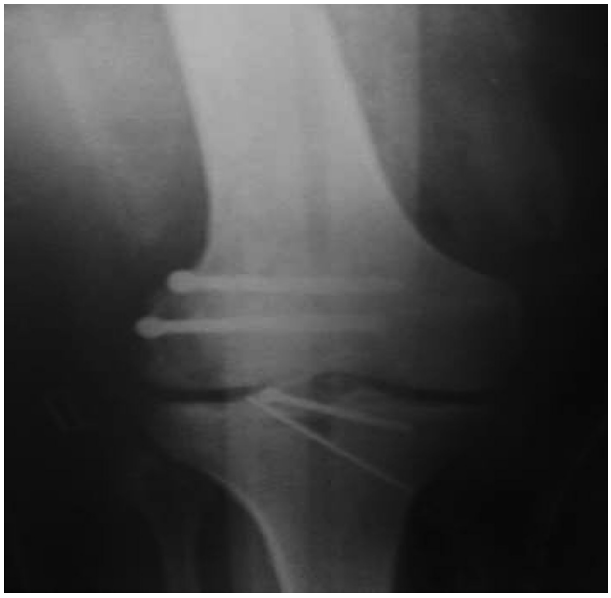

Fig. 9 – Case 2 – Postoperative X-ray Rt knee AP view after fixation of Hoffa fracture and Avulsed PCL.

knee flexed during the surgery relaxes the posterior capsule, gastronemius and protects the neurovascular structures. Soft tissue attachments of the fractured fragment constitute the sole source of blood supply and must be preserved.[4] The joint was carefully inspected for associated injuries. After reduction the fragments were temporarily fixed with Kirschner wires. Partially threaded cancellous screws were used in the lag mode to secure compression across the fracture. A minimum of two screws is mandatory to provide rotational stability.[7] Counter sinking of lag screws was done to avoid articular incongruence if any. Ligament avulsion was evaluated regarding direction of avulsion and site of avulsion. Cortical screw fixation at anatomic site of attachment of ligaments was done. Postoperatively knee brace was applied for 3 weeks. Physiotherapy was started at 3 weeks with range of motion brace. Partial weight bearing was started at 6 weeks after early sigh of union on X rays. Functional outcome was evaluated with KOOS functional knee score. Excellent and good functional score were observed.

5. Conclusion

In conclusion, Hoffa fracture[9] associated with cruciate ligament avulsion fracture are the rare injuries encountered in orthopaedics and treatment protocol of a Hoffa fracture should include proper evaluation of condylar fracture pattern[10] and possible accompanying injuries in order to provide the best functional outcome.

Conflicts of interest

All authors have none to declare.

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JOURNAL OF ARTHROSCOPY AND JOINT SURGERY 2 (2015) 42–46

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Case Report

A case of bilateral posterior medial meniscus root tear: Partial menisectomy versus pull-out suture repair

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ARTICLE INFO

Article history:
Received 7 September 2014
Accepted 9 December 2014
Available online 7 January 2015

Keywords:
Knee arthroscopy
Meniscal root tear
Bilateral
Partial menisectomy
Meniscal repair

ABSTRACT

The meniscal roots are sites where the knee meniscus attaches to the central tibial plateau, adjacent to the tibial insertions of the cruciate ligaments. Medial meniscus root tears (MMRTs) are commonly associated with other intra-articular pathology and have a debilitating effect on knee kinematics due to loss of circumferential hoop stresses. Many surgical options for repair have been described in the literature including partial or total menisectomy, pullout sutures and suture anchors. We present a unique case of a 27 year old female who sustained a bilateral posterior horn MMRT. One knee was repaired using the pullout suture technique and the other knee underwent partial menisectomy. We found no significant difference in Lysholm scores in the short or medium term between the two methods. To our knowledge, this is the first reported case of a bilateral medial meniscus root tear.

1. Case report

A 27 year old female housewife presented with a 1 month history post-traumatic bilateral knee pain and intermittent swelling, interfering with her activities of daily living.

The patient allegedly had a twisting injury to both knees with subsequent pain and swelling and decreased range of motion bilaterally. The pain was continuous, non-radiating, aggravated on bending & sitting, relieved on lying. The patient complained of reduced mobility of both knees with an impact on her activities of daily living. There was no history of locking or giving way. There was no audible pop at the time of injury. There was no history of constitutional symptoms or any co-morbidities.

On examinations, both knees had postero-medial joint line tenderness with evidence of swelling. The medial McMurray test was positive bilaterally as was the squatting test and Thessaly test. The patient's range of motion was restricted bilaterally to 80° flexion. There was no evidence of ACL, PCL, MCL, LCL or lateral meniscus damage. There was no evidence of distal neurovascular deficit.

Lab investigations revealed elevated CRP (36.0 mg/L) but were otherwise normal. Radiographs revealed bilateral Kellgren-Lawrence Grade I osteoarthritic changes (Fig. 1). MR imaging revealed bilateral posterior medial meniscus root tears

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http://dx.doi.org/10.1016/j.jajs.2014.12.005

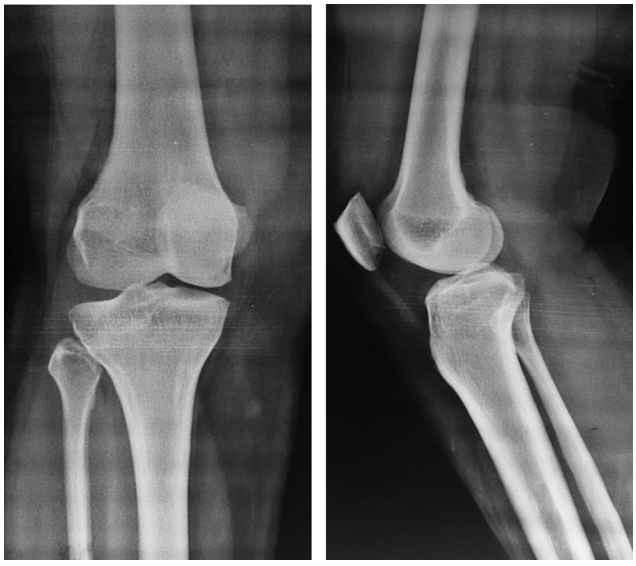

Fig. 1 – Pre-operative antero-posterior and lateral radiograph of the right knee.

with root extrusion posteriorly (Fig. 2). There was evidence of slight effusion but no other structural damage to the knee joint.

We performed a left knee arthroscopic pull-out repair of the MMRT, using Ethybond © 2-0 suture and Arthrex © suture disc, and a right knee arthroscopic partial menisectomy of the MMRT (Fig. 3 and Fig. 4). Post-operatively the patient was immobilized in a bilateral knee brace in extension with isometric strengthening exercises beginning on the first post-operative day. The patient was made full weight bearing as tolerated with crutches. Progressive active assisted range of motion exercises and active range of motion exercises were started at the end of the first post-operative week.

The Lysholm scores for the patient were recorded pre-operatively, at 2 weeks and at 3 months (Fig. 5). At 2 weeks and 3 months follow-up the patient was pain free and had good range of motion of both knees. There was no local or systemic post-operative complications. At around the 1 month mark the patient was able to return to most of her activities of daily living without pain.

2. Discussion

The meniscal roots are the sites where the knee meniscus attaches to the central tibial plateau,[1] adjacent to the tibial insertions of the cruciate ligaments. The posterior horn of the medial meniscus inserts directly anterior to the tibial insertion of the posterior cruciate ligament, on the down slope of the posterior intercondylar fossa behind the posterior horn insertion of the lateral meniscus.[2] The posterior root attachment site of the medial meniscus is critical for maintaining normal meniscal positioning, preventing extrusion and preserving meniscal function.[3] The partial immobility of the posterior horn, related to the adhesion of the medial meniscus to the MCL, makes this portion of the meniscus more susceptible to damage by axial and radial forces.[4,5]

The etiology of MMRTs is controversial. Most tears appear to be chronic and related to degenerative changes. A posterior horn MMRT is often associated with another intra-articular structural abnormality, association with MCL injuries, knee dislocations, reverse Segond fractures and marginal fractures of the medial tibial plateau have been reported.[6–8] In 1994, De Smet and Graf reported a case of posterior lateral meniscus root tear in a larger series of meniscal injuries in patients with an ACL tear.[9] A recent study found that in female patients, posterior MMRTs are associated with higher BMI, greater valgus mechanical axis angle and lower sports activity level.[10] It is thus postulated that intrinsic risk factors predispose to MMRTs.[8]

Medial meniscus extrusion (MME) is a significant medial displacement of the medial meniscus with respect to the central margin of the medial tibial plateau and is closely associated with MMRTs.[4] The meniscus is considered extruded when it extends beyond the tibial margin.[11] The critical length of extrusion is approximately 3 mm.[3,12] Other authors have attempted to correlate the ratio of extrusion length to maximal transverse length, defining an extrusion ratio threshold of 10%.[13]

Some authors have reported an association between medial subluxation or extrusion of the medial meniscus, medial femoro-tibial arthritis and posterior medial meniscus root tear.[4,12] These authors postulated that MMRTs disrupt the hoop stress function provided by circumferential fiber bundles of the meniscus. This permits radial expansion and displacement of the meniscus from the joint space (i.e. subluxation or extrusion). As such, axial compressive forces on the knee during weight bearing are transmitted directly to the articular cartilage, predisposing to premature cartilage degeneration and subsequent osteoarthritis. In a study of 293 patients with ACL tears, LMRTs were more prevalent than MMRTs, however meniscus extrusion was more common with the MMRTs.[1]

Many meniscal root tears remain unrepaired, potentially due to under-recognition and the technical challenge of repairing them.[7] When recognized, we advocate surgical intervention due to the crucial role of the roots in knee kinematics.

Many surgical options have been described in the literature. Partial or total menisectomy, commonly used in the past, relieves symptoms in most patients, with no effect on the progression of osteoarthritis.[14] Recently, the pullout suture[15] and suture anchor techniques[16] have been proposed. Because the meniscal root is vascularized,[17] it can be repaired. In acute cases, where severe cartilage damage has been excluded, the root can be repaired to restore the circumferential hoop tension, essential to guarantee the biomechanical functions of weight bearing and shock absorption.[8]

Pullout sutures reattach the detached portion of the meniscus to the tibia through a tibial tunnel from the anteromedial cortex of the proximal tibia to the insertion site of the posterior horn of the meniscus, using an ACL tibial drilling guide. When the meniscal root is attached non-anatomically, the conversion of femoro-tibial loads into circumferential

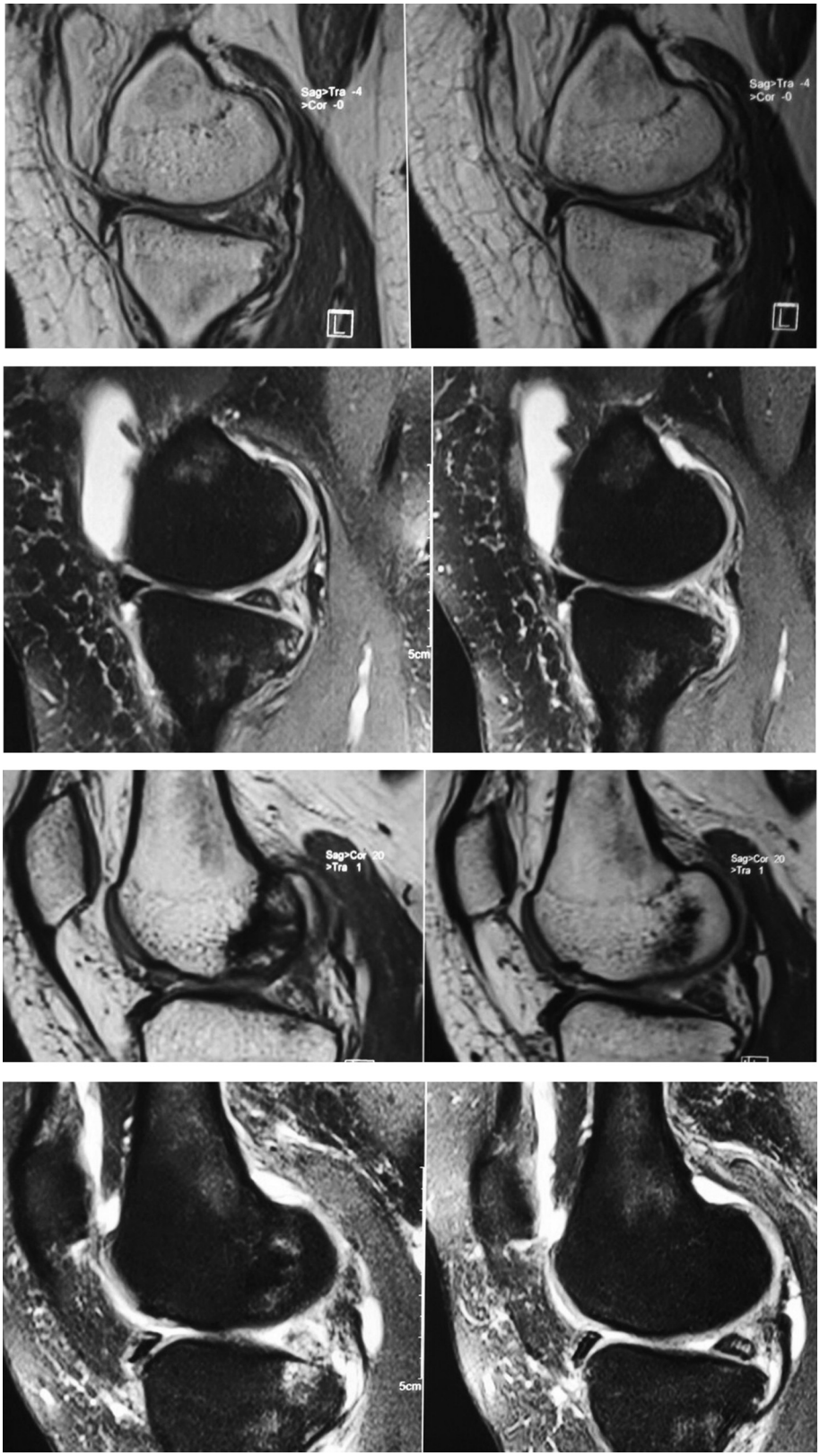

Fig. 2 – Pre-operative MRI (T1 and STIR images) of the left and right knees showing bilateral posterior meniscal root tears with medial meniscal extrusion (translation values given on MR).

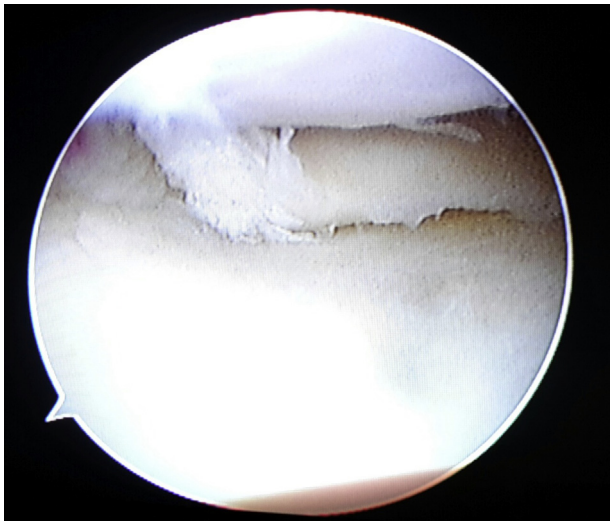

Fig. 3 – Intra-operative arthroscopic view of right MMRT.

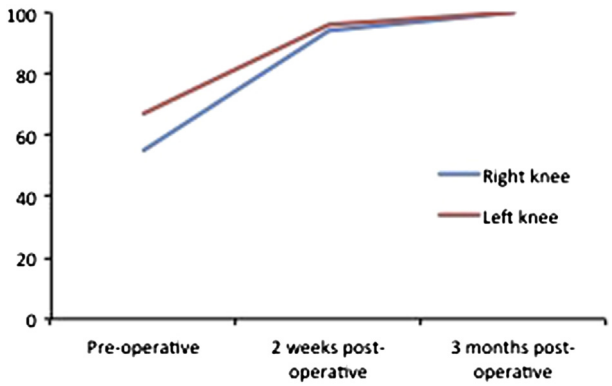

Fig. 5 – Graph of Lysholm scores of both knees pre-operatively, at 2 weeks post-operative and 3 months post-operative.

tension may be altered, with functional impairment of the knee. Thus, the reattachment site should be near anatomical.

As opposed to partial menisectomy, pullout sutures restore the hoop tension of the menisci and lead to better clinical and radiological results,[18] whereas similar results were found at 2 years in another study.[19] Suture anchors may also be used to repair these lesions, with a significant improvement in the baseline function, reduction of MME and restoration of knee function.[16]

Compared to the pullout suture, suture anchors offer the advantage of no tibial tunnel and adequate control of tension while securing the knot. Our case is unique in that a bilateral MMRT occurred in the same patient, allowing a direct comparison of partial menisectomy with pullout suture. We found no significant difference between the two techniques in the short or medium term.

Papalia et al[8] reviewed the literature of meniscal root tears and suggested acute tears and chronic meniscal tears with symptomatic grade 1 or 2 chondral changes be repaired. For, chronic tears with grade 3 or 4 changes, they suggested partial menisectomy. They[8] further advise that post-operatively, a full knee brace blocked in full extension be used for the first 2 post-op weeks and then progressive increase in knee flexion of 20° per week until full flexion is achieved. Active flexion is allowed after four weeks in the safe range of 0–90° because full flexion may impair healing of the tear. Isometric strengthening exercises are started on the first day post-op, and partial weight bearing at 6 weeks and full weight bearing at 8 weeks post-op.[8] We followed a similar rehabilitation program in our case.

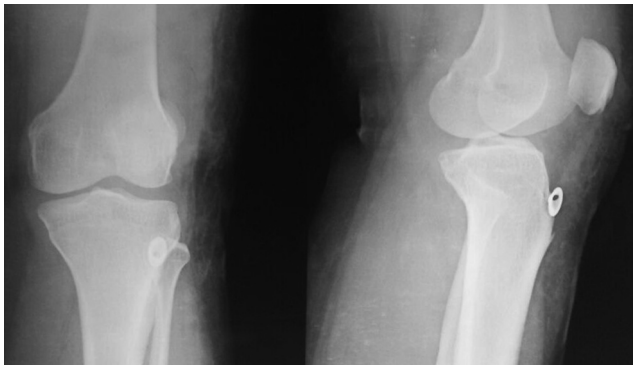

Fig. 4 – Post-operative antero-posterior and lateral radiograph of the left knee.

3. Conclusion

We present a case of a non-sporting female who sustained a post-traumatic bilateral posterior MMRT. To our knowledge, this is the first such reported case in the literature. We performed a right knee arthroscopic partial menisectomy and a left knee pullout suture repair. We found no significant difference in Lysholm scores in the short or medium term for either method.

Conflicts of interest

All authors have none to declare.

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Case Report

Ulnar nerve neuropathy following total elbow replacement

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Keywords:
Ulnar nerve
Neuropathy
Entrapment

ABSTRACT

There are numerous possible reasons behind sensory impairment of the ulnar nerve, the commonest being an iatrogenic injury occurring due to stretching of the ulnar nerve. Prolonged surgery and tourniquet time are the other possible causes. The natural course following such an injury is usually benign and the nerve recovers in three to six months. In this case the nerve failed to recover even after six months. Exploration was done at six months which showed that the nerve was in the elbow joint. This unique finding has been reported with the discussion regarding anterior transposition of the ulnar nerve in cases of total elbow arthroplasty.

1. Case report

Forty year old female presented to our orthopaedic department with complaints of paraesthesia and tingling over the little and ring fingers. She was operated upon one month back for neglected inter-condylar fracture of distal end of humerus. An operation of total elbow arthroplasty was done. On Examination she had paraesthesia over the distribution of ulnar nerve in the hand without any motor weakness. Range of motion of the elbow was 10–110. The X-rays of the elbow (Fig. 1) showed well-fixed cemented total elbow implant. There was no evidence of any loose body or extruded cement. The EMG-NCV studies suggested ulnar nerve impairment.

2. What is your diagnosis for the ulnar nerve impairment?

There are numerous possible reasons behind sensory impairment of the ulnar nerve, the commonest being an iatrogenic injury occurring due to stretching of the ulnar nerve. Prolonged surgery and tourniquet time are the other possible causes. The natural course following such an injury is usually benign and the nerve recovers in three to six months. In this case the nerve failed to recover even after six months. The sensory impairment worsened further and the patient developed sensory loss. The patient experienced paraesthesia with flexion of the elbow. The patient was taken up for surgery with a surgical plan of exploration of the nerve and internal neurolysis. The case is being reported because of the unique intraoperative findings.

3. Intraoperative findings

During exploration the nerve was found to be in the elbow joint and had a tortuous course. It was interesting to note that the nerve was getting compressed when the elbow was flexed passively (Fig. 2).

The possible cause in this case could be very specific. The primary surgeon seems to have performed sub-muscular

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http://dx.doi.org/10.1016/j.jajs.2014.12.004

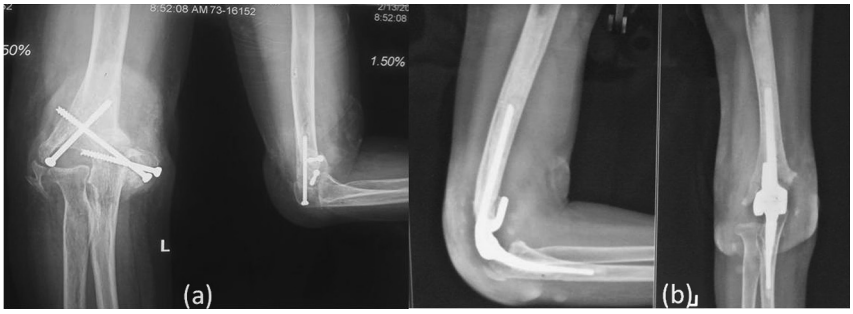

Fig. 1 – Preoperative (a) and postoperative (b) photographs of the patient showing well-fixed cemented implant.

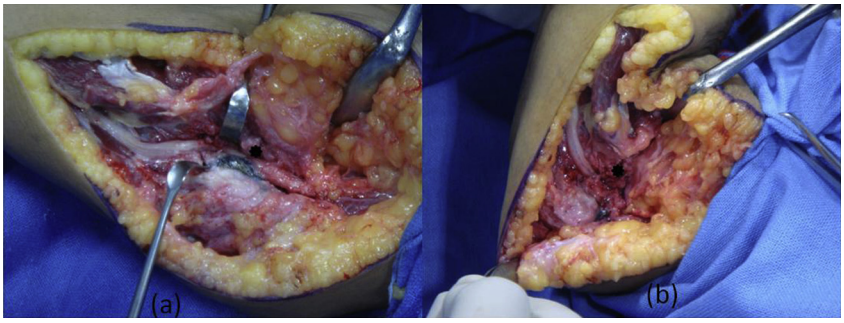

Fig. 2 – Intraoperative photographs showing ulnar nerve in the elbow joint. The ulnar nerve was getting compressed with flexion of the elbow as shown by the asterix (b).

anterior transposition of the ulnar nerve. The internal neurolysis was done and the nerve was transposed anteriorly subcutaneously. The patient improved completely in next three months.

4. Discussion

Total elbow arthroplasty is a standard technique for comminuted inter-condylar fracture of humerus which are not reconstructable.[1] Ulnar nerve impairment has been stated from 5% to 12%.[2,3] Subcutaneous transfer of the ulnar nerve is the most common method for anterior transposition of the ulnar nerve.[2] The other methods that had been described for anterior transposition of ulnar nerve are (1) intramuscular transfer and (2) sub-muscular transfer. The later described methods are much surer way for anterior transposition. After total elbow arthroplasty, the sub-muscular transfer is not done routinely. Total elbow arthroplasty for comminuted distal humerus fracture results in significant shortening of the limb. This leads to a tortuous course of the ulnar nerve due to its relative lengthening. Sub-muscular anterior transposition may lead to entrapment of the nerve into the joint. The purpose of this case report is to highlight this issue so that sub-muscular transfer may not be done in cases of total elbow arthroplasty for comminuted distal humerus fractures. Similarly, the authors also advocate that sub-muscular transfer may also be avoided in cases of revision elbow arthroplasty for the same reasons. We advocate sub-cutaneous anterior transposition of ulnar nerve in cases where it is likely to be entrapped.

Conflicts of interest

All authors have none to declare.

Acknowledgements

Nature of the work performed by the authors for this study: Mohammed Tahir Asnari: Manuscript preparation, First Assistant Surgeon Praksah P. Kotwal: First surgeon and manuscript preparation.

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JOURNAL OF ARTHROSCOPY AND JOINT SURGERY 2 (2015) 49–53

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Resident's corner

Activity related hip pain in a young adult

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ARTICLE INFO

Article history:
Received 12 December 2014
Accepted 23 December 2014
Available online 21 January 2015

Keywords:
Femoroacetabular impingement
Hip impingement
Pincer
Cam
Hip arthroscopy

ABSTRACT

Two most common causes of non-inflammatory hip disease in the adolescent and young adult patient population are FAI or hip dysplasia. This article describes the clinical presentation of a patient with femoroacetabular impingement (FAI). It explains presentation and pathophysiology, and goes on to discuss important radiological parameters to diagnose FAI. In the end, treatment strategy of FAI is summarised.

1. Case summary

A 27 years old lady was referred by general practitioner, with complaints of having painful right hip that has progressively worsened over past 2 years. She describes her pain as sharp and deep inside the hip joint. This pain is especially worse on prolonged sitting and long distance driving. Occasionally her hip pain has been severe enough to restrict her daily activities with pain score of 8/10. She used to be a keen runner but due to her hip pain she can no longer continue with her recreational activities.

In addition to pain, she also feels clicking inside her hip, often with associated giving away sensation. There is no history of previous trauma, back ache or radiating pain down the leg, and she is otherwise fit and well. There is no relation of hip pain with her menstrual cycle. Apart from taking regular analgesics, she is not on any other medications.

Clinical examination reveals normal gait with no true or apparent leg length discrepancy. There is no swelling in the groin or around the hip joint and there are no signs of any hernias. Hip examination reveals bilaterally equal hip flexion of 100° with external rotation of 50°. At 90° of hip flexion, both hips have markedly reduced internal rotation of 15° with right hip painful. Pain on internal rotation was sharp and localised to the groin. Straight leg raise test is negative. Knee and lumbosacral examination is normal with no distal neurovascular deficit. Abdominal examination is also normal.

X-ray AP pelvis performed and shown in Fig 1.

2. Questions (answers overleaf)

1. What is the differential diagnosis of groin pain in an active young adult?
2. What are the positive findings on the X-ray shown in Fig. 1?
3. What are the clinical symptoms and signs of femoroacetabular impingement (FAI)?
4. What is the pathophysiology of FAI?

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http://dx.doi.org/10.1016/j.jajs.2014.12.008

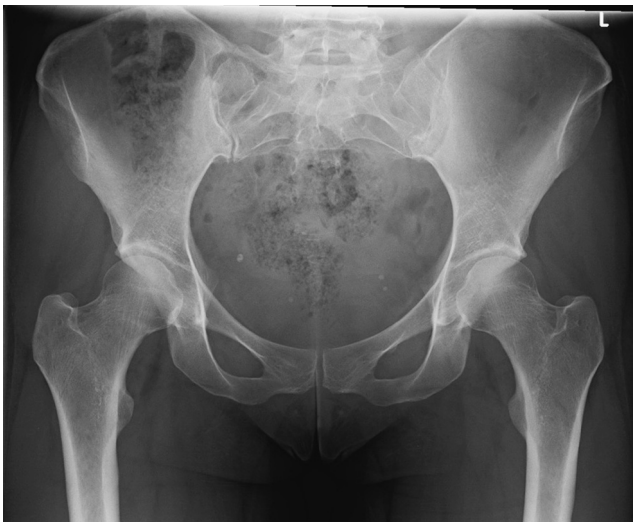

Fig. 1 – Standing anteroposterior (AP) pelvis X-ray showing both hip joints.

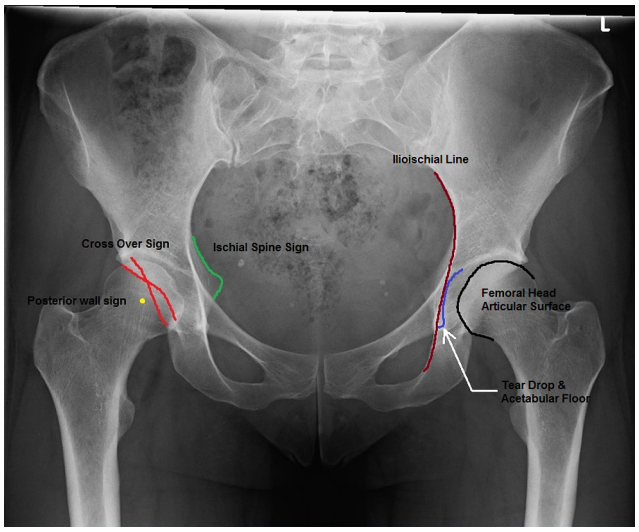

Fig. 2 – Standing AP pelvis X-ray, showing Cross over (red), Ischial spine (green), and Posterior wall sign (yellow) in right hip. Left hip shows normal relationship of ilioischial line (maroon), acetabular floor (blue) and femoral head articular surface (black).

5. What are the radiological parameters of pincer lesion?
6. What are the radiological parameters of cam lesion?
7. Why is it important to looks for signs of hip dysplasia in suspected cases of FAI?
8. What are the secondary abnormalities caused by FAI?
9. How do you treat FAI?

1. What is the differential diagnosis of groin pain in an active healthy young adult?

Groin pain can emanate from hip, abdomen, spine and pelvis. In the absence of any history and clinical signs and symptoms of abdominal or spinal disorders, the groin pain is most likely due to hip joint disorders. The differential diagnosis of hip joint disorders causing groin pain in adolescents and adults includes FAI, hip dysplasia, stress fractures, avascular necrosis, iliopsoas tendinopathy, adductor strain, rectus femoris strain, tumour, infection and arthritis. Two most common causes of non-inflammatory hip disease in the adolescent and young adult patient population are FAI and hip dysplasia.[1]

2. What are the positive findings on the X-ray shown in Fig. 1?

Fig. 1 shows appropriately performed X-ray AP pelvis without any signs of pelvic rotation (tip of coccyx in line with centre and 2–3 cm above pubic symphysis, symmetrical obturator foramina, tear drops and iliac wings).

There are signs of bilateral acetabular retroversion. These signs are highlighted as cross over, ischial spine and posterior wall sign in Fig. 2. There are no signs of hip dysplasia or osteoarthritis (OA) with well preserved joint space.

3. What are the clinical symptoms and signs of FAI?

Patients with symptomatic FAI usually complain of pain in anterior groin. Large majority of patients at some stage had been involved in physical activities resulting in extreme flexion and rotational movements of hip joint like athletics and dancing. Patients often localise their pain to the groin by holding the anterolateral thigh and groin with hand in a cupping position called 'C sign'. Internal rotation is markedly restricted followed by hip flexion. The most sensitive test pointing towards FAI is impingement test causing sharp groin pain with hip in flexion, adduction and internal rotation (FADIR).[2] In a recent study, impingement test (FADIR) was positive in 88% of confirmed cases of FAI.[2]

Patients with labral tears secondary to impingement also have mechanical symptoms presenting as clicking or snapping deep inside the groin with occasional associated giving away sensation. These mechanical symptoms can be elicited while performing impingement test.

4. What is the pathophysiology of FAI?

In FAI, there is abnormal abutment of femur against the acetabulum due to anatomical abnormalities of femoral head–neck junction and/or acetabulum. This impingement is a dynamic process and occurs during joint motion. Over a period of time, the process of impingement results in damage to acetabular labrum and/or cartilage. There is some evidence to suggest that FAI may be the cause of 40%–50% cases of hip arthritis.[3] Anatomical abnormality causing FAI can exist as either cam or pincer lesion. If anatomical abnormality causing FAI is at the femoral head–neck junction then it is called 'cam lesion', where as an abnormally prominent acetabular rim causing impingement is known as 'pincer lesion'. Quite often it is a variable combination of both of these lesions that results in impingement.

Cam lesion is usually located at the anterior or anterosuperior femoral head–neck junction and these lesions mostly if not always cause damage deep into the acetabular cartilage at the chondrolabral junction.[4]

On the other hand, pincer lesion results in acetabular 'over-coverage'. This over-coverage of acetabulum can be either 'focal' or 'global'. Acetabular retroversion is the most common cause of focal pincer lesion. On the other hand, global pincer type lesion is secondary to abnormally deep acetabulum either due to coxa profunda or protrusio

acetabuli[5] (Fig. 2). Pincer lesions mostly result in intra-substance labral tears in contrast to cam lesions.[4]

5. What are the radiological parameters of pincer lesion?

A number of radiological parameters have been described that aid in the diagnosis of FAI and also help to delineate the type of FAI (i.e. cam, pincer or combination). The standard radiographic evaluation includes AP pelvis and horizontal beam lateral view of proximal femur.

While taking AP pelvic X-ray, the pelvis must not be rotated or tilted. Acetabular retroversion is assessed by looking for three important radiological parameters i.e. cross over, ischial spine and posterior wall sign. All three signs should be present to diagnose true acetabular retroversion.

Normal acetabulum has an average anteversion of 15°. As a result on AP pelvis, the line representing anterior acetabular rim appears to join the line of posterior acetabular rim at the superior edge of the weight bearing roof of acetabulum called 'sourcil'. Cross over sign is observed if the line of anterior acetabular rim crosses or over laps that of posterior acetabular rim and represents either acetabular retroversion or anterior over coverage (Fig. 2).

The presence of prominent ischial spine on AP pelvic radiograph represents a retroverted acetabulum and is a common finding in the presence of cross over sign[6] (Fig. 2).

In normal anteverted acetabulum, the outline representing posterior acetabular rim should descend lateral or centre to the femoral head.[7] Posterior wall sign is positive if the visible edge of posterior acetabular rim is medial to the centre of femoral head thus representing deficient posterior wall (Fig. 2).

Absent posterior wall sign in the presence of cross over and ischial spine sign represents anterior over coverage without retroversion.

In normal hip joint, acetabular floor and femoral head articular surface is lateral to ilioischial line (Fig. 2). The presence of 'global pincer lesion' secondary to either coxa profunda or protrusio acetabuli is determined by how far acetabular floor has medialised with respect to the ilioischial line. In coxa profunda, only acetabular floor is medial to ilioischial line, however if femoral head also follows the acetabular floor then it is defined as acetabular protrusion.

6. What are the radiological parameters of cam lesion?

Although AP pelvic view can be used to assess cam lesion, it is better evaluated using lateral view of proximal femur. Femoral head is normally spherical and sphericity is determined by making a concentric circle (Mose template) over the centre of femoral head[8] (Fig. 3). If the femoral epiphysis extends beyond the confines of circle by > 2 mm, the femoral head is defined as aspherical.[9] An objective parameter of assessing the cam lesion on lateral view is by measuring the alpha (α) angle. This angle is measured by drawing a perfect concentric circle around femoral head followed by drawing two lines to show the limbs of the angle. First line is made along the long axis of femoral neck toward the centre of previously drawn circle. Second line is drawn from the centre of the circle anteriorly towards the point where the head extends beyond the circle[10] (Fig. 4). Normal mean α angle is < 50°.

7. Why is it important to looks for signs of hip dysplasia in suspected cases of FAI?

Hip dysplasia associated with FAI follows a different route of surgical management. Inappropriate diagnosis can often lead to treatment failure and sometimes worsening of symptoms. Two important radiological parameters for hip dysplasia on any AP pelvis X-ray are lateral centre edge (LCEA) and Tonnis angle.

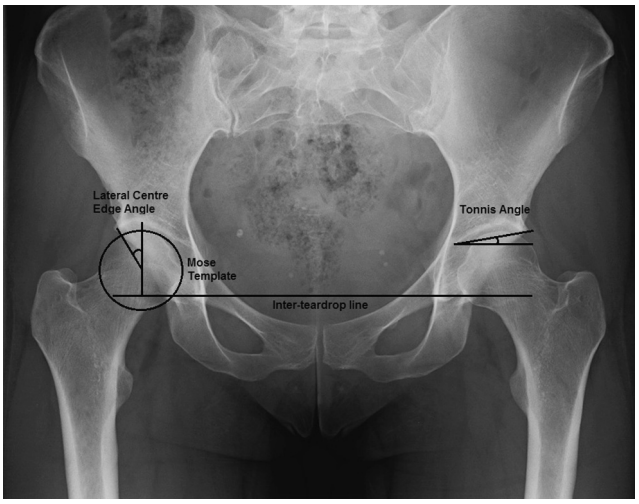

Fig. 3 – Mose template (circle drawn on right femoral head) showing femoral head sphericity. Inter-tear drop line is used as pelvic reference line to measure lateral centre edge angle on right and Tonnis angle on left hip.

LCEA determines the adequacy of femoral head coverage on AP radiograph of pelvis. This angle is measured by using three lines. First line is the inter-teardrop line with second perpendicular to the first line and passing through the centre of the femoral head. The third line joins the centre of the femoral head to the lateral edge of the acetabular sourcil. The angle formed by the second and third line is the lateral centre edge angle (Fig. 3). Angle <20° represents under-coverage of femoral head by the acetabulum and thus points toward dysplasia. Normal LCEA is between 25° to 40°.

Tonnis angle represents the inclination of the weight bearing dome (sourcil) of the acetabulum. Normal Tonnis

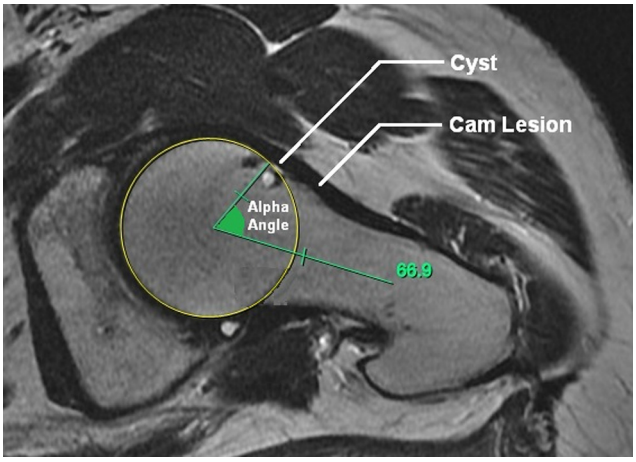

Fig. 4 – Axial MRI of left hip showing high α angle (66.9°) with cam lesion. Subchondral cyst is also seen at the anterior femoral head.

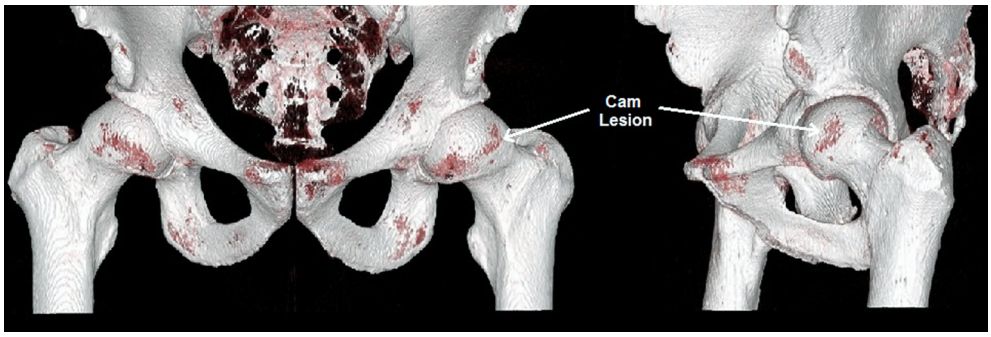

Fig. 5 – CT scan with 3D reconstruction showing large anterosuperior cam lesion at the femoral head–neck junction.

angle is between 0°-10° with <0° classified as decreased and >10° as increased angle.

It is measured by drawing three lines. Line 1 is the inter-teardrop line with line 2 drawn parallel to the inter-teardrop line and centred over the inferomedial edge of the acetabular sourcil. The third line (line 3) joins the superolateral edge of the sourcil to its inferomedial edge (where line 2 is intersecting the medial sourcil edge). The angle subtended between line 2 and line 3 is the Tonnis angle[9] (Fig. 4).

Presence of reduced LCEA and increase Tonnis angle points towards hip dysplasia, thus warranting further investigations and increased clinical vigilance.

8. What are the secondary abnormalities caused by FAI?

Primary lesions of FAI (cam and/or pincer) eventually lead to cartilage and/or labral damage. These present as labral tears, cartilage fissuring or delamination and cyst formation (Fig. 4).

Intrasubstance labral tears are more commonly associated with pincer lesion where the impingement occurs more peripherally at the level of acetabular rim. On the other hand, tears at chondrolabral junction are the hall mark of cam lesion. The best modality to identify the labral tears is MRA (MR Arthrogram) with reported sensitivity and accuracy of 100% and 94% respectively.[11]

9. How do you treat FAI?

The approach to treating FAI depends on the type of FAI (cam, pincer or both), presence of secondary abnormalities, extent of arthritis, and any associated hip dysplasia.

In cases of FAI without hip dysplasia and no or low grade arthritis, the treatment of choice is arthroscopic excision of impingement lesion. In addition to excising the impingement lesions, any associated secondary abnormalities are also treated by debridement or repair. However, arthroscopic approach has its limitations as one can not easily access far posterior labral or impingement lesions.

Surgical hip dislocation (SHD) using trochanteric osteotomy approach has been popularised by Ganz and is employed to treat any form and extent of FAI.[12] In a 7 year follow-up study of 213 patients, there was not even a single case of iatrogenic AVN associated with SHD. Complications requiring re-operations were Brooker grade 4 heterotopic ossification (0.9%) and non-union of trochanteric osteotomy (1.4%).[12]

The presence of dysplasia with impingement lesion should be assessed very carefully. Any attempt to excise a potential pincer lesion in the presence of dysplastic acetabulum can result in further hip instability and failure of treamtent.[13] Any signs of dysplasia should ideally be further investigated by CT scan with 3D reconstruction to determine the extent of femoral head coverage offered by acetabulum (Fig. 5). These patients can be treated with adjunctive arthroscopic cam excision with or without labral repair, but impingement secondary to pincer lesion is corrected by peri-acetabular osteotomy and/or proximal femoral osteotomy. These redirective osteotomies tend not only to correct pincer impingement but also improve the femoral head coverage and instability.

Conflicts of interest

All authors have none to declare.

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Corrigendum

Corrigendum to "A review of functional anatomy and surgical reconstruction of medial patellofemoral ligament" [J Arthrosc Joint Surg 1 (1) (2014) 1–50]

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The authors would like to inform that in the above mentioned paper, one of the co-author was missed to be included on the authorship line. The authors would like to apologize to the readers for the error.

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DOI of original article: http://dx.doi.org/10.1016/j.jajs.2013.11.006.
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