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Knee & Shoulder Arthroscopy And Arthroplasty ISKSAA

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Aims and Scope

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

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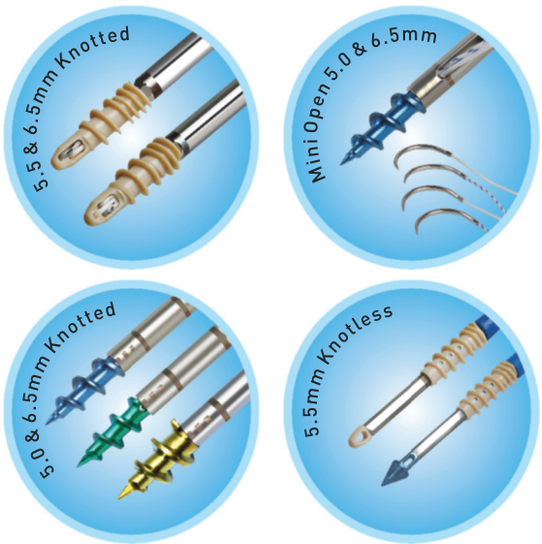

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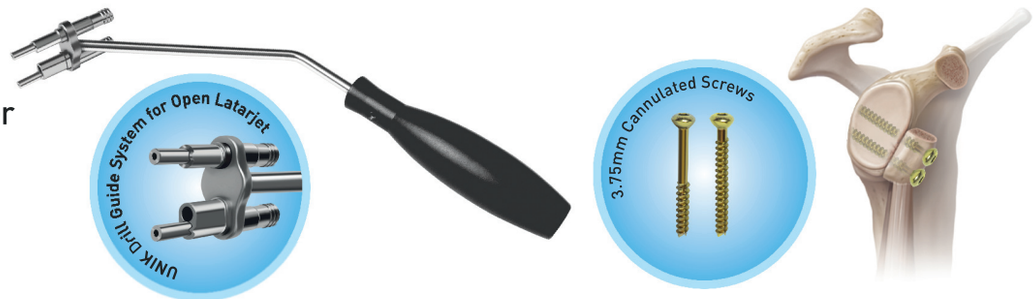

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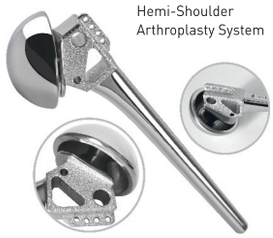

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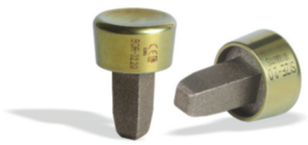

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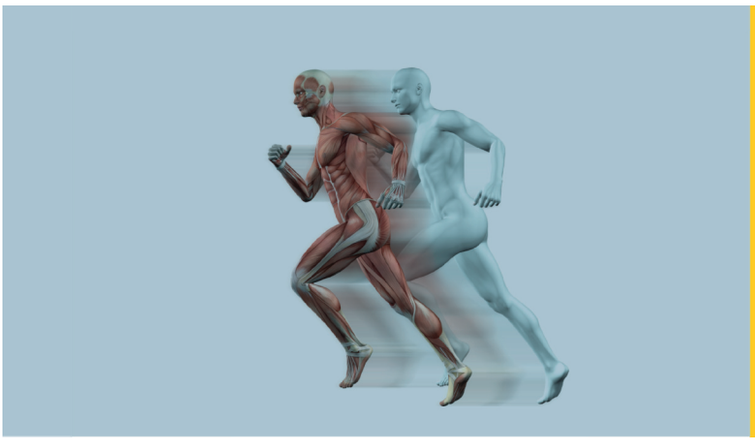

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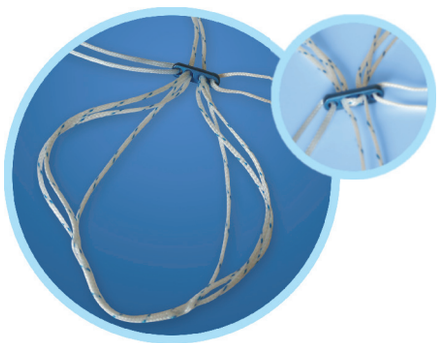

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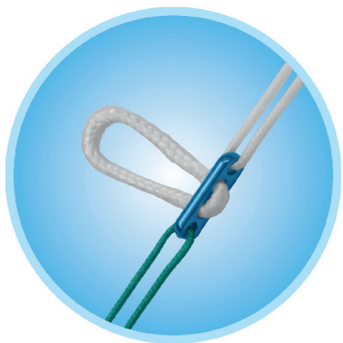

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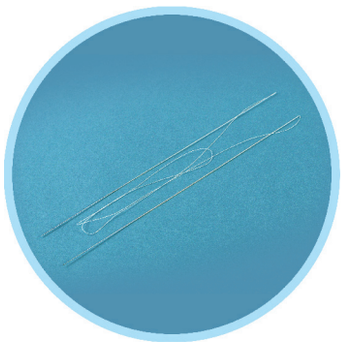

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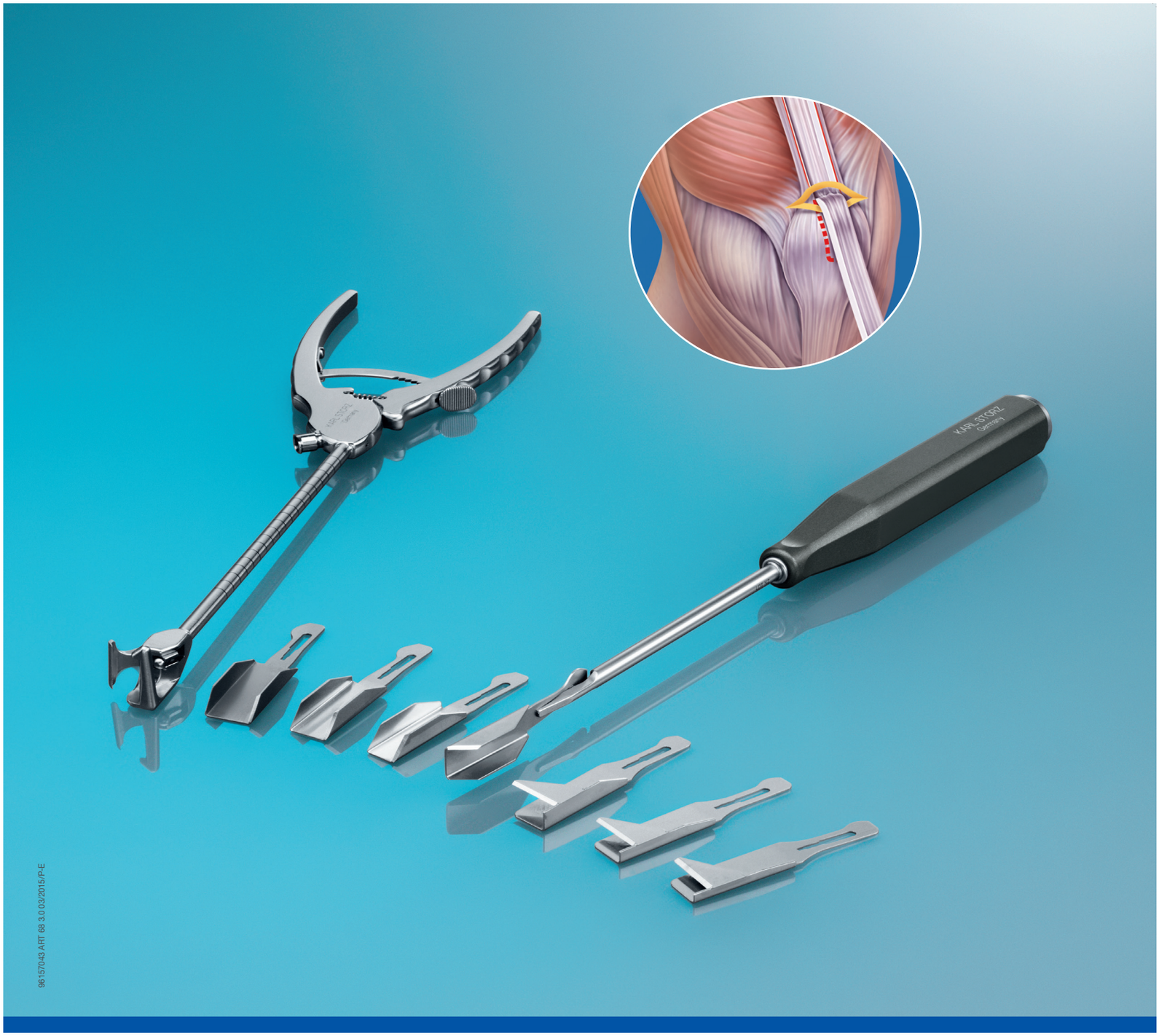

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Decompression surgery under pressure

Keywords:
Subacromial impingement
Subacromial decompression
CSAW
FIMPACT

1. Introduction

Painful shoulders pose a substantial economic burden[1] accounting for 2–4% of primary care consultations in the UK[2] and 4.5 million visits to physicians annually in the USA.[3]

Neer[4] described the subacromial impingement syndrome as a potential cause of subacromial pain. The mechanism proposed involved mechanical contact between the rotator cuff tendons and the extrinsic overlying acromion or bone spur that often forms at the anteroinferior margin of the acromion, narrowing the subacromial space.

Whilst subacromial pain accounts for up to 70% of all shoulder pain problems[5] it is important to realise that such pain may be caused by a spectrum of shoulder pathology including subacromial impingement but also rotator cuff tears and calcific tendinitis. In addition, subacromial impingement is commonly associated with other pathologies including biceps tendonitis and acromioclavicular joint arthritis.

1.1. This editorial focusses on isolated subacromial impingement

There have been a number of studies published which advocate the use of physiotherapy in the treatment of subacromial impingement. A study by Hallgren et al.[6] published in 2014 in the British Journal of Sports Medicine showed an improvement in patients treated by a three month exercise specific programme. Only 20% of patients treated by exercise went on to surgery compared to 63% in the control group. Similarly, in 2013 Ketola et al.[7] published a randomised control trial comparing an exercise programme to subacromial decompression (in conjunction with the exercise programme). In their study of 109 patients, at 5-year follow up, no significant difference could be found between the two groups.

In contrast, other studies have indicated an improved outcome following subacromial decompression surgery over therapy. In 2018, Farfaras et al.[8] published a prospective randomised trial with a ten year follow up period which showed significantly better outcomes in patients treated by open and arthroscopic subacromial decompression over physiotherapy alone.

Whilst there is no doubt that many patients with isolated subacromial impingement will respond to non operative treatment alone,[9] surgical intervention is often used in the treatment of recalcitrant cases.

In 2015, the British Elbow and Shoulder Society published a patient care pathway for the management of subacromial shoulder pain.[10] This care pathway formed the basis of the commissioning guidelines which were NICE approved.[11]

The commissioning guidelines for the management of rotator cuff tendinopathy/subacromial impingement suggest the following measures should be considered in the initial treatment of this condition:

- Education, rest, NSAIDs, simple analgesia
- Appropriate structured physiotherapy with goal setting for 6 weeks to include postural correction and motor control retraining, stretching, strengthening of the rotator cuff and scapula muscles and manual therapy
- Do not consider further physiotherapy unless there is improvement during the first 6 weeks of treatment
- Injection of corticosteroid into the subacromial space. Normally, only one injection should be considered as repeated injections may cause tendon damage
- A second injection is occasionally appropriate after 6 weeks, but should only be administered in patients who received good initial benefit from their first injection and who need further pain relief to facilitate their structured physiotherapy treatment

The guidelines further recommend arthroscopic shoulder decompression (acromioplasty) should be considered for patients with:

- Impingement pain in the absence of a rotator cuff tear
- Impingement pain with an irreparable rotator cuff tear
- Impingement pain with a cuff tear that the patient chooses not to have repaired
- Failure of appropriate conservative management

The guidelines advise that a shared decision making model should be adopted, defining treatment goals and taking into account personal circumstances.

Historically it has been considered that the mechanism by which decompression surgery is effective is by increasing the subacromial space, hence preventing extrinisic impingement of the rotator cuff tendons by the overlying acromion process.[4] This is done by excising the anterior bony acromial spur, flattening the undersurface of the acromion and excising the overlying bursal tissue

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(bursectomy). However it should be noted that this mechanism has been brought in to question in the light of recent research.

In 2009, a RCT performed by Henkus et al.[12] compared subacromial decompression (acromial resection) plus bursectomy with bursectomy alone and reported no significant difference in clinical outcome between the groups.

Recently, the Can Shoulder Arthroscopy Work (CSAW) study[13] was published in the Lancet. This trial focused specifically on subacromial decompression in isolation and aimed to investigate whether the proposed critical surgical element, removal of bone and soft tissue, is necessary.

All of the patients in the study were suffering from subacromial impingement pain and had had symptoms for a minimum duration of three months. All patients had an intact rotator cuff or partial thickness tendon tear and had failed to respond to physiotherapy treatment and at least one cortisone injection.

The trial randomised patients to three treatment options:

i. Arthroscopic surgery with surgical decompression
ii. Arthroscopy without surgical decompression (placebo surgery)
iii. No surgery and observation only.

The results of the trial were as follows:

i. There was no difference between arthroscopic subacromial decompression and arthroscopy only (placebo surgery)
ii. Patients improved without further treatment and with observation only
iii. Surgery (both decompression and placebo) conveyed a small, statistically significant improvement compared to observation only but this was not considered to be clinically relevant.
iv. The trial concluded that the difference between the surgical routes and no treatment might be the result of a placebo effect or postoperative physiotherapy

When published, the trial raised significant media interest and unsurprisingly, the economic benefit of subacromial decompression surgery was immediately brought into question.

In response to the study, a joint statement was issued by the British Elbow and Shoulder Society, British Orthopaedic Association and the CSAW study group.[14] The statement noted that the trial had shown the mechanism by which subacromial decompression surgery provided improvement was uncertain and had demonstrated that some patients can improve without surgery. Furthermore, it highlighted the importance of involving patients in a decision making process and of applying appropriate commissioning guidelines.

There is published evidence that treating patients according to national guidelines is associated with improved outcomes. In 2017 Jacobsen et al.[15] evaluated arthroscopic subacromial decompression in 244 patients selected according to national guidelines. The guidelines stated that pain must have been present for longer than 6 months and a physiotherapy programme (non-specific) must have been be undertaken for a minimum of 3 months before decompression surgery was considered. Patients treated on this basis demonstrated significant clinical improvements following decompression at 6 month follow up. The authors concluded that arthroscopic subacromial decompression was a valid treatment, reducing pain and improving quality of life for patients selected for surgery according to the Danish national guidelines.

Shortly after publication of the CSAW study, a simillar study was published, in the BMJ - the Finnish Shoulder Impingement Arthroscopy Control Trial (FIMPACT).[16] The aim of this study was to assess the efficacy of arthroscopic subacromial decompression, comparing it with a placebo surgical intervention (diagnostic arthroscopy) and with a non-operative alternative, exercise therapy, in a more pragmatic setting. It was a multicentre three group randomised double-blind, sham control trial. There were 210 participants with symptoms consistent with shoulder impingement syndrome for more than 3 months that had failed to improve with conventional conservative treatment.

In the primary intention to treat analysis (arthroscopic subacromial decompression versus diagnostic arthroscopy) no clinically relevant between-group differences were seen in the Visual Analogue Scale (VAS) scores at arm rest or on arm activity at 24 months. In the secondary comparison (arthroscopic subacromial decompression versus exercise therapy), statistically significant differences were found in favour of arthroscopic subacromial decompression in both VAS at rest and on arm activity at 24 months but the mean differences between groups did not exceed the prespecified minimal clinically important difference (MCID).

The FIMPACT authors argue that diagnostic arthroscopy can be perceived as a placebo intervention as tidal irrigation and arthroscopic lavage have both failed to provide a benefit over placebo procedures in knee osteoarthritis.[17,18] One could argue that this might not be the case. If there has been an overestimation of the effects of the anterior bony spur in isolated subacromial impingement, patients may be comparatively more symptomatic from subacromial bursitis (or bursal degeneration) than previously thought.[12] It is known that corticosteroid injections have a local anti-inflammatory effect on the bursa and are a recognised treatment modality for subacromial impingement and therefore one could postulate that arthroscopic bursoscopy may dilute the effect of local inflammatory mediators associated with subacromial bursal degeneration leading to a reduction in pain.

Nonetheless, the results of the CSAW and FIMPACT trials clearly question the role by which subacromial decompression surgery is effective and raise the possibility that there is a significant placebo effect.

Whilst it is easy for surgeons to ignore the results of these important studies, good professional practice dictates that we must accept the results of these well designed trials and question our own clinical practice.

The British Elbow and Shoulder Society is working with the Royal College of Surgeons, the British Orthopaedic Association and NICE to producing revised commissioning guidelines for decompression surgery.

In addition, further clinical research is required to help surgeons define the criteria by which patients who would benefit from decompression surgery can be identified.

Finally, it is important to reiterate that the results from the CSAW and FIMPACT studies focus on isolated subacromial impingement and do not consider other possible co-existing shoulder pathologies for which subacromial decompression is performed concurrently.

Conflict of interest declaration

None.

References

1. Urwin M, Symmons D, Allison T, et al. Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Ann Rheum Dis*. 1998;57:649–655.
2. Linsell L, Dawson J, Zondervan K, et al. Prevalence and incidence of adults consulting for shoulder conditions in UK primary care; patterns of diagnosis and referral. *Rheumatology*. 2006;45:215–221.
3. Oh LS, Wolf BR, Hall MP, Levy BA, Marx RG. Indications for rotator cuff repair: a systematic review. *Clin Orthop Relat Res*. 2007;455:52–63.
4. Neer CS. Anterior acromioplasty for the chronic impingement syndrome in the

shoulder. *J Bone Joint Surg Am*. 2005;87:1399.
5. Mitchell C, Adebajo A, Hay E, Carr A. Shoulder pain: diagnosis and management in primary care. *BMJ*. 2005;331:1124–1128.
6. Hallgren HC, Holmgren T, Oberg B, Johansson K, Adolfsson LE. A specific exercise strategy reduced the need for surgery in subacromial pain patients. *Br J Sports Med*. 2014 Oct;48(19):1431–1436. https://doi.org/10.1136/bjsports-2013-093233.
7. Ketola S, Lehtinen J, Rousi T, et al. No evidence of long-term benefits of arthroscopic acromioplasty in the treatment of shoulder impingement syndrome: five-year results of a randomised controlled trial. *Bone Joint Res*. 2013 Jul 1;2(7):132–139. https://doi.org/10.1302/2046-3758.27.2000163.
8. Farfaras S, Sernert N, Rostgard Christensen L, Hallström EK, Kartus JT. Subacromial decompression yields a better clinical outcome than therapy alone: a prospective randomized study of patients with a minimum 10-year follow-up. *Am J Sports Med*. 2018 May;46(6):1397–1407. https://doi.org/10.1177/0363546518755759.
9. Cummins CA, Sasso LM, Nicholson D. Impingement syndrome: temporal outcomes of nonoperative treatment. *J Shoulder Elbow Surg*. 2009;18:172–177.
10. Kulkarni R, Gibson J, Brownson P, et al. Subacromial shoulder pain BESS/BOA patient care pathways. *Shoulder Elbow*. 2015;7(2):135–143.
11. 2014 Commissioning Guide: Subacromial Shoulder Pain. BOA/RCS/CSP/BESS/ https://www.boa.ac.uk/wp-content/uploads/2014/08/Subacromial-Shoulder-Commissioning-Guide_final.pdf.
12. Henkus HE, de Witte PB, Nelissen RG, Brand R, van Arkel ER. Bursectomy compared with acromioplasty in the management of subacromial impingement syndrome. *J Bone Joint Surg [Br]*. 2009;91-B:504–510.
13. Beard DJ, Rees JL, Cook JACSAW Study Group, et al. Arthroscopic subacromial decompression for subacromial shoulder pain (CSAW): a multicentre, pragmatic, parallel group, placebo-controlled, three-group, randomised surgical trial. *Lancet*. 2018;391:329–338. https://doi.org/10.1016/S0140-6736(17)32457-1.
14. https://www.boa.ac.uk/wp-content/uploads/2017/11/BOA-and-BESS-statement-Subacromial-Decompression-21.11.17.pdf.
15. Jacobsen JR, Jensen CM, Deutch SR. Acromioplasty in patients selected for operation by national guidelines. *J Shoulder Elbow Surg*. 2017 Oct;26(10):1854–1861. https://doi.org/10.1016/j.jse.2017.03.028.
16. Paavola M, Malmivaara A, Taimela S, et al. For the Finnish Shoulder Impingement Arthroscopy Controlled Trial (FIMPACT) Investigators. Subacromial decompression versus diagnostic arthroscopy for shoulder impingement: randomised, placebo surgery controlled clinical trial. *BMJ*. 2018;362:k2860http. https://doi.org/10.1136/bmj.k2860.
17. Moseley JB, O'Malley K, Petersen NJ, et al. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. *N Engl J Med*. 2002;347:81. https://doi.org/10.1056/NEJMoa013259.
18. Bradley JD, Heilman DK, Katz BP, Gsell P, Wallick JE, Brandt KD. Tidal irrigation as treatment for knee osteoarthritis: a sham-controlled, randomized, double-blinded evaluation. *Arthritis Rheum*. 2002;46:100–108. https://doi.org/10.1002/1529-013.

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Review article

Is there a difference in treatment outcome for monomicrobial and polymicrobial periprosthetic joint infections? Systematic review and study quality analysis

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ABSTRACT

Purpose: To perform a systematic review comparing the functional and objective outcomes for periprosthetic joint infection (PJI) caused by a single organism versus polymicrobial PJI.
Methods: A systematic review of the treatments, as well as functional and objective outcomes of clinical studies comparing single organism and polymicrobial PJI was performed, with a mean follow up of at least 24 months and minimum level of evidence of III. Following review of the literature, a quantitative comparison between success/failure rates after the treatment of monomicrobial vs polymicrobial PJI was performed. The methodological quality of each study was assessed using a modified version of the Coleman methodology score (mCMS).
Results: The systematic search identified 6 studies, including 1075 patients (829 in the single organism group and 246 in the polymicrobial group). All the studies were case control studies. Definitions for success and treatment failure were heterogeneous. The mean success rate for any treatment of monomicrobial infection was 70.4% (range, 64.7–87.5%) and 58.4% (range, 27.8–85.7%) for polymicrobial infections, respectively ($p = 0.29$). The mean survivorship for treated monomicrobial and polymicrobial PJI were 69.4% (range, 66–72.8%) and 58% (52–63.8%).
Conclusions: Quantitative analysis demonstrated that although polymicrobial infections have been identified as a risk factor for failure after a PJI, they did not result in significantly worse outcomes after treatment. Though not statistically significant, polymicrobial PJI with gram negative organisms typically resulted in poorer outcomes as compared to PJI with gram positive organisms. Antibiotic coverage should be evaluated to ensure proper coverage of such gram-negative organisms.
Level of evidence: Systematic Review of Level III Studies.

1. Introduction

Infection has been reported to be the most common etiology for revision after a total knee arthroplasty (TKA) and total hip arthroplasty (THA). According to the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) database, periprosthetic infection accounts for 20.4%[1] and 14.8%[2] of complication following TKA and THA, respectively. Patients with a periprosthetic joint infection (PJI) have been reported to have significantly longer hospitalizations (5.3 vs. 3.0 days), higher rates of readmission (3.6 vs. 0.1 readmissions), and more clinic visits (6.5 vs. 1.3 visits) when compared to the matched group.[3] This represents an important economic burden to the healthcare system, with a calculated case cost of USD 390,806 per 65-year-old patient with an infected THA.[4]

Berbari et al.[5] reported that the four most important risk factors

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predictive of PJI were postoperative surgical site infection, national nosocomial infection surveillance score greater than 2, concurrent malignancy, and prior joint arthroplasty. Polymicrobial periprosthetic joint infections are relatively infrequent with a reported rate between 6% and 37%.[6–9] Despite this relative infrequency, polymicrobial PJI are believed to have higher failure rates as compared to single organism PJI. Potential explanations for the divergence in failure rates between poly- and monomicrobial PJI include older average age, greater comorbidities,[10,11] and more virulent organisms such as enterococcus and gram negatives,[9,11–13] among patients with polymicrobial PJI.[14,15]

Due to such aforementioned reasons, there is a critical need to determine differences in outcomes and failures rates between single and polymicrobial periprosthetic joint infections. Therefore, the purpose of this paper was to perform a systematic review on the outcomes for PJI caused by a single organism and multiple organisms. It was hypothesized that standard treatment would result in hardware retention in both single organism and polymicrobial PJI and there would be no significant differences in outcomes between the single organism polymicrobial PJI following treatment.

2. Materials and methods

2.1. Article identification and selection

This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement.[16] A systematic review of the literature regarding functional and objective outcomes for PJI caused by a single organism and polymicrobial PJI was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1990–2017) and Medline (1990–2017). The queries were performed in December 2017.

The literature search strategy inclusion criteria were as follows: functional and objective outcomes of clinical studies comparing single organism and polymicrobial PJI treatment, mean follow-up of at least 24 months, and a level I, II or III of evidence within the English literature.

The following 2 searches were performed.

Search 1 (Knee): periprosthetic[All Fields] AND (“joints"[MeSH Terms] OR ″joints"[All Fields] OR ″joint"[All Fields]) AND (“infection"[MeSH Terms] OR ″infection"[All Fields]) AND (“knee"[MeSH Terms] OR ″knee"[All Fields] OR ″knee joint"[MeSH Terms] OR (“knee"[All Fields] AND ″joint"[All Fields]) OR ″knee joint"[All Fields])

Search 2 (Hip): periprosthetic[All Fields] AND (“joints"[MeSH Terms] OR ″joints"[All Fields] OR ″joint"[All Fields]) AND (“infection"[MeSH Terms] OR ″infection"[All Fields]) AND (“hip"[MeSH Terms] OR ″hip"[All Fields])

Cadaveric studies, animal studies, basic science articles, editorial articles and surveys were excluded. Two investigators (initials blinded for review) independently reviewed the abstracts from all identified articles. Full-text articles were obtained for review if necessary to allow further assessment of inclusion and exclusion criteria. Additionally, all references from the included studies were reviewed and reconciled to verify that no relevant articles were missing from the systematic review.

2.2. Data collection and analysis

The level of evidence of the studies was assigned according to the classification as specified by Wright et al.[17] Patient demographics, follow-up, surgical techniques and objective and subjective outcomes were extracted and recorded. For continuous variables (e.g., age, timing, follow-up, outcome scores), the means, standard deviations, and interquartile ranges were collected (if reported). Data was recorded into a custom spreadsheet using a modified information extraction table.[18]

Means and standard deviations were required to calculate weighted mean differences of continuous outcomes between PJI caused by a single organism and polymicrobial PJI. For studies that only reported on ranges, the SD was imputed as range divided by 4 or interquartile range divided by 1.35.[19] Studies that only reported median subjective scores[20,21] were not included in the synthesis calculations as these outcome scales are known to have ceiling effects postoperatively, and thus the median is not considerate a good estimate of the mean.[22] For comparing survivorship, the paired samples *t*-test was utilized for normally distributed data. For non-parametric data, the Wilcoxon-Signed Rank test was used. Comparisons of two categorical data were performed by use of Chi-square tests and Fisher Exact tests. All p-values were two-tailed and p-values of <0.05 were considered significant.

2.3. Literature quality evaluation

Two reviewers (*initials blinded for review*) used a modified version of the Coleman methodology score (mCMS) [to better fit the included studies] to assess the methodological quality of each study.[23] The two-part mCMS grades cartilage-related studies based on ten criteria. The maximum score of the mCMS is 100, which indicates a study largely avoids chance, biases and confounding factors.

3. Results

3.1. Study selection

The process for study selection is presented in Fig. 1. Searches identified 1670 individual titles and abstracts. After removal of duplicates, 1520 studies were eliminated based on inclusion/exclusion criteria, leaving 134 articles for full-text review. After a thorough review of these articles and their citations, a total of 6 level III studies were identified that explicitly reported demographics and characteristics of mono and polymicrobial PJI.

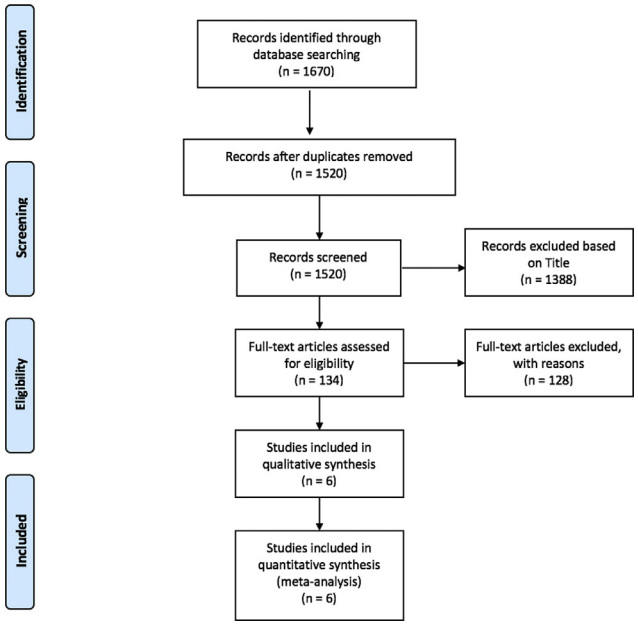

Fig. 1. PRISMA flowchart for the selection of the studies.

3.2. Patient demographics

The 6 studies included 1075 patients (829 in the single organism group and 246 in the polymicrobial group), and reported on 323 TK A and 497 THA, as summarized in Table 1 (Table 1). Mean patient age was 65.8 (range, 28–93).

3.3. Treatment approaches

The overall mean time from primary surgery to primary debridement was 7.7 months (range, 0.47–337 months). Thirty-one percent of monomicrobial PJI were treated within three months of index joint replacement (mean: 8.1 months, range: 0.47–337 months). Forty-three percent of polymicrobial PJI were treated within 3 months of index joint replacement (mean: 7.2 months, range: 2.6–307 months). There was significantly greater number of monomicrobial PJI treated in the delayed phase compared to polymicrobial PJI ($p = 0.001$). Treatment modalities are reported in Table 2 (Table 2).

3.4. Outcomes of treatment

The mean success rate for any treatment of monomicrobial infection was 70.4% (range, 64.7–87.5%) and 58.4% (range, 27.8–85.7%) for polymicrobial infections ($p = 0.29$). Two studies reported two-year survivorship for both mono and polymicrobial PJI.[10,11] The mean survivorship for treated monomicrobial and polymicrobial PJI was 69.4% (range, 66–72.8%) and 58% (52–63.8%). One study reported 5 and 10-year survivorship following PJI. For mono and polymicrobial PJI the reported 5-year survivor ship was 64% and 49.3%, respectively. The reported 10-year survivorship for mono and polymicrobial PJI was 62% and 46.8%, respectively. Definitions of failure and outcomes of treatment are summarized in Table 3 (Table 3).

3.5. Literature quality evaluation

A detailed analysis of the quality is demonstrated in Table 4 (Table 4).

4. Discussion

The most important finding of this study was that, following treatment, the functional and objective outcomes of polymicrobial PJI are consistently poorer than single organism infections. However, no significant difference was found between survival rates of both groups. Patients with polymicrobial infections were older and usually included infections by enterococcus and gram negatives. Only one study reported on long term outcomes: for mono and polymicrobial PJI the reported 5-year survivorship was 64% and 49.3%, respectively. The reported 10-year survivorship for mono and polymicrobial PJI was 62% and 46.8%.[11] Methodologic quality of the included studies ranged from 48 to 69 points (out of 100 possible points) deeming the available literature as acceptable.

Although the risk of infection after primary joint replacement is relatively low (ranges from 1.7% to 2.1%),[24] the consequences of its occurrence are potentially devastating. PJIs have been reported to impact several aspects of patients' lives including ability to work, as well as straining relationships with family members who become care-givers during patient's relatively immobile periods .[25] Moreover, prolonged time of treatment was directly related with patient dissatisfaction.[25] Patients experienced a poorer sense of well-being following a 2-stage versus a 1-stage revision, due to greater immobility between stages, and higher rates of psychological distress.[25] Participants interviewed in this study, expressed a need for more psychological and rehabilitative support during treatment and long-term recovery.[25]

Staphylococcus aureus and coagulase negative staphylococci were the main pathogens reported for single organism PJI, whereas Enterococcus and gram negatives were more frequently reported for polymicrobial infections. Bozhkova et al.[13] reported that in the monomicrobial group, the proportion of methicillin-resistant strains in patients with unsuccessful and successful outcomes was 8.7 and 17.3%, respectively. Similar findings were found in the polymicrobial group with 23.6 and 35.3% of all staphylococci, respectively. Of note, Gram-negative pathogens caused polymicrobial PJI in 61.5% of cases with infection recurrence (OR 4.4; 95% CI 1.18–16.37; $p = 0.03$).[13] The authors suggested that cases with microbial associations were more likely to result in infection recurrence (OR 7.7; CI 95%,3.79–15.73).

Table 1
Characteristics of the selected studies. L.O.E: level of evidence, M: male, F: female.

Author (Year)	Journal	L.O.E	Type of Study	Group	Microorganisms (majority)	# of Patients	Sex Distribution	Age (range)
Marculescu (2008)	Clin Orthop Relat Res	III	Retrospective	Monomicrobial	Gram Positive	140	M: 60 F: 80	63 (28–89)
				Polymicrobial	Gram Positive	34	M: 15 F: 19	69.5 (32–93)
Zmistowski (2011)	J Arthroplasty	III	Retrospective	Monomicrobial	Gram Positive/Neg	270	NR	66.4 (33–89)
				Polymicrobial	Gram Positive	12	NR	73.7 (67–80)
Wimmer (2015)	International Orthopaedics (SICOT)	III	Retrospective	Monomicrobial	Gram Positive	40	M: 26 F: 14	68.8 (NR)
				Polymicrobial	Gram Positive	37	M: 16 F: 21	67.9 (NR)
Tan (2016)	J Bone Joint Surg	III	Retrospective	Monomicrobial	Gram Positive	200	M:102 F: 98	65.4 (41.4–85.4)
				Polymicrobial	Gram Positive	95	M: 50 F: 45	65 (43.8–86.2)
Bozhkova (2016)	J Orthopaed Traumatol	III	Retrospective	Monomicrobial	Gram Positive	135	M: 92 F: 97	57 (49–67)
				Polymicrobial	Gram Positive	54	NR	57 (44–69)
Figa (2017)	Anaerobe	III	Retrospective	Monomicrobial	Gram Positive	24	M: 9 F: 15	73 (66.5–77.8)
				Polymicrobial	Gram Positive	14	M: 12 F: 2	63 (52.5–69.3)

Table 2
Treatment characteristics for both monomicrobial and polymicrobial infections. NR: not reported, abx: antibiotics. DAIR: debridement and implant retention.

Author (Year)	Group	Mean time primary surgery to primary debridement (Months)	Early (<3 months)	Delayed (>3 months)	Antibiotic Therapy	Single or Staged Surgery	Main Procedure
Marculescu (2008)	Monomicrobial	15.1 (0.47–337.7)	28.6	71.4	Depending on the specimen	Single: 65% Staged: 35%	Debridement and retention
	Polymicrobial	1.7 (3.3–307)	55.9	44.1	Depending on the specimen	Single: 73.6% Staged: 26.4%	Debridement and retention
Zmistowski (2011)	Monomicrobial	NR	16	84	NR	Single: 15% Staged: 85%	2 Stage- removal at first stage, abx spacer, replant
	Polymicrobial	NR	50	50	NR	Single: 33.3% Staged: 66.7%	2 Stage- removal at first stage, abx spacer, replant
Wimmer (2015)	Monomicrobial	2.6 (NR)	NR	NR	Depending on the specimen	Single: 48.1% Staged: 51.9&	
	Polymicrobial	4.3 (NR)	NR	NR	Depending on the specimen	Single: 51.9% Staged: 48.1%	
Tan (2016)	Monomicrobial	NR	NR	NR	Depending on the specimen	NR	NR
	Polymicrobial	NR	NR	NR	Depending on the specimen	NR	NR
Bozhkova (2016)	Monomicrobial	12 (3–50)	27.4	23.7	Vancomycin with beta-lactam or quinolones; alternatively, betalactam with quinolones or aminoglycosides	Staged	
	Polymicrobial	20 (10–52.5)	20.4	25.9			
Figa (2017)	Monomicrobial	2.8 (2.6–3)	54	46	Clindamicin	Single: 42% Staged: 58%	2-Stage, Non-DAIR 1 Stage
	Polymicrobial	2.8 (2.6–3)	43	57	Clindamicin + Rifampin	Single: 7% Staged: 93%	2 Stage; Non-DAIR

Table 3
Failure definitions by each of the studies and rates of success and failure. %: percentage; ys: years; NR: not reported.

Author (Year)	Definition of Failure	Group	Failure (%)	Success Rate (%)	Survivorship (2ys)	Survivorship (5ys)	Survivorship (10ys)
Marculescu 2008	Relapse, Reinfection, presence of acute infection/purulence in the joint space, development of a sinus tract communicating with the prosthesis, superinfection or indeterminate clinical failure	Monomicrobial	32.8	67.2	72.8	NR	NR
		Polymicrobial	35.3	64.7	63.8	NR	NR
Zmistowski 2011	Need for infection related component removal after first surgical treatment	Monomicrobial	33.3	66.7		NR	NR
		Polymicrobial	66.7	33.3		NR	NR
Wimmer 2015	Persistence or recurrence of PJI with the same or an unknown pathogen during or after the completion of antimicrobial therapy	Monomicrobial	12.5	87.5		NR	NR
		Polymicrobial	33.4	67.6		NR	NR
Tan 2016	(1) Failure to eradicate infection (indicated by presence of wounds with fistula, drainage, pain, infection by same organism strain), (2) need for surgical intervention for infection after reimplantation surgery, (3) occurrence of PJI-related mortality.	Monomicrobial	31.5	68.5	66	64	62
		Polymicrobial	50.5	49.5	52.2	49.3	46.8
Bozhkova 2016	Inflammatory signs remained or reappeared during the period between first step and reimplantation presence of acute inflammation with high levels of serum CRP, development of a sinus tract and relapse or reinfection.	Monomicrobial	25.2	74.8	NR	NR	NR
		Polymicrobial	72.2	27.8	NR	NR	NR
Figa 2017	Recurrence of PJI with any pathogen despite either 1 or 2 stage procedure + Abx	Monomicrobial	20.8	79.2	NR	NR	NR
		Polymicrobial	14.3	85.7	NR	NR	NR

Traditionally, polymicrobial infection is associated with higher failure rates and was considered a contraindication for one stage re-implantation in the management of PJIs. Previous studies demonstrated persistent infection in 6%–28% of patients after first-stage debridement, thus requiring repeated debridements.[13] Zmitowski et al.[26] reported that a single debridement and retention of prosthesis was successful in 70% of isolated gram negative cases, compared with 33.3% of methicillin-sensitive gram positive, 48.9% of methicillin-resistant gram positive, and 57.1% of polymicrobial cases. Of those patients undergoing a planned 2-stage exchange, a successful re-implantation was performed in 52% of gram-negative, 51% of methicillin-resistant gram-positive, 69% of methicillin-sensitive gram-positive, and 0% of polymicrobial PJI cases. The authors suggested that PJIs due to gram-negative (E Coli, Proteus, Serratia) pathogens, although less common, have poorer outcomes due to their limited treatment success.[26] Similarly, Yoon et al.,[27] reported an increased debridement frequency correlated significantly with high comorbidity ($P < 0.001$), a lower preoperative Harris hip score (HHS; $P < 0.001$), antimicrobial resistance, and gram-negative and polymicrobial infection ($P = 0.002$) at 5.4 years follow-up. Marculescu and Cantey[10] identified patients 65 years of age and older, presenting with a soft tissue defect or wound dehiscence and drainage, and those who had prior local irradiation and less bacteremia as potential risk factors predicting polymicrobial infections in a univariate regression. The presence of a sinus tract was reported as an additional risk factor for polymicrobial PJI, according to Tan et al., likely due to the lack of soft tissue integrity which allows for entry of organisms into the joint. Obesity and elevated CRP have also been found to increase risk of polymicrobial PJI.[13]

Tan et al. also evaluated the survivorship of the polymicrobial periprosthetic joint infection group and reported a 52.2%, a 49.3%,

Table 4
Modified version of the Coleman methodology score (mCMS).

Part A	Score	Figa	Bozhkova	Tan	Wimmer	Marculescu	Zmitowsky
Study size: Number of patients							
>60	10		10	10	10	10	10
41–60	7						
20–40	4	4					
>20, not stated	0						
Mean follow-up, month							
>60	10		10	10	10		
24–60	7	7				7	7
12–24	4						
<12, not stated	0						
No. of different treatment procedures included in each reported outcome. More than 1 method may be assessed, but separate outcomes should be reported							
1 procedure	10			10	10		
Surgical methods and/or nonoperative treatment methods More than 1 method but >90% of subjects undergoing the 1 procedure	7	7	7				7
Not stated, unclear, or <90% of subjects undergoing the 1 procedure	0					0	
Type of study							
Randomized control trial	15						
Prospective cohort study	10						
Retrospective cohort study	0	0	0	0	0	0	0
Description of surgical procedure given							
Adequate (technique stated and necessary details of that type of procedure given)	5	5	5				5
Fair, technique only stated without elaboration	3			3	3	3	
Inadequate, not stated or unclear	0						
Cohort comorbidities matching				0			
Cohorts matched	5		5	5	5	5	5
Unmatched or undefined	0	0					
Description of postoperative rehabilitation							
Well described	5						
Not adequately described	2						
Protocol not reported	0	0	0	0	0	0	0
Laboratory assessment							
Reported	10	10	10	10	10	10	10
Not reported	0						
Part B							
Outcome criteria							
Outcome measures clearly defined	3			3	3	3	3
Use of outcome criteria that has reported good reliability and sensitivity	2	2	2	2	2	2	2
Treatment success definition							
Well defined	5	5	5	5	5	5	5
Not defined	0						
Implant survivorship							
Reported	5			5		5	5
Not reported	0	0	0		0		
Procedure for assessing clinical outcomes							
Patients recruited (i.e., result not taken from surgeon' files)	3	3	3	3	3	3	3
Investigator independent of surgeon	4					4	
Completion of assessment by patients themselves with minimal investigator assistance	2						
	3			3	3	3	3
	5	5	5				
	3						
Total		**48**	**62**	**69**	**64**	**60**	**65**

and a 46.8% survival rate at the 2, 5 and 10-year follow-up respectively.[11] Patients with polymicrobial periprosthetic joint infection had higher rates of amputation (odds ratio [OR], 3.80 [95% confidence interval (CI), 1.34 to 10.80] p 0.012), arthrodesis (OR, 11.06 [95% CI, 1.27 to 96.00] p 0.029), and periprosthetic joint infection-related mortality (OR, 7.88 [95% CI, 1.60 to 38.67]p 0.0011) compared with patients with monomicrobial periprosthetic joint infection.[11] Similar findings were reported for Marculescu and Cantey,[10] who showed that the 2-year cumulative probability of success of polymicrobial PJIs was 63.8% (95% confidence interval [CI], 43.8%–80.5%) and that of monomicrobial PJIs was 72.8% (95% CI, 63%–80.9%). Conversely, Figa et al. reported no significant outcome differences between monomicrobial and polymicrobial PJIs cases; with success rates of 79.2% and 85.7% respectively ($P > 0.05$).[28]

Among the interventions commonly used to treat PJI, 2-stage revision resulted in consistently better outcomes, as compared to 1-stage revision or debridement and retention.[10,11] This may be due to the use of an antibiotic spacer in the 2-stage technique. Of note, however, Zmistowski et al.[26] noted that 2-stage revision is less successful in the treatment of polymicrobial PJI with gram negative organisms than it is with polymicrobial PJI with gram positive organisms. Gram negatives release lipopolysaccharide which initiates persistent inflammation and increases the ability of other organisms to implant, enhancing its virulence which may contribute to poorer treatment outcomes.[26]

The authors acknowledge limitations to the present study, including heterogeneity in the reporting of subjective outcomes, definitions of successful treatment and failure of the procedure. Furthermore, surgeon specific indications for performing specific antibiotic therapy and single or staged procedures may have affected the results in the included studies. Finally, some of the included studies included concomitant pathology and/or procedures, which may have altered outcomes. As with all systematic

reviews, it possible that relevant articles or patient populations were not identified with our search criteria.

5. Conclusion

Quantitative analysis demonstrated that although polymicrobial infections have been identified as a risk factor for failure after a PJI, they did not result in significantly worse outcomes after treatment. Though not statistically significant, polymicrobial PJI with gram negative organisms typically indicated poorer outcomes as compared to PJI with gram positive organisms. Antibiotic coverage should be evaluated to ensure proper coverage of such gram-negative organisms. As heterogeneous success/failure rates were reported in the literature, further research using standardized definitions, is indicated.

Disclosures

The authors have no disclosures to report.

References

1. Delanois RE, Mistry JB, Gwam CU, Mohamed NS, Choksi US, Mont MA. Current epidemiology of revision total knee arthroplasty in the United States. *J Arthroplasty*. 2017;32(9):2663.
2. Bozic KJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The epidemiology of revision total hip arthroplasty in the United States. *J. Bone Joint Surg. Am. Vol.* 2009;91(1):128.
3. Kapadia BH, McElroy MJ, Issa K, Johnson AJ, Bozic KJ, Mont MA. The economic impact of periprosthetic infections following total knee arthroplasty at a specialized tertiary-care center. *J Arthroplasty*. 2014;29(5):929.
4. Parisi TJ, Konopka JF, Bedair HS. What is the long-term economic societal effect of periprosthetic infections after THA? A markov analysis. *Clin Orthop Relat Res*. 2017;475(7):1891.
5. Berbari EF, Hanssen AD, Duffy MC, et al. Risk factors for prosthetic joint infection: case-control study. *Clin Infect Dis. Official publ. Infectious Dis. Soc. Am.* 1998;27(5):1247.
6. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res*. 2008;466(7):1710.
7. Holleyman RJ, Baker P, Charlett A, Gould K, Deehan DJ. Microorganisms responsible for periprosthetic knee infections in England and Wales. *Knee Surg Sports Traumatol Arthrosc. Official journal of the ESSKA*. 2016;24(10):3080.
8. Moran E, Masters S, Berendt AR, McLardy-Smith P, Byren I, Atkins BL. Guiding empirical antibiotic therapy in orthopaedics: the microbiology of prosthetic joint infection managed by debridement, irrigation and prosthesis retention. *J Infect*. 2007;55(1):1.
9. Peel TN, Cheng AC, Buising KL, Choong PF. Microbiological aetiology, epidemiology, and clinical profile of prosthetic joint infections: are current antibiotic prophylaxis guidelines effective? *Antimicrob Agents Chemother*. 2012;56(5):2386.
10. Marculescu CE, Cantey JR. Polymicrobial prosthetic joint infections: risk factors and outcome. *Clin Orthop Relat Res*. 2008;466(6):1397.
11. Tan TL, Kheir MM, Tan DD, Parvizi J. Polymicrobial periprosthetic joint infections: outcome of treatment and identification of risk factors. *J. Bone Joint Surg. Am. Vol.* 2016;98(24):2082.
12. Wimmer MD, Friedrich MJ, Randau TM, et al. Polymicrobial infections reduce the cure rate in prosthetic joint infections: outcome analysis with two-stage exchange and follow-up >/=two years. *Int Orthop*. 2016;40(7):1367.
13. Bozhkova S, Tikhilov R, Labutin D, et al. Failure of the first step of two-stage revision due to polymicrobial prosthetic joint infection of the hip. *J Orthop Traumatol. Official J. Ital. Soc. Orthop. Traumatol.* 2016;17(4):369.
14. Castellani L, Daneman N, Mubareka S, Jenkinson R. Factors associated with choice and success of one- versus two-stage revision arthroplasty for infected hip and knee prostheses. *HSS J. Musculoskel. J. Hosp. Special Surg.* 2017;13(3):224.
15. Kheir MM, Tan TL, Higuera C, et al. Periprosthetic joint infections caused by enterococci have poor outcomes. *J Arthroplasty*. 2017;32(3):933.
16. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*. 2009;151(4):264.
17. Wright JG, Swiontkowski MF, Heckman JD. Introducing levels of evidence to the journal. *J Bone Joint Surg Am Vol*. 2003;85-a(1):1.
18. Harris JD, Quatman CE, Manring MM, Siston RA, Flanigan DC. How to write a systematic review. *Am J Sports Med*. 2014;42(11):2761.
19. Schumm WR, Higgins M, Lockett L, et al. Does dividing the range by four provide an accurate estimate of a standard deviation in family science research? *A Teaching Editorial. Marriage & Family Review*. 2016;1.
20. Yoon KH, Bae DK, Song SJ, Cho HJ, Lee JH. A prospective randomized study comparing arthroscopic single-bundle and double-bundle posterior cruciate ligament reconstructions preserving remnant fibers. *Am J Sports Med*. 2011;39(3):474.
21. Houe T, Jørgensen U. Arthroscopic posterior cruciate ligament reconstruction: one- vs. two-tunnel technique. *Scand J Med Sci Sports*. 2004;14(2):107.
22. Cumming TB, Churilov L, Sena ES. The missing medians: exclusion of ordinal data from meta-analyses. *PLoS One*. 2015;10(12), e0145580.
23. Kon E, Verdonk P, Condello V, et al. Matrix-assisted autologous chondrocyte transplantation for the repair of cartilage defects of the knee: systematic clinical data review and study quality analysis. *Am J Sports Med*. 2009;37(Suppl 1):156S.
24. Ilchmann T, Zimmerli W, Bolliger L, Graber P, Clauss M. Risk of infection in primary, elective total hip arthroplasty with direct anterior approach or lateral transgluteal approach: a prospective cohort study of 1104 hips. *BMC Musculoskelet Disord*. 2016;17(1):471.
25. Moore AJ, Blom AW, Whitehouse MR, Gooberman-Hill R. Deep prosthetic joint infection: a qualitative study of the impact on patients and their experiences of revision surgery. *BMJ open*. 2015;5(12), e009495.
26. Zmistowski B, Fedorka CJ, Sheehan E, Deirmengian G, Austin MS, Parvizi J. Prosthetic joint infection caused by gram-negative organisms. *J Arthroplasty*. 2011;26(6 Suppl):104.
27. Yoon YC, Lakhotia D, Oh JK, Moon JG, Prashant K, Shon WY. Is two-stage reimplantation effective for virulent pathogenic infection in a periprosthetic hip? A retrospective analysis. *World J Orthoped*. 2015;6(9):712.
28. Figa R, Muneton D, Gomez L, et al. Periprosthetic joint infection by Propionibacterium acnes: clinical differences between monomicrobial versus polymicrobial infection. *Anaerobe*. 2017;44:143.

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Mid to long-term outcomes of the primary constrained condylar knee arthroplasty

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ABSTRACT

Background: The design of the constrained condylar knee (CCK) implant is meant to provide significantly more varus-valgus and anterior-posterior stability than a standard implant system. We hypothesized that while an increased constraint in design may lead to radiographic signs of loosening, the pain and functional outcome scores for patients with constrained implants remain acceptable at a mid to long term follow-up.

Methods: 113 patients who underwent a primary TKA with a CCK implant by a single surgeon between the years 2008–2015 were contacted. 28 patients (30 knees) responded and returned for evaluation, which consisted of a Knee Society Score questionnaire and repeat radiographs. The average time to follow-up was 49.5 months.

Results: Pain outcome scores (total of 30 knees) included, 19 excellent (63.3%), 7 good (23.3%) and 4 poor outcomes (13.3%). Function scores included 19 excellent (63.3%), 2 good (6.6%), 4 fair (13.3%), and 5 poor (16.7%) outcomes. There was a significant difference ($p = 0.032$) in pain scores between patients with no signs of radiographic lucency (mean pain score of 88.6) and patients with signs of implant loosening (mean pain score of 78.3). There was no significant difference in functional scores.

Conclusion: The CCK implant is an acceptable option for a total knee arthroplasty which requires the extra stability not provided by a standard implant system. More studies with larger sample sizes, different populations and longer follow-up are needed to further evaluate outcomes in CCK implant recipients.

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1. Introduction

A primary total knee arthroplasty is a safe option with predictable outcomes for patients with painful arthritis who have failed other interventions. The incidence of both primary and revision total knee arthroplasty has significantly increased over the last decade due to many factors including an aging population and more widespread availability. Additionally, the volume of primary total knee Medicare patients has increased by 161.5% between the years 1991 and 2010.[8] The need for primary and revision total knee replacements is estimated to more than triple by 2030.[7] With this increase in demand, there has also been an increase in research into different operative techniques and implant designs. As more patients gain access to orthopaedic care, including those with baseline deformity or ligamentous laxity, CCK implants are more frequently used in obtaining a stable well-aligned knee.

Historically, a constrained total knee arthroplasty has been most often used in revision surgeries. It has also been used during surgeries in which the surgeon is unable to balance a knee intraoperatively.[5] Indications include a knee with medial or lateral ligamentous insufficiency, loss of bone stock, significant deformities and neuropathic or rheumatoid arthropathy.[2] The design

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of the implant provides varus-valgus and anterior-posterior stability that cannot be obtained with routine coronal plane balancing alone. Along with this increase in implant constraint, there exists a potential increase in implant wear and failure rates. Previous studies have reported the revision rate for primary TKAs using a constrained implant is more than two times higher compared to unconstrained knees at 10 years.[3] The overall revision rate for constrained total knee implants has been reported up to 22% at 10 years, and up to 35% for revision knees, with the most common reason being infection.[2]

At our institution the use of a constrained total knee implant has been utilized in many primary total knee cases. Specifically, it has been used in patients who are found to have medial or lateral laxity that is unacceptable for standard posterior stabilized total knee implants intra-operatively. The purpose of this study was to retrospectively review a population of patients that have undergone primary total knee arthroplasty using a constrained condylar knee implant, and evaluate them based on pain, function, and radiographic scales. We hypothesized that despite the increased constraint of their implant, patients would still have positive outcomes as measured by pain and function scores.

2. Methods

After IRB approval, a retrospective chart review was performed on a single-surgeon patient population between the years 2008 and 2015. A cohort of patients who underwent a primary TKA using a constrained condylar implant between 2008 and 2015 with a

Fig. 1. Knee Society Score Pain form utilized during patient encounters.

minimum of 1 year follow-up was identified. All of the patients underwent surgery in the same medical center with a single surgeon. Each received a Zimmer Legacy Constrained Condylar Knee (LCCK, Warsaw, IN) implant after intraoperative evaluation of ligamentous laxity performed by the attending surgeon.

All patients underwent medial parapatellar or midvastus approach. After initial bone cuts were made the flexion and extension gaps were examined, and trial components placed. If the coronal plane balance and alignment of the knee could not be restored with bone cuts or soft tissue balancing the decision was made intra-operatively to transition to LCCK stemmed implants. Stem size was determined by reaming both tibial and femoral canals with progressively larger reamers until adequate diaphyseal fit was obtained. All implants were cemented utilizing a metaphyseal cementing technique.

Patients who met inclusion criteria were contacted via a written letter requesting participation in the study. A total of 113 letters were sent with 28 patients consenting to return for pain, functional and radiographic evaluation. Two of those 28 patients had undergone bilateral TKA with constrained implants for a total of 30 knees to be evaluated. A small monetary incentive in the form of a gift card was offered to the patients as compensation for their time. Those who consented to participating in the study were seen in the office for a single follow-up visit. During this visit they filled out a Knee Society Score pain and function questionnaire (Figs. 1 and 2), had repeat radiographs and were examined by one of the authors. The KSS is a validated outcome measurement that includes subjective patient responses on pain and daily function levels as well as an objective score based on range of motion measurements, laxity, and overall clinical alignment.[1] These physical exam findings were evaluated with goniometer measurements in the office. Additionally, an AP and Lateral radiograph was obtained of each operative knee. Immediate post-operative radiographs were obtained from the hospital database for comparison to the new images (Fig. 3). Each radiograph was evaluated independently by two musculoskeletal radiologists for any radiographic changes. The radiologists

Fig. 2. Knee Society Score Function form utilized during patient encounters.

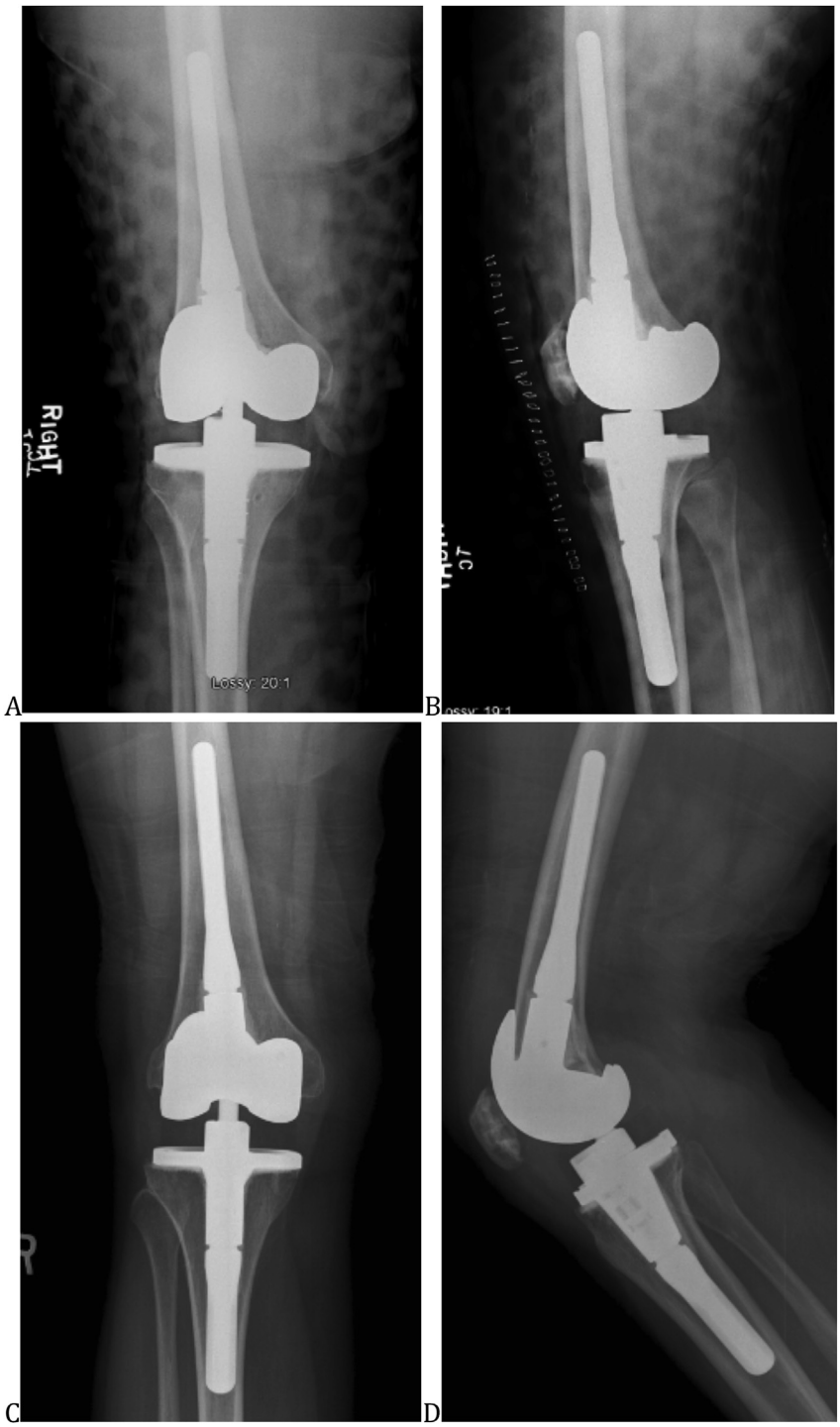

Fig. 3. The immediate postoperative AP (A) and Lateral (B) x-rays of a patient were independently evaluated and compared to AP (C) and Lateral (D) x-rays at follow up by a radiologist.

were blinded to all demographics, dates of surgery as well as patient KSS responses. Each knee x-ray was compared to its initial post-operative radiograph, evaluated for loosening and given a grade of 1–3. A Grade 1 corresponded to no radiographic changes compared to initial radiograph. A Grade 2 corresponded to evidence of lucency around the implant. This was further subdivided into A and B groups. A Grade 2A was assigned for lucency around a single component. A Grade 2B was assigned for lucency around both the femoral and tibial components (Fig. 4). A Grade 3 was assigned for any grossly loose implants with changes in position or alignment. The mean scores of all the KSS results were then compared the independent radiographic grade (Table 1). An unpaired *t*-test was used to evaluate for significance between the groups.

3. Results

A total of 28 patients responded to our written request for participation. Of those, 17 were male (60.7%) and 11 were female

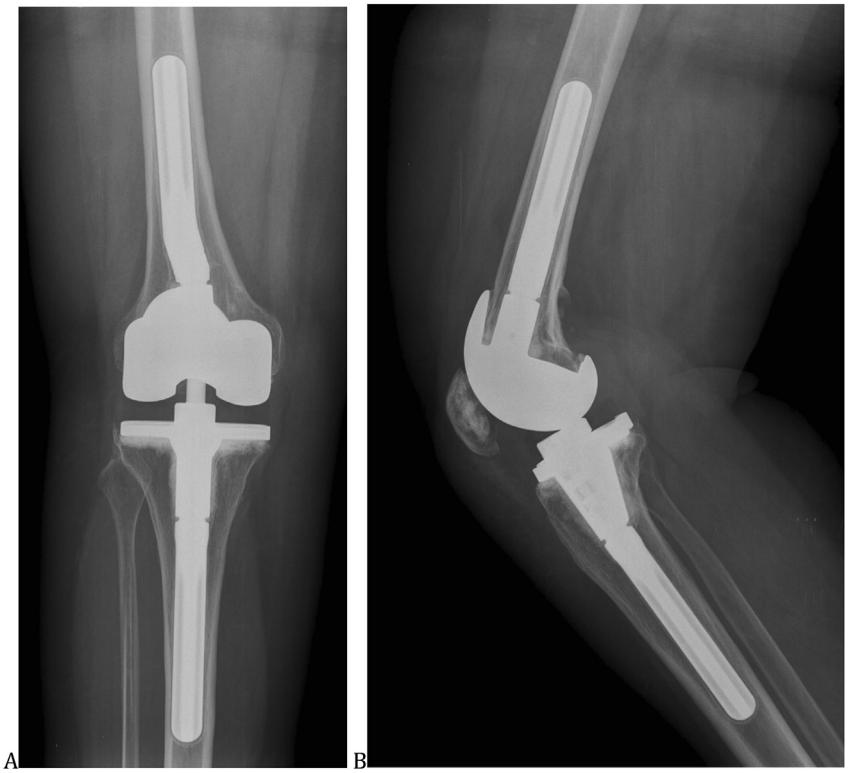

Fig. 4. Example of AP (A) and Lateral (B) radiographs showing Grade 2B loosening around both tibial and femoral components.

Table 1
This data includes the average pain and function scores for patients grouped by their radiographic grade of loosening.

RadiographicScore	Number of Patients	Average Pain Score	Average Function Score
1 - No Loosening	11 (36.7%)	88.6	83.5
2a - Single Component Loosening	17 (56.7%)	79.6	75
2b - Both Component Loosening	2 (6.7%)	78	76.6

(39.2%). The mean patient age at the time of surgery was 64.4 years (Range 45–84 years) and the mean BMI was 31.7 (range: 24.2–42.5). The average time to follow-up was 49.5 months (range 18–98 months). Of the 28 patients, 2 had undergone TKA of the contralateral knee using a constrained implant for a total of 30 knees evaluated in this study. The patients that had bilateral TKA with constrained implants filled out separate score sheets for each knee. None of the patients who followed-up had undergone repeat surgery.

The Knee Society scores are based on a weighted scale of 0–100 with Excellent outcomes being 80–100, Good 70–79, Fair 60–69, and Poor outcomes <60. In our study, 19 results were excellent (63.3%), 7 were good (23.3%) and 4 had poor pain outcomes (13.3%). Within the function score results, 19 were excellent (63.3%), 2 were good (6.6%), 4 were fair (13.3%), and 5 were poor (16.7%).

The independent radiographic evaluation found that 11 TKAs were a Grade 1 and had no evidence of lucency or changes compared to the initial post-operative x-rays (36.7%). 17 had a Grade 2A with lucency around a single component (56.7%) and 2 had a Grade 2B with lucency around both the tibial and femoral components (6.7%). No x-rays showed any significant changes in overall alignment or gross loosening of the implant (Grade 3).

We then compared the KSS scores with the radiographic grading to see if there was any correlation. Patients without evidence of changes on x-rays (Grade 1) had a mean pain score of 88.6. Patients with evidence of radiographic loosening (Grade 2) had a mean pain score of 78.3. The difference between the two groups was found to be significant ($p = 0.032$) with the mean difference of 10.3 (CI 95%, 0.93 to 19.18).

The average function score for Grade I and Grade II knees was 83.5 and 76.6, respectively, however this difference was not statistically significant. If further subdivided based on Grade 2A or 2B, patients graded 2A had a mean pain score of 79.6 and mean function score of 75, the 2B group had a mean pain score of 78 and mean function score of 90. Neither the pain nor function score difference was statistically significant among the Grade 2 knees ($p > 0.05$).

4. Discussion

Constrained condylar primary total knee arthroplasty is an appropriate option for patients with knees that continue to be unstable after attempted intra-operative soft tissue balancing. The current available evidence is mixed as to whether increasing constraint definitively leads to an increased rate of loosening, complications, and revisions.[2–4,6,9] Some authors report no significant difference in survivorship analysis or aseptic loosening of posterior stabilized knees vs. constrained condylar knees at long-term follow-up, while some studies report double to triple the revision rate.[2–4,6,9,10] It is important to note when comparing these two patient groups, that the patients requiring constrained condylar knees typically have more significant knee disease.

In our patient series, we report 86% good to excellent pain

outcomes at an average of 4.2 year follow-up. Functional scores were mostly excellent, however, a few patients rated their current function as poor (16.7%). Radiographic loosening around at least one component was evident in 19 of 30 patients (63.4%), which may be a precursor to aseptic loosening of the implant. This is higher than what has been reported in other studies, which cite non-progressive radiolucent lines around the tibial or femoral components at 9–16%.[10] This loosening might be clinically significant as patients with some evidence of loosening tended to have higher pain scores than patients with no evidence of lucencies ($p = 0.032$). Lucency around a single component vs. both components did not seem to be clinically significant ($p > 0.05$). We found no patients that required LCCK revision during our study period, which is indicative of the longevity of this implant despite the potential development of radiolucencies.

A limitation of this study was the inability of 85 of the 113 patients to come for follow-up examination. The 28 patients (30 knees) that did come for evaluation may represent a sampling error. It is possible that these patients that came for evaluation may be doing better or worse than those that did not come. Multiple patients that were able to follow-up did eventually request to the see the primary surgeon, which may indicate that these patients were more likely to participate in the study due to an ongoing problem with their knee. We are unsure of how many of the patients were not able to follow-up due to moving from the area or death. Secondly, KSS scores were obtained only on the return visit, rather than both pre and post-operatively, limiting its utility in evaluating any changes in pain and function. Finally, we did not have a control group undergoing a standard posterior stabilized total knee arthroplasty during the same time period to compare our findings to. However, this would be difficult to do radiographically, as the majority of the radiolucency was seen at the stems, which are not present in a standard implant. Additionally, patients requiring a CCK implant typically have much more progressed level disease making their preoperative KSS scores likely much lower than their standard posterior stabilized counterparts. This could have a significant effect on the final data and without preoperative KSS evaluation for all patients may lead to incorrect conclusions about pain and function scores in CCK implant recipients.

In conclusion, the constrained condylar implant is an acceptable implant for primary total knee arthroplasty. Our patient series had no revisions and excellent pain and good to excellent functional outcome scores at mid to long-term follow-up. Further studies with larger sample sizes and longer-term outcomes are needed to confirm this trend.

References

1. Martimbianco A, Calabrese F, Iha L, Petrilli M, Neto O, Filho M. Reliability of the "American knee society score" (AKSS). *Acta Ortopédica Bras*. 2012;20(1):34–38.
2. Siqueira M, Jacob P, McLaughlin J, et al. The varus-valgus constrained knee implant: survivorship andOutcomes. *J Knee Surg*. 2016;29.
3. Martin R, Beahrs T, Stuhlman C, Trousdale R. Complex primary total knee arthroplasty: long- term outcomes. *J Bone Joint Surg Am*. 2016;98:1459–1470.
4. Feng X, Yang C, Fu D, et al. Mid-term outcomes of primary constrained condylar knee arthroplasty for severe knee deformity. *J Huazhong Univ Sci Technol*. 2016;36(2):231–236.
5. Delanois R, Mistry J, Chukwuweike G, Mohamed N, Choski U, Mont M. Current epidemiology of revision total knee arthroplasty in the United States. *J Arthroplasty*. 2017;1–6.
6. Moussa M, Lee Y, Westrich G, Mehta N, Lyman S, Marx R. Comparison of revision rates of non-modular constrained versus posterio stabilized total knee arthroplasty: a propensity score match cohort study. *HSS J*. 2017;13:61–65.
7. Kutrz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007;89:780–785.
8. Cram P, Lu X, Kates S, Singh J, Li Y, Wolf B. Total knee arthroplasty volume, utilization, and outcomes among Medicare benefiiaries, 1991-2010. *J Am Med Assoc*. 2012;308(12):1227–1236.
9. Cholewinski P, Putman S, Vasseur L, et al. Long-term outcomes of primary constrained condylar knee arthroplasty. *J Orthop Traumatol*. 2015;101:449–454.
10. Maynard L, Sauber T, Kostopoulos V, Lavigne G, Sewecke J, Sotereanos N. Survival of primary condylar constrained total knee arthroplasty at a minimum of 7 years. *J Arthroplasty*. 2014;29:1197–1201.

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Functional outcome of single stage bilateral total knee replacement measured using oxford knee score☆

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ABSTRACT

Arthritis of the knee joint is one of the most common cause of knee pain in middle age and elderly population. Among all, osteoarthritis remains the most common cause, followed by rheumatoid arthritis and other types of inflammatory arthritis. Though medical management remains the most common modality of treatment, patient with severe arthritis see total knee replacement as the definitive way to improve their quality of life. Bilateral total knee replacement in one stage has an advantage of single hospital admission, shorter rehabilitation and is less expensive. But till recently single stage bilateral total knee replacement was in limited vogue due to fear of the perioperative complications. This study was done to evaluate the functional outcome of this surgery.

Aim: To study the clinical and functional outcome in a series of 101 patients who were operated for single stage bilateral total knee replacement using oxford knee score.

Materials and methods: The study is a prospective 1 year pilot study involving a series of 101 consecutive patients who were operated for single stage bilateral total knee replacement using Optetrak posterior stabilised high flex knee system (Exatech). Inclusion criteria were patients with bilateral osteoarthritis who underwent single stage bilateral total knee replacement. All patients underwent a pre and post-operative evaluation using oxford knee score at 3rd and 12th month.

Result: The mean age of our study population was 65.06 ± 7.53, 73.3% were female. The mean duration of hospital stay was 7.02 ± 0.346. The mean preoperative oxford knee score improved from 11.47 preoperatively to 35.57 three months postoperative. At one year the mean oxford knee society score was 46.31. The mean change in oxford knee score from preoperative to 3 month postoperative and from 3 month postoperative to 1 year postoperative was statistically significant.

Discussion: Single stage bilateral total knee arthoplasty improves the quality of life in patients with severe osteoarthritis as reflected in oxford knee score.

1. Introduction

Osteoarthritis is prevalent among 80% of population above 65 years. One third of the patients present with symptoms pertaining to both the knees. Two third of the patients who undergo total knee arthoplasty have bilateral degenerative disease.[1] The options before these patients are to go for a single stage bilateral total knee replacement or staged total knee replacement either during the same hospitalisation or two different hospital stay. The duration between the two admission can be 3 months, 6 months or even longer. 20% of patients undergoing unilateral total knee arthoplasty undergo surgery of 2nd knee within 2 years since the first.[2] Moreover when the disease is bilateral addressing only one knee will give both suboptimal results and impaired benefits of the replaced knee.[3]

Most of these patient get benefitted by bilateral total knee replacement. It is now well accepted that total knee arthroplasty is a good treatment for pain relief and restoration of function in patients with advanced degenerative disease.[4] Single stage bilateral knee replacement has the advantage of shorter hospital stay, shorter rehabilitation and reduced patient management costs.[5]

Single stage bilateral total knee replacement has been studied both retrospective[6–9] and prospective.[10] There appears to be some

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difference in complication rates with some studies finding a decrease in morbidity,[11,12] some similar[13–15] and some a higher morbidity rates.[16,17] Studies have shown financial savings ranging between 18% and 50% when performing bilateral rather than two unilateral replacements.[18,19]

The aim of this prospective study was to evaluate the clinical and functional outcome of single stage bilateral total knee arthoplasty, and perioperative complications.

2. Materials and methods

This was a 2 year prospective pilot study in a series involving 100 consecutive patients who were operated for single stage bilateral total knee replacement under same anaesthesia without a control group. Inclusion criteria were primary or secondary osteoarthritis of knees. Exclusion criteria were rheumatoid and other inflammatory arthritis, patients who opted for staged knee replacement and revision arthroplasty.

3. Anaesthesia methodology

A systematic preoperative workup with anaesthesia consultation was done 2 weeks prior to the surgery. That included complete blood count, coagulation, liver & renal function test, urine examination, chest X ray and cardiac examination (electro and echocardiogram). The anaesthesiologist then assessed the patients and determined whether the patient was apt for surgery. After which a combined decision was taken to decide whether the patient can be planned for single stage bilateral total knee replacement by the orthopedician and the anaesthetist.

The patients were then explained about the pros and cons of undergoing single stage bilateral total knee replacement and an informed consent was obtained. Patients either received general anaesthesia or spinal anaesthesia based on anaesthetic assessment. All patients received nerve block (femoral or adductor) immediately after the surgery.

4. Surgical procedure

Patients were administered prophylactic injection cefuroxime 1.5 gm during induction of anaesthesia and another dose just before second knee incision was made. Following which the patients receive 2 more doses of antibiotic every 8th hour postoperatively.

All patients were operated by standard anteromedial approach. Soft tissue balancing and bone cuts were made using standard techniques. A cemented posterior stabilised knee implants (Optetrak Exatech Hi flex) were used.

A bilateral sequential pneumatic tourniquet was used in all cases. The surgical procedure was done by the principal surgeon and investigator in the study, began when tourniquet was inflated. Only when the 1st knee skin was closed and tourniquet released, the pneumatic tourniquet in the 2nd knee inflated. Haemostasis achieved before skin closure and none of our patients had drain left in situ. Preventive anticoagulant therapy with oral novel anticoagulant started within 12 h after surgery and continued for 15 days.

5. Postoperative protocol

The patients were educated and advised to start on active ankle toe mobilization immediately after the surgery. The patients were mobilized full weight bearing on 1st postoperative day and were taken for staircase climbing on 2nd postoperative day. Knee bending also were started on day 1. Then goal was to ambulate the patient to the restroom full weight bearing and knee bending to 90° by the 7th day. They were routinely discharged on day 7 and sutures were removed on day 14 in outpatient department.

6. Pre, peri and postoperative evaluation

Radiological assessment was done based on bilateral AP and lateral knee X rays. Assessment of clinical function was based on the oxford knee score. Clinical assessment was done preoperatively, 3 months and 1 year postoperatively.

6.1. Statistical analysis

The collected data were analysed with IBM.SPSS statistics software 23.0 Version. To describe about the data descriptive statistics frequency analysis, percentage analysis were used for categorical variables and the mean & S.D were used for continuous variables. To find the significant difference in the multivariate analysis for repeated measures the Repeated measures of ANOVA was used with Bonferroni correction to control the type I error on multiple comparison. In all the above statistical tools the probability value 0.05 is considered as significant level.

6.2. Results

101 patients were included in the study with age ranging between 50 and 83. Mean age was 65.06 ± 7.539. The average duration of stay in hospital was 7.02 days ±0.346 (Table 1). There were 74 female and 27 male in our study. So female accounted for 73.3% of the study population (Table 2) (Fig. 1). All patients were given the scoring sheet containing oxford knee score to be filled on the day of admission. The patients were usually admitted on the day before the surgery and started on incentive spirometry, static quadriceps exercise.

The same scoring sheet was given both at 3 month postoperatively and 1 year postoperatively. The score filled by them was then updated to the database. These data was then statistically analysed using IBM SPSS software 23.0 version.

The mean oxford knee score was 11.465 ± 0.117 preoperatively. It increased significantly to 35.574 ± 0.186 at 3 month postoperative period. There was a 24 point increase in the oxford knee score during this period. The mean oxford knee score was 46.307 ± 0.093 at 12 month follow up. Thereby an increase in 35 points since preoperative period and increase in 11 points between 3rd and 12 month postoperative. The P value and F value were significant between the preoperative and 3rd month follow up, between preoperative and 12th month follow up and also between 3rd and 12th month follow up. (P value − 0.0005/F value − 15204) (Table 3) (Fig. 2).

In our study we encountered minor complication in 10 patients (postoperative confusion, superficial wound infection and pressure sore). They were not statistically significant. None of our study population encountered major complications (Table 4).

7. Discussion

Literature reviews have substantiated the significant beneficial effects of single stage bilateral total knee replacement in terms of

Table 1
Descriptive statistics.

	N	Minimum	Maximum	Mean	Std. Deviation
Age	101	50	83	65.06	7.539
Hospital stay	101	6	8	7.02	.346

Table 2
Sex.

Sex	Frequency	Percent
Female	74	73.3
Male	27	26.7

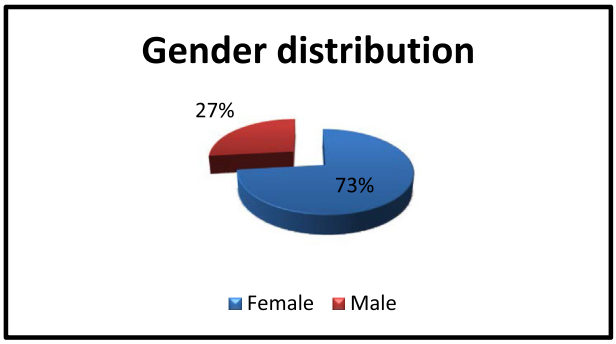

Fig. 1.

Table 3
Descriptive Statistics oxford knee score.

	Mean	Std. Deviation	N
preoperative oxford knee score	11.47	1.180	101
3rd month postoperative oxford knee score	35.57	1.867	101
12th month postoperative oxford knee score	46.31	.935	101

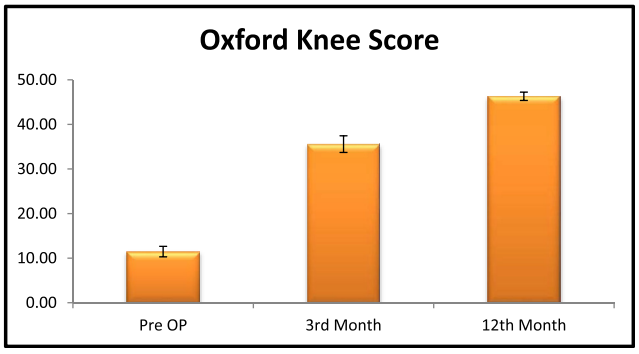

Fig. 2.

Table 4
Complication.

Complications	incidence
MINOR	
Superficial wound infection	6/101
Postoperative confusion	3/101
Urinary tract infection	0/101
Pressure sore	1/101
MAJOR	
Symptomatic DVT/PE	0/101
MI	0/101
Deep infection	0/101
Stroke	0/101
Mortality	0/101

hospital stay, cost effectiveness and in enhancing the patient rehabilitation. Our study too is in concurrence with those studies. In our study we noted an increase in mean oxford knee score from 11.47 preoperatively to 35.57 at the 3rd month follow up. The mean duration of hospital stay in our study population was 7.02 days.

There are conflicting evidences in literature regarding complications associated with single stage bilateral total knee replacement varying from superficial wound infection, deep wound infection, deep vein thrombosis, pulmonary embolism, cardiac complications and mortality. In our study none of the patients developed major complication like deep infection requiring secondary surgical procedures, symptomatic deep vein thrombosis/pulmonary embolism or mortality. We had six patients who had superficial wound infection which was managed successfully with oral antibiotics.

The rates of perioperative complications and morbidity were higher after simultaneous bilateral TKR than unilateral TKR.[23]The complication rates were associated with age-related comorbidities, blood loss, and delayed rehabilitation.[2]But in our study no major complications were encountered. Simultaneous bilateral TKR is more economical, enables higher patient satisfaction and quicker return to function, compared with staged bilateral TKR, which doubles the length of hospital stay and is 18%, or even 50%, more expensive.[24] Simultaneous bilateral TKR is 36% less costly than 2 unilateral TKR.[19] The mean reduction in the length of hospitalisation is 7 days,[25] which was similar to the findings in our study. The length of hospital stay is 4 days longer for staged TKR than for single stage bilateral TKR.[2] Expenditure on rehabilitation is about 2 fold greater in staged TKR.[6]

The perioperative mortality rate is similar in those having single stage bilateral TKR and unilateral TKR.[8] But we didn't encounter major complication like perioperative mortality in our study.

Study by Lombardi et al.,[20] in 2001 reported higher incidence of complication in patients more than 80 years, but in our study we had 4 patients with ≥80 years. But none of them had any complications. Rauh et al.,[21] in 2004 reported higher incidence of complication in patients with ASA grade III, but in our study we didn't classify them based on ASA classification.

Girish et al.,[22] in 2011 noted increase in incidence of neurological complication, predominantly confusion during the postoperative period, but in our study we noted only 3 patients with postoperative confusion secondary to hyponatremia but it was not statistically significant (P-0.264).In concurrence with our study Sabari et al.,[22] have reported occurrence of postoperative confusion in 3 patients following single stage bilateral total knee replacement, but he didn't notice any incidence of fat embolism or cardiovascular complications.

Acute renal failure too has been reported as relatively rare complication of single stage bilateral total knee replacement in few studies. But in our study we hadn't encountered complication related to acute renal failure. Urinary tract infection also has been reported in few studies due to retaining indwelling catheter for a longer duration. But we didn't encounter urinary tract infection as we removed catheter on 2nd postoperative day as soon the patients were ambulant.

One patient developed pressure sore on her heel as she kept herself confined to bed for most of the postoperative duration except for the time that she was walking. It developed after she was discharged and was noted during the follow up which she came for suture removal. She was treated with oral antibiotics and by educating her.

The major limitation of the this study was that it was not comparative. Hence, no conclusions could be made regarding the outcome. But this study confirms, simultaneous bilateral TKR is safe as long as a proper protocol is followed for patient selection. Aggressive pain management and rehabilitation enables early recovery and thus decreases the overall health care expenses.

8. Conclusion

Single stage bilateral total knee replacement has a definitive advantage of reduced hospital stay, cost effective and early rehabilitation of patients suffering from bilateral osteoarthritis of knee. The mean postoperative oxford knee score in each follow up period at 3rd and 12th month and difference between the preoperative and postoperative period was satisfactory. Moreover in this study we haven't encountered any major complications. But we have to admit that our study has certain shortcomings like smaller study population, absence of control group, single centre study design and absence of cost evaluation. However like any surgical procedure, the ultimate result depends on expertise of the surgeon and the established pattern of preoperative medical evaluation and postoperative rehabilitation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jajs.2019.01.010.

References

1. Legré V, Boyer T. *Diagnostic et traitement d'un genou douloureux*. EMC-Appareil locomoteur; 2003 [14-325-A-10].
2. Ritter M, Mamlin LA, Melfi CA, Katz BP, Freund DA, Arthur DS. Outcome implication for the timing of bilateral total knee arthroplasties. *Clin Orthop Relat Res*. 1997;345:99–105.
3. Stanley D, Stockley I, Getty CJ. Simultaneous or staged bilateral total knee replacements in rheumatoid arthritis: a prospective study. *J Bone Joint Surg Br*. 1990;72:772–774.
4. Kolettis GT, Wixson RL, Peruzzi WT, et al. Safety of 1-stage bilateral total knee arthroplasty. *Clin Orthop Relat Res*. 1994:102–109 ([PubMed]).
5. Bilateral Total Knee Arthroplasty in a One-Stage Surgical Procedure, C.TrojaniB.BugnasM.BlayM.CarlesP.Boileau.
6. Lane GJ, Hozack WJ, Shah S, et al. Simultaneous bilateral versus unilateral total knee arthroplasty. Outcomes analysis. *Clin Orthop Relat Res*. 1997;345:106–112.
7. Leonard L, Williamson DM, Ivory JP, Jennison C. An evaluation of the safety and efficacity of simultaneous bilateral total knee arthroplasty. *J Arthroplasty*. 2003;18:972–978.
8. Shin YH, Kim MH, Ko JS, Park JA. The safety of simultaneous bilateral versus unilateral total knee arthroplasty: the experience in a Korean hospital Singapore. *Med J*. 2010;51:44–49.
9. Luscombe JC, Theivendran K, Abudu A, Carter SR. The relative safety of one-stage bilateral total knee arthroplasty. *Int Orthop*. 2009;33:101–104.
10. Peak EL, Hozack WJ, Sharkey PF, Rothman RH. One-stage bilateral total joint arthroplasty: a prospective. *comparative study of total hip and total knee replacement Orthopaedics*. 2008;31:131.
11. McLaughlin TP, Fisher RL. Bilateral total knee arthroplasties. Comparison of simultaneous (two-team), sequential, and staged knee replacements. *Clin Orthop Relat Res*. 1985:220–225.
12. Soudry M, Binazzi R, Insall JN, et al. Successive bilateral total knee replacement. *J Bone Joint Surg*. 1985;67:573–576.
13. Alemparte J, Johnson GV, Worland RL, Jessup DE, Keenan J. Results of simultaneous bilateral total knee replacement: a study of 1208 knees in 604 patients. *J South Orthop Assoc*. 2002;11(3):153–156. Fall.
14. Hardaker Jr WT, Ogden WS, Musgrave RE, Goldner JL. Simultaneous and staged bilateral total knee arthroplasty. *J Bone Joint Surg Am*. 1978 Mar;60(2):247–250.
15. Morrey BF, Adams RA, Ilstrup DM, Bryan RS. Complications and mortality associated with bilateral or unilateral total knee arthroplasty. *J Bone Joint Surg Am*. 1987 Apr;69(4):484–488.
16. Gradillas EL, Volz RG. Bilateral total knee replacement under one anesthetic. *Clin Orthop Relat Res*. 1979 May;(140):153–158.
17. Hozack WJ, Shah S, Rothman RH, Booth Jr RE, Eng K, Smith P. Simultaneous bilateral versus unilateral total knee arthroplasty. Outcomes analysis.Lane GJ. *Clin Orthop Relat Res*. 1997 Dec;(345):106–112.
18. Brotherton SL, Roberson JR, de Andrade JR, Fleming LL. Staged versus simultaneous bilateral total knee replacement. *J Arthroplasty*. 1986;1(4):221–228.
19. Reuben JD, Meyers SJ, Cox DD, Elliott M, Watson M, Shim SD. Cost comparison between bilateral simultaneous, staged, and unilateral total joint arthroplasty. *J Arthroplasty*. 1998 Feb;13(2):172–179.
20. Lombardi AV, Mallory TH, Fada RA, et al. Simultaneous bilateral total knee arthroplasties: who decides? *Clin Orthop Relat Res*. 2001;392:319–329.
21. Rauh MA, Krackow KA. In-hospital deaths following elective total joint arthroplasty. *Orthopaedics*. 2004;27(4):407–411.
22. Girish Sabari, Gopalakrishnan KC, Sugath Subin, Anoop S. Simultaneous bilateral total knee arthroplasty - is it the final answer? *Kerala J Orthop*. 2011;24:15–22.
23. Bullock DP, Sporer SM, Shirreffs Jr TG. Comparison of simultaneous bilateral with unilateral total knee arthroplasty in terms of perioperative complications. *J Bone Joint Surg Am*. 2003;85:1981–1986.
24. Brotherton SL, Roberson JR, de Andrade JR, Fleming LL. Staged versus simultaneous bilateral total knee replacement. *J Arthroplasty*. 1986;1:221–228.
25. Pavone V, Johnson T, Saulog PS, Sculco TP, Bottner F. Perioperative morbidity in bilateral one-stage total knee replacements. *Clin Orthop Relat Res*. 2004;421:155–161.

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Comparative evaluation of periarticular infiltration of two cocktail regimens for analgesia in post-operative patients of total knee replacement

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ABSTRACT

Purpose: To compare the efficacy of two periarticular cocktail regimens for analgesia in postoperative patients of total knee replacement.

Method: This is a Randomized Control study done over the duration of 1.5 years. Twenty-five knees of either gender were selected with inclusion criteria (All osteoarthritis patients planned for TKA) and exclusion criteria (Inflammatory arthritis, patients allergic to local anaesthetic e.g. Ropivacaine, bupivacaine, known cardiac disorder patient having AV block, arrhythmia) & divided into 2 groups.

Group A was given a cocktail of Ropivacaine, adrenaline, clonidine & cefuroxime.

Group B was given a cocktail of bupivacaine, fentanyl, methylprednisolone & cefuroxime. The preoperative pain of the patient was assessed using VAS score. Combined spinal and epidural anaesthesia was given using 0.5% 2 ml of bupivacaine heavy in all patients. After taking bone cuts & before the placement of the implant, cocktail of the drug was infiltrated using sterile technique into 9 specific sites. The amount of drug infiltrated was calculated according to the weight of the patient.

The patients were assessed on: Pain relief postoperatively at specific duration using VAS score. The amount & frequency of epidural top-ups required. Knee ROM, Quadriceps strength, Extensor lag & Knee society score were assessed.

Results: Out of the total 25 knees included in the study, 12 belonged to Group A and 13 belonged to Group B. It was observed that 4 (33%) out of 12 Group A patient needed injection tramadol for 2–3 days and fentanyl patch 25mcg. In Group B, one (8%) out of 13 patients required injection tramadol and fentanyl dermal patch for 2–3 days. The difference in additionally required analgesic between patients of the two groups is statistically significant.

VAS Score: The VAS score of Group B was statistically lower than Group A patients till first 24 h postoperatively.

The extension lag was lower in group B compared to group A at 24 h after the surgery and up to 5 days. Overall after 6 weeks of follow-up, the extensor lag between the groups was not statistically significant. Average KSS in group A was 79.58 and in the group, B was 83.99 and the difference in KSS between patients of the two groups was statistically significant.

Conclusion: Both the cocktail regimens are effective in pain control postoperatively. The relief in pain with regimen B containing bupivacaine, fentanyl, methylprednisolone and cefuroxime was more striking in the first 24 h. By the end of two days, both regimens were found to be equally effective.

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1. Introduction

Total knee arthroplasty (TKA) is one of the very common surgeries performed now a day. It is associated with postoperative pain. Severe postoperative pain after TKA can add not only to patient suffering but also negatively affect postoperative recovery. If the severe postoperative pain is managed inadequately under these circumstances, the surgery-induced responses can be exacerbated, posing a serious danger to patients. Specifically, severe postoperative pain has been associated with serious complications including ischemic cardiac events and myocardial insufficiency that result from increased stress on the cardiovascular system.[1] In addition, immobilization caused by pain may increase the risk of decreased pulmonary function, gastrointestinal complications, such as ileus, and thrombus formation that are related to surgical stress.[2,3] An increase in stress hormone and sleep disorder due to severe pain can worsen the already decreased immunity, which leads to higher risk of infection. In particular, this may affect the mental status of elderly patients, causing delirium or anxiety disorder.[4]

LIA (Local Infiltration Analgesia) is a relatively simple technique that has shown early promise as a method of pain relief after TKA and it is simple, practical, safe, and effective for pain management after knee and hip surgery. Intraoperative periarticular multimodal drug injection using opioids and long-acting local anaesthetic agents is effective for postoperative pain management. Periarticular injection (PAI) significantly reduces pain without any complications, such as infection and produces additional pain-relieving effects when incorporated into multimodal pain control protocols.[5,6] However, the proper dosage and composition of injection cocktail and injection techniques have not been established and there is disagreement over its influence on reduced opioid consumption. Its efficacy is limited in time and patients should be informed on the occurrence of rebound pain after half-life of the treatment agents. The most commonly used drugs for periarticular injections include local anaesthetics, such as bupivacaine and ropivacaine, morphine, ketorolac, clonidine, and steroids.

In this study, we have compared the efficacy of two periarticular cocktail regimens for postoperative analgesia in patients with TKA.

2. Materials and methods

This is a Randomized Control study done over the duration of 1.5 years in our institute.

Twenty-five knees of either gender were selected based on the criteria given below.

2.1. Inclusion criteria

1. All osteoarthritis grade 3 or 4 patients who failed conservative treatment for adequate duration and requiring TKA.
2. More than 60 years of age of either gender.
3. Patients who are fit for spinal/epidural anaesthesia.

2.2. Exclusion criteria

1. Inflammatory arthritis
2. Patients allergic to local anaesthetic (for e.g. Ropivacaine, bupivacaine)
3. Known cardiac disorder patient having AV block, arrhythmia.

2.3. Method

The study included 25 knees which were divided randomly into 2 groups based on a computerized lottery system.

The two groups were demographically matched including the age of the patients, grade of osteoarthritis, preoperative VAS score and Range of motion of the affected knee.

Group A was given a cocktail of Ropivacaine, adrenaline, clonidine & cefuroxime (Fig. 1(a and b)).

Group B was given a cocktail of Bupivacaine, fentanyl, methylprednisolone & cefuroxime (Fig. 2(a and b)).

The preoperative pain of the patient was assessed using VAS score and recorded. An epidural catheter was placed and combined spinal and epidural anaesthesia was given using 0.5% 2 ml of bupivacaine heavy in all patients. In perioperative period all patients were given tablet Gabapentine 300 mg HS. All the surgeries were done by a single surgeon using similar surgical technique in all the patients. The implant make and rehabilitation protocol was similar in all the patients.

After taking appropriate femur and tibia bone cuts, a lamina spreader was introduced to visualize the surrounding soft tissues. Before the placement of implant, cocktail of drug was infiltrated using sterile technique into 9 specific sites: ACL femoral attachment, PCL attachment, posteromedial capsule along the residual posterior meniscal rim and posterior capsule attachment and into the residual middle and anterior residual rim of medial meniscus, postero-lateral capsule along the residual posterior rim of the lateral meniscus and posterior capsule attachment and in middle and anterior portion of the lateral meniscus according to the study group of the patient (Figs. 3 and 4).

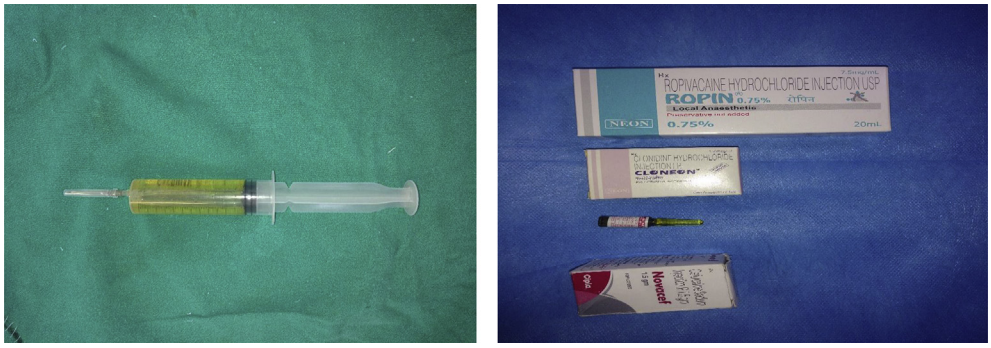

Fig. 1. (a,b)Photos showing periarticular injection and drugs
Regimen A (Ropivacaine, clonidine, adrenaline and cefuroxime).

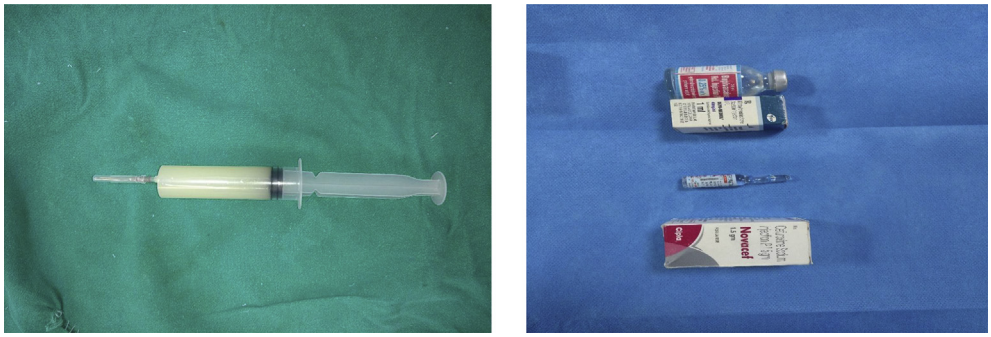

Fig. 2. (a,b) Photos showing periarticular injection and drugs
Regimen B (Bupivacaine, methylprednisolone, fentanyl and cefuroxime).

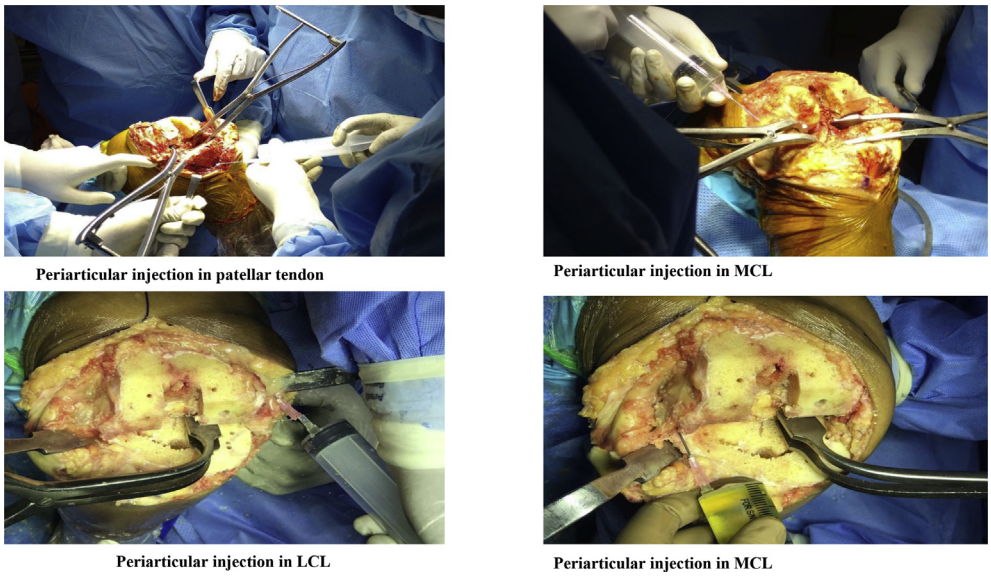

Fig. 3. (a,b,c,d) Photos showing infilteration of periarticular injections.

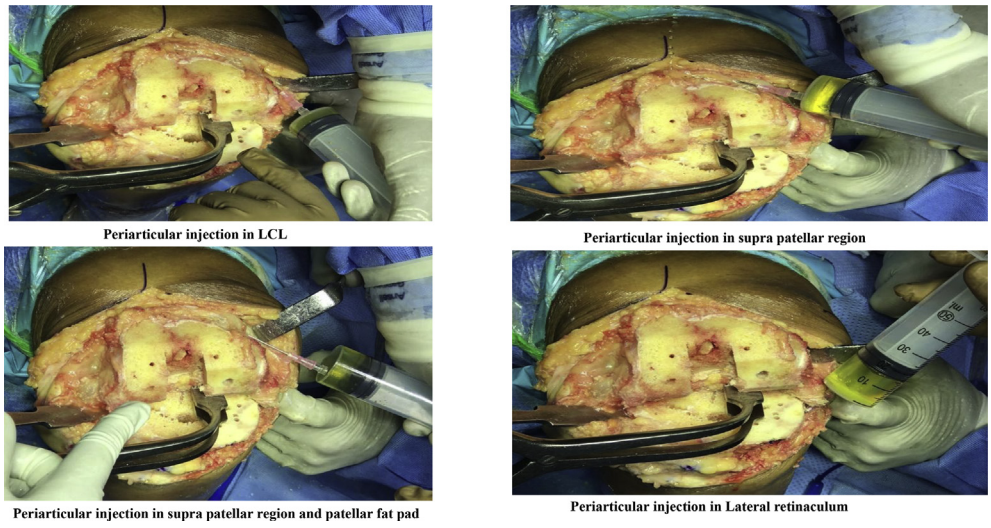

Fig. 4. (a,b,c,d). Photos depicting injection sites in suprapatellar region and lateral aspect of the knee.

The amount of drug infiltrated was calculated according to the weight of the patient.

REGIMEN A	Weight <70 kg	Weight >70 kg
Ropivacaine (0.75%)	300 mg (40 cc)	400 mg (53.3 cc)
Adrenaline(1:1000)	0.3 cc	0.3 cc
Clonidine(500μg/ml)	0.6 cc	0.8 cc
Cefuroxime (750 mg)	750 mg	750 mg
Normal Saline	4.1 cc	5.6 cc
Total volume	45 cc	60 cc
REGIMEN B	Weight <70 kg	Weight >70 kg
Bupivacaine (0.25%)	100 mg (40 cc)	133 mg (53.3 cc)
Methyl prednisolone acetate (40 mg/ml)	40 mg (1 cc)	40 mg (1 cc)
Fentanyl (50μg/ml)	100μg (2 cc)	100μg (2 cc)
Cefuroxime (750 mg)	750 mg	750 mg
Normal saline	2 cc	3.7 cc
Total volume	45 cc	60 cc

The patients were assessed on:

1. Pain relief postoperatively at the immediate postoperative period, at 3 h, at 6 h, at 12 h, at 24 h of the surgery, alternate day, weekly up to 3 weeks, day of discharge & at 6 weeks using VAS scoring.
2. The amount & frequency of epidural top-ups required for adequate analgesia was compared.
3. Knee ROM was assessed by goniometer at 24 h after the surgery, alternate day till the day of discharge, at 3 weeks & at 6 weeks.
4. Quadriceps strength was assessed by MRC grading at 24 h after the surgery, alternate day till the day of discharge, at 3 weeks & at 6 weeks.
5. Extensor lag was assessed by goniometer at 24 h after the surgery, alternate day till the day of discharge, at 3 weeks & at 6 weeks.
6. Knee society score was assessed at 6 weeks.

3. Results

Out of the total 25 knees included in the study, 12 belonged to Group A and 13 belonged to Group B. The difference in the distribution of gender and age between the two groups was not statistically significant as per the Chi-square test (P value 0.673).

Post-operative additional analgesic requirement: Injection tramadol, Fentanyl dermal patch, Buprenorphine dermal patch and bupivacaine top up were kept for rescue analgesia. Injection tramadol and fentanyl patch 25mcg for 2 days was used as first line of additional analgesic in patients with VAS Score more than or equal to 5 on postoperative day 1. Buprenorphine dermal patch and bupivacaine top up were considered as second line of additional analgesic, if VAS score is still more than or equal to 5 after administering injection tramadol and fentanyl patch for 1 day. It was observed that 4 (33%) out of 12 Group A patient needed injection tramadol and fentanyl patch 25mcg for 2 days. In Group B, one (8%) out of 13 patients required injection tramadol and fentanyl dermal patch 25mcg for 2 days. No patients in both groups required additional buprenorphine dermal patch and bupivacaine top up. The difference in additionally required analgesic between patients of the two groups is statistically significant as per the Chi-Square Tests. (P value 0.036).

VAS Score: The average pre-operative VAS score was noted in both group. The score was lower in group A (1.9) than group B (2.3). The difference pre-operative VAS between the patients of the two groups is statistically not significant.

At 0 h: Average VAS score in group B (2.84) was lower as compared to group A (3.5). The difference in VAS score between patients of the two groups was statistically significant. (p-value 0.037).

At 3 h: Average VAS score in group B (2.6) was lower as compared to group A (3.6). The difference in VAS score between patients of the two groups was statistically significant. (P value 0.028).

At 6 h: Average VAS score in group B (2.4) was lower as compared to group A (3.5). The difference in VAS score between patients of the two groups was statistically significant. (P value 0.018).

At 12 h: Average VAS score in group B (2.1) was lower as compared to group A (2.9). The difference in VAS score between patients of the two groups was statistically significant. (P value 0.04).

At 24 h: Average VAS score in group B (1.9) was lower as compared to group A (2.8). The difference in VAS score between patients of the two groups is statistically significant. (P value 0.035).

After 24 h of surgery, VAS score between the patients of both groups was almost equal and statistically not significant.

Average VAS score after 24 h of surgery between the patients of both groups.

GROUP	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	3 weeks	6 weeks
A	2.2	1.6	1.5	1.16	1	1	1	1
B	2	1.8	1.3	1.2	1	1	1	0.8

After 24 h of surgery, VAS score between the patients of both groups was almost equal and statistically not significant.

In group A, flexion ranged from 66.2° to 103.7° and in group B flexion ranged from 72° to 105° in the post-operative period.

Mean flexion in group A after 24 h of surgery was 66.2° and in the group, B was 72°.

At 3 days, the mean flexion 78.2° and 77.5°, at 5 days 83° in both group, at 7 days 84.3° and 88°, at 9 days 88.3°, at 11 days 90° and 93.8°, at 13 days 90° and 93.8°, at 3 weeks 97° and 97.3°, at 6 weeks 103° and 105° in respective group A and B.

The extension lag was lower in group B compared to group A at 24 h after the surgery and up to 5 days. After which, the average extensor lag was not much different. Overall after 6 weeks of follow-up the extensor lag between the groups was not statistically significant (p-value 0.355).

Average KSS in group A was 79.58 and in the group, B was 83.99 and the difference in KSS between patients of the two groups was statistically significant using Mann Whitney test (p-value 0.006).

The quadriceps strength after 24 h surgery are almost equal (3+) in both group up to 3 days of post-operative period. After 3 days of surgery, quadriceps strength were better in group B patient up to 10 days after the surgery. After 2 weeks, quadriceps strength (4+) were almost equal in both group. The quadriceps strength between the groups was not statistically significant as per the Chi square test.

Other Complications: In group A, one of the patients had persistent low blood pressure postoperatively. It was treated with intravenous fluid.

In group B, one of the patients complains of suture site soakage at post-operative day 5. His culture was sterile and wound healed normally.

4. Discussion

The usefulness of a multimodal approach to pain control after TKA has been reported.[7] The concepts of pre-emptive analgesia and

multimodal pain protocols are commonly used. Periarticular injection of a combination of agents is the most important component of the multimodal approach[8] and also a key component.[9,10]

We found that the level of post-operative pain and the use of rescue analgesia in the early postoperative period in the first 24 h was less in the group B than group A. The relief in pain with regimen B containing bupivacaine, fentanyl, methylprednisolone and cefuroxime was more striking in the first 24 h. There have been two RCTs which do not support the efficacy of corticosteroid (methylprednisolone) in periarticular injection[11,12] and four RCTs which do.[13–15]. We have found that patients who were administered group B regimen infiltration obtained a better range of motion in the operated knee at 24 h and 7 days after the surgery as compared to group B regimen. Most of the subjects from B group obtained less extensor lag as compared to group A. Dexamethasone is a long-acting glucocorticoid with potent anti-inflammatory properties. Its anti-inflammatory effects, both locally and systemically, were confirmed in this study by evaluating IL-6 in drain fluid and serum CRP. Regarding the duration of the analgesic effects, our results were consistent with the physiological effects of dexamethasone remaining for 36–72 h in the human body. Chia et al. have advised against injecting the extensor mechanism because of the risk of delayed tendon rupture.[12] Transient peroneal nerve palsy may occur, because of infiltration into the area of the common peroneal nerve. Cautious infiltration in the posterior aspect of the capsule is done. In our study, there is no such complication.

Limitations: This study was conducted in a single centre and only one surgeon was involved. Second, the sample size was underpowered to make definitive conclusions about the ratio of complications, including surgical site soakage and wound complication. Several studies have reported patients developing a surgical site infection after periarticular injection which contained corticosteroid.[16] To analyze the impact of corticosteroid on surgical site infection, a larger sample size is needed.

5. Conclusion

Both the cocktail regimens are effective in pain control postoperatively. The relief in pain with regimen B containing bupivacaine, fentanyl, methylprednisolone and cefuroxime was more striking in the first 24 h. By the end of two days, both regimens were found to be equally effective. This initial pain relief by regimen B improved the patient's satisfaction and early participation in post-operative rehabilitation.

Conflicts of interest

The authors & co-authors declare that they have no conflict of interest.

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Ethical approval

Ethical Approval taken from the Ethics Committee of the Institute.

Informed consent

Informed consent was obtained from all individual participants included in the study.

References

1. Mangano DT, Wong MG, London MJ, Tubau JF, Rapp JA. Perioperative myocardial ischemia in patients undergoing noncardiac surgery–II: incidence and severity during the 1st week after surgery. The Study of Perioperative Ischemia (SPI) Research Group. *J Am Coll Cardiol*. 1991;17:851–857.
2. Wisner DH. A stepwise logistic regression analysis of factors affecting morbidity and mortality after thoracic trauma: effect of epidural analgesia. *J Trauma*. 1990;30:799–804.
3. Wattwil M. Postoperative pain relief and gastrointestinal motility. *Acta Chir Scand Suppl*. 1989;550:140–145.
4. Carr DB, Goudas LC. Acute pain. *Lancet*. 1999;353:2051–2058.
5. Andersen LO, Husted H, Kristensen BB, Otte KS, Gaarn-Larsen L, Kehlet H. Analgesic efficacy of subcutaneous local anaesthetic wound infiltration in bilateral knee arthroplasty: a randomised, placebo-controlled, double-blind trial. *Acta Anaesthesiol Scand*. 2010;54:543–548.
6. Mullaji A, Kanna R, Shetty GM, Chavda V, Singh DP. Efficacy of periarticular injection of bupivacaine, fentanyl, and methylprednisolone in total knee arthroplasty:a prospective, randomized trial. *J Arthroplasty*. 2010;25:851–857.
7. Berend ME, Berend KR, Lombardi Jr AV. Advances in pain management: game changers in knee arthroplasty. *Bone Joint Lett J*. 2014;96-B:7–9 (11Supple A).
8. Parvataneni HK, Ranawat AS, Ranawat CS. The use of local periarticular injections in the management of postoperative pain after total hip and knee replacement: a multimodal approach. *Instr Course Lect*. 2007;56:125–131.
9. Mahadevan D, Walter RP, Minto G, et al. Combined femoral and sciatic nerve block vs combined femoral and periarticular infiltration in total knee arthroplasty: a randomized controlled trial. *J Arthroplasty*. 2012;27:1806–1811.
10. Sakai N, Inoue T, Kunugiza Y, Tomita T, Mashimo T. Continuous femoral versus epidural block for attainment of 120° knee flexion after total knee arthroplasty: a randomized controlled trial. *J Arthroplasty*. 2013;28:807–814.
11. Christensen CP, Jacobs CA, Jennings HR. Effect of periarticular corticosteroid injections during total knee arthroplasty. A double-blind randomized trial. *J Bone Joint Surg [Am]*. 2009;91-A:2550–2555.
12. Chia SK, Wernecke GC, Harris IA, et al. Peri-articular steroid injection in total knee arthroplasty: a prospective, double blinded, randomized controlled trial. *J Arthroplasty*. 2013;28:620–623.
13. Ikeuchi M, Kamimoto Y, Izumi M, et al. Effects of dexamethasone on local infiltration analgesia in total knee arthroplasty: a randomized controlled trial. *Knee Surg Sports Traumatol Arthrosc*. 2014;22:1638–1643 [PubMed].
14. Sean VW, Chin PL, Chia SL, et al. Single-dose periarticular steroid infiltration for pain management in total knee arthroplasty: a prospective, double-blind, randomised controlled trial. *Singap Med J*. 2011;52:19–23.
15. Kwon SK, Yang IH, Bai SJ, Han CD. Periarticular injection with corticosteroid has an additional pain management effect in total knee arthroplasty. *Yonsei Med J*. 2014;55:493–498.
16. Sachiyuki Tsukada MD, Motohiro Wakui MD, Akiho Hoshino MD. A randomized controlled trial comparing periarticular injection and epidural analgesia. *J Bone Joint Surg Am*. 2015;97(5):367–373. Mar 04.

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How effective is periarticular drug infiltration in providing pain relief following Total Knee Replacement as compared to epidural analgesia?

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ABSTRACT

Introduction: The aim of the study was to compare the efficacy of pericapsular injection of analgesic drugs (PAI) with epidural analgesia (EA), in providing post-operative pain relief and early functional improvement of following Total Knee Arthroplasty.

Materials and methods: 50 patients were randomized to 2 arms of 25 patients each, receiving either pericapsular injection or epidural analgesia. The Visual Analogue Scale (VAS), functional outcomes and side effects related to the EA and PAI groups were assessed.

Results: The PAI group had significantly better pain relief on the first post-operative day with a mean VAS on 3.6 as opposed to 7 in the epidural group($p = 0.006$). Functional outcomes in the PAI group were significantly better in the early post-operative period with patients taking less time to achieve the same physiotherapy goals – straight leg raising, climb 14 steps and walking 50 m. Side effects like nausea, vomiting, pruritus and urinary retention were less with PAI. However, by the 5th postoperative day, functional independence and pain control were similar in both groups.

Conclusion: Pericapsular injection of analgesic drugs in total knee arthroplasty provides better pain control and functional recovery than epidural analgesia in the early post-operative period, and can be the choice method for analgesia following total knee replacement.

1. Introduction

The demand for Total Knee Replacement surgery has been on the rise and is predicted to grow even more significantly by the year 2030.[1] Post-operative pain associated with major operations like Total Knee Replacement (TKR) is quite considerable. More than half of these patients receive sub-optimal pain control and hence experience severe pain in the early postoperative period.[2] Adequate pain relief is essential for early mobilization and functional recovery.[3,4] Control of postoperative pain also reduces hospital stay and subsequent readmissions.[5–7]

Several therapeutic methods have been used to control pain and improve function in the post-operative period. These include patient controlled analgesia (PCA), femoral and adductor nerve blocks, epidural analgesia using a catheter and periarticular infiltration[6,8–10]. Though femoral nerve blocks are effective in pain control, the possible quadriceps weakness could delay the rehabilitation and ambulation.[11–13] While epidural analgesia is useful in postoperative pain control,[14,15] it is an invasive procedure and necessitates restricting the patient's mobility till the patient has recovered complete motor power. Epidural anaesthesia, like PCA, is associated with side effects that include nausea and vomiting, itching, in addition to urinary retention and motor deficits that may delay mobilization. The purpose of this study was to assess the efficacy of periarticular infiltration of an analgesic cocktail, in providing good pain control and aiding with early rehabilitation and mobilization following TKR. This was done by comparing the efficacy and complications with the current method of post-operative pain control at our institution i.e. epidural analgesia with bupivacaine.

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2. Methodology

Patients undergoing primary unilateral total knee replacement were recruited for the study. Exclusion criteria included patients with age >80 years, history of cardiac illnesses, or arrhythmias, patients undergoing complex primary or revision arthroplasty and severely painful opposite knee. Their functional status was measured preoperatively using the KSS (Knee Society Score) and the pain was assessed using the Visual analogue scale (VAS).

Patients were randomized into two arms by block randomization with concealed envelope method. In one arm, the patients received *epidural analgesia* with 0.1% Bupivacaine and 2mcg/ml of Fentanyl @ 4–6 ml per hour for 48 h postoperatively, and in the other, they received periarticular infiltration of an analgesic cocktail of drugs. The *analgesic cocktail* consisted of 50 ml of 0.2% Ropivacaine, 10 ml Normal saline, 0.3 ml Noradrenaline (0.6 mg), 40 mg Methylprednisolone acetate (Depomedrol), 10 mg Morphine, 30 mg Ketorolac, and 1gm Cefazolin. The first 30 ml of the cocktail was injected into the posterior knee capsule and soft tissues around the medial and lateral collateral ligaments before implantation of the actual prosthetic components. The quadriceps muscle, retinacular tissues, pes-anserinus, suprapatellar and infrapatellar fat pad were infiltrated with the remaining cocktail mixture.

All patients had perioperative analgesia with other drugs, which included Tab. Aceclofenac 100 mg twice daily, Cap. Omeprazole 20 mg twice daily, Cap. Pregabalin 75 mg twice daily - all started 36 h before the surgery and postoperatively with Inj. Paracetamol (Perfalgan – M/S Bristol Myers Squibb) 1gm IV once every 6 h for 48 h followed by Tab. Paracetamol 1gm once every 6 h for 7days. Injection Morphine 5 mg (subcutaneous) was given as required for breakthrough pain in the immediate postoperative period. Patients on epidural infusion had either bolus doses or an increase in the infusion rate for breakthrough pain. Inj. Ondansetron was used intravenously for postoperative nausea and vomiting.

Surgery was performed under general anaesthesia/spinal anaesthesia using a standard medial para-patellar arthrotomy using a pneumatic tourniquet by surgeons who were specialized in knee surgery. Prostheses used were Genesis II (Smith & Nephew, Memphis, TN, USA) and HP Sigma (DePuy, Johnson & Johnson, Warsaw, IN, USA). The implants were fixed with cement and patellae were resurfaced as required. A closed suction drain was placed inside the knee joint capsule before wound closure and removed 48 h later. Inj. Tranexamic[16] acid (10–15 mg/kg) was injected intravenously 15 min before tourniquet was released, and top up doses were given 3 and 6 h later. Anticoagulation was initiated postoperatively as per institutional guidelines.

Patients underwent a standard physiotherapy program that involved ankle pump exercises in bed, and SLR (Straight leg raise) from the first postoperative day – initially with a knee brace and subsequently without. They were encouraged to walk from the second postoperative day. A brace for the knee was used till the patient could do an active SLR. Number of days taken to walk 50 m without the brace and to climb a flight of 14 steps was documented. The distance walked in 6 min with a walker was recorded on the 10th postoperative day.

Pain experienced by the patient postoperatively was assessed using the Visual Analogue Scale by the primary investigator on a daily basis. It was also noted every 4 h by the hospital pain team for the first 72 h. The maximum VAS score for each day, as recorded by the primary investigator or the pain team, was noted. Additional medication used for breakthrough pain was noted.

Side effects including nausea, vomiting, pruritus, headache, urinary retention, cardiovascular complications, infection/postoperative wound ooze, ICU stay, nerve palsy and mortality were noted.

Institutional ethics committee clearance was given for the study; after which patients who consented for the study were recruited.

2.1. Statistical analysis

Setting the mean (SD) of the pain scale on a 10 point Likert scale, at about 4 (±1.5), and keeping the non-inferiority margin at 1.5, with alpha and beta errors at 5% and 20% respectively, the sample size required was 12 subjects in each arm. We have analysed the results of 25 in each arm. SPSS version 20 was used for analysis.

3. Results

50 patients were recruited for the study; of which 25 were randomized to receive the periarticular infiltration cocktail (PAI) and 25 received epidural analgesia (EA). Both the groups were demographically comparable. The demographic details of these patients are described in Table 1.

In the EA group, there were 19 cruciate retaining (CR) knees, and 6 posterior stabilized (PS) knees; where as in the PAI group, there were 20 CR knees and 5 PS knees. Five patients in the EA group and 4 in the PAI group had their patella replaced.

In terms of postoperative pain relief, the PAI group had significantly better relief of pain on the first post operative day (Fig. 1) ($p = 0.006$). The mean VAS on day 1 for the PAI group was 3.6 (±3.2), whereas it was 7(±2.8) for the EA group. Six out of the 25 patients who received EA had a pain score of 10 on the first day, while only 1 patient who received PAI had a score of 9. For the remaining postoperative duration, the PAI group consistently had better pain relief than the EA group till the 10th postoperative day – though the differences were not statistically significant (Fig. 1).

50% of the patients who had PAI required top up Morphine for postoperative pain control, while 72% (18 of 25 patients) on EA required either bolus doses of epidural infusion or a hike in the infusion rate or subcutaneous morphine to control pain postoperatively.

On assessment of functional outcome, the PAI group had significant early functional recovery, but by the 5th day, though the PAI group was functionally slightly better, the difference was not statistically significant (Table 2). All patients could climb a flight of 14 steps prior to discharge.

The EA group had a significantly higher percentage of side effects - probably due to the Fentanyl used in the epidural infiltration. 64% (16/25) of patients had postoperative nausea/vomiting, 36% (9/25) had pruritus and 36% (9/25) had a feeling of urinary retention. None had to be catheterized.

Table 1
Demographic profile.

	Epidural Analgesia (EA)	Periarticular Infiltration (PAI)
Number	25	25
Mean age (Years)	55	59
Preop functional score, KSS (0–100)	43	59
Sex		
Male	12	11
Female	13	14
Side		
Right	10	8
Left	15	17
Diagnosis		
Osteoarthritis	15	18
Rheumatoid Arthritis	8	7
Gout	2	0

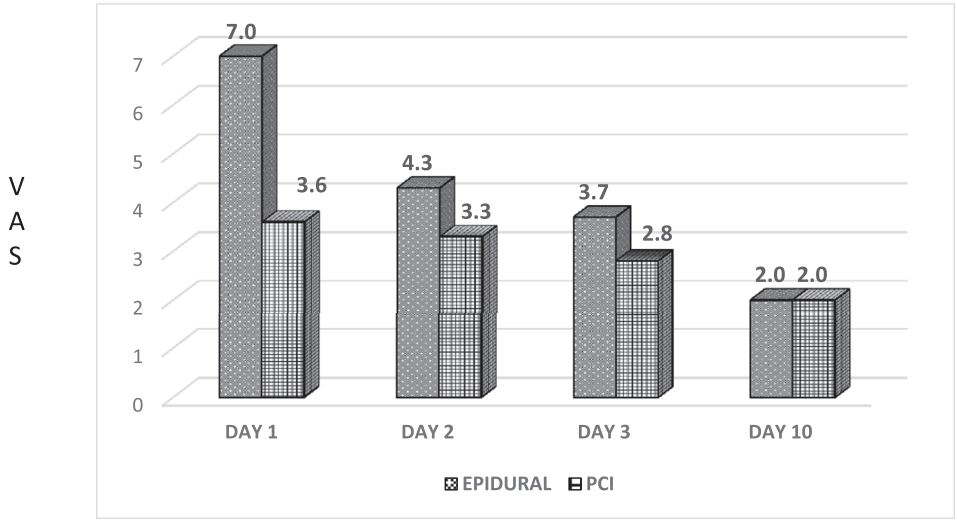

Fig. 1. Postoperative VAS scores.
Legend Figure 1 – Visual analogue scores (VAS) for pain following epidural analgesia (EA) and Periarticular injection (PAI).

Table 2
Functional outcome.

	Epidural Analgesia (EA)	Periarticular Infiltration (PAI)	P value
Time taken to do SLR while supine (without a brace)	3.9 days (1–7)	2.4 days (1–4)	0.032
Time taken to walk 50 m	3.5 days (2–7)	2.7 days (2–4)	0.050
Time taken to climb 14 steps	5.2 days (3–9)	4.95 days (4–7)	0.455
Distance walked in 6 min on Day 10	142 m	138 m	0.786
Knee flexion on 10th POD (mean)	97°	93°	0.889

In the PAI group, 32% (8/25) of patients had postoperative nausea/vomiting, 16% (4/25) had pruritus and 16% (4/25) had a feeling of urinary retention.

One patient who received PAI had a transient rise in blood pressure with bradycardia when the tourniquet was released. She required ICU observation for 1 day. This was probably because of the Noradrenaline in the cocktail mixture. None of the other patients required HDU/ICU admission. None of the patients had postoperative headache, backache, infections, meningitis, nerve palsies or wound related complications postoperatively.

4. Discussion

Postoperative pain after TKR is a significant concern to patients and a focus of several recent research papers. Several techniques such as patient controlled analgesia, femoral and adductor nerve blocks, epidural analgesia and periarticular injection of medications have been reported.

In this study, we have studied the efficacy of periarticular infiltration of a cocktail of drugs in controlling pain and enabling early functional recovery. The study shows that the periarticular infiltration is significantly better than the epidural injection in the first 24 h after the surgery. Even after the first 24–48 h, when we would have expected the analgesic effect of the injection to wear out, the pain scores were consistently less in the PAI group than in the epidural group. Functional ability in the first 24 h was also significantly better in the PAI group.

An additional advantage of the PAI over the EA is the reduced incidence of side effects like nausea, vomiting and pruritus. Additionally, mobilization is easier, as there are no catheters restricting the patient.

Arun Mullaji[17] in 2009 reviewed the effectiveness of a mixture of opioid, corticosteroid and a local anesthetic for periarticular injection in patients undergoing bilateral TKR. They injected one of the two knees with the drug cocktail. They reported significantly lower pain scores and better quadriceps recovery on the side that had periarticular injection of the anesthetic cocktail, as compared to the side that did not have the injection.

Thorsell et al.[18] in his comparative study on total knee arthroplasty patients using local infiltration anaesthesia technique with Ropivacaine, Ketorolac and Adrenaline to epidural anaesthesia reported earlier mobilization in the group treated with local infiltration technique. They concluded that this technique also offered better patient satisfaction and hence was better for postoperative pain relief than epidural anaesthesia.

Nattapol Tammachote et al.[19] compared the pain control effect of intrathecal morphine and multimodal drug injections in patients undergoing total knee arthroplasty. They found that though initially there was no difference between the two modalities, 12–16 h postoperatively, the intrathecal group consumed significantly more Ketorolac and that the side effects of nausea and vomiting was also more in this group compared to the group treated with multimodal drug injections.

Gudmundsdottir et al.[20] showed in a randomized double controlled study in 69 patients that there was no additional advantage of giving continuous adductor canal block on pain control or on early mobilization following knee replacement. Hence there is probably no need for additional nerve blocks for postoperative analgesia.

Spreng et al.[21] compared the efficacy of periarticular infiltration anaesthesia and epidural anaesthesia in total knee arthroplasty patients and reported that epidural anaesthesia provided better

pain relief in the immediate postoperative period, where as local infiltration anaesthesia provided better pain relief after the initial 24 h.

The above observations are contrary to what was found in our study, where we found better relief of pain with periarticular injection in the first 24 h. The level of analgesia was better for the remaining hospital stay as well, though the difference was not statistically significant. Early functional recovery was possible with PAI, though most patients in both groups were able to climb 14 steps by the 5th postoperative day. The reason for the prolonged beneficial effect of the PAI has not been fully explained by other investigators. Several theories have been postulated. It is possible that the excellent pain relief in the immediate postoperative period minimized the central neural sensitization, thereby reducing the pain thereafter. The steroid in the cocktail could also have a role in reducing the inflammatory pain postoperatively.

One of the major limitations in this study is that the epidural catheters were introduced by anaesthesiologists with varied skill and seniority. This could potentially have an effect on the efficacy of the infiltration. It is also possible that the infusion pump may occasionally have been turned off in the postoperative ward due to episodes of hypotension, and then restarted later by the surgical team. This could result in difficulties in titration of drugs to achieve the desired level, and an increased pain score in the immediate postoperative period.

While several surgeons use epidural anaesthesia to provide adequate analgesia and hypotension during the surgery, the necessity to continue the use of the epidural infusion[22] postoperatively should be questioned. This could potentially lead to issues with postoperative pain control and delayed functional improvement. Postoperative hypotension has not been a significant issue with PAI. This study demonstrates that better analgesia and pain control is provided by PAI, and the use of postoperative EA may not be required.

It has been reported that liposomal bupivacaine provided a longer duration of analgesia, and hence is to be choice for pericapsular cocktails and nerve blocks. However a recent Cochrane review[23] did not support its superiority over bupivacaine hydrochloride. We have used Ropivacaine hydrochloride for the cocktail in this study, as it has reportedly less cardiac side toxicity, and hence was preferred for this population.[24]

The study does not assess the effect on hospital stay, as at our center, most patients opt to stay till suture removal, which is very unusual in the current health care scenario. This is due to the fact that most patients come from long distances, and find it difficult to get safe lodging outside the hospital. However, it is assumed that early functional improvement will translate to early discharge in a different environment. In both groups, adequate control of pain provided the patient an opportunity to participate in the physiotherapy program at an early stage and attain functional independence within 4–5 days.

5. Conclusion

Both epidural analgesia and periarticular infiltration of analgesic cocktail are effective in controlling pain after total knee replacement. In this study we have shown that periarticular infiltration provides significantly better pain control and functional recovery in the first 24 h following surgery. Side effects like nausea, vomiting, pruritus and urinary retention are also less with periarticular infiltration of the analgesic cocktail. By the 5th postoperative day, functional independence and pain control are similar in both groups. We therefore conclude that periarticular injection of a cocktail of drugs is more effective than epidural analgesia, especially in the first 24 h, and can be the choice method for analgesia following total knee replacement.

Conflicts of interest

Nil.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jajs.2019.02.001.

References

1. Parvizi J, Miller AG, Gandhi K. Multimodal pain management after total joint arthroplasty. *J Bone Jt Surg*. 2011 Jun 1;93(11):1075–1084.
2. Guidelines for the management of postoperative pain after total knee arthroplasty. *Knee Surg Relat Res*. 2012 Dec;24(4):201–207.
3. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Jt Surg - Ser A*. 2007 Apr;89(4):780–785.
4. Ekman EF, Koman LA. Acute pain following musculoskeletal injuries and orthopaedic surgery: mechanisms and management. *Instr Course Lect*. 2005;54:21–33.
5. Parvataneni HK, Shah VP, Howard H, Cole N, Ranawat AS, Ranawat CS. Controlling pain after total hip and knee arthroplasty using a multimodal protocol with local periarticular injections: a prospective randomized study. *J Arthroplasty*. 2007 Sep;22(6 Suppl 2):33–38.
6. Maheshwari AV, Blum YC, Shekhar L, Ranawat AS, Ranawat CS. Multimodal pain management after total hip and knee arthroplasty at the Ranawat Orthopaedic Center. *Clin Orthop*. 2009 Jun;467(6):1418–1423.
7. Parvizi J, Porat M, Gandhi K, Viscusi ER, Rothman RH. Postoperative pain management techniques in hip and knee arthroplasty. *Instr Course Lect*. 2009;58:769–779.
8. Sinatra RS, Torres J, Bustos AM. Pain management after major orthopaedic surgery: current strategies and new concepts. *JAAOS - J Am Acad Orthop Surg*. 2002 Apr;10(2):117.
9. Krych A, T Horlocker T, Hebl J, Pagnano M. Contemporary pain management strategies for minimally invasive total knee arthroplasty. *Instr Course Lect*. 2010 Jan 1;59:99–109.
10. Singelyn FJ, Ferrant T, Malisse MF, Joris D. Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous femoral nerve sheath block on rehabilitation after unilateral total-hip arthroplasty. *Reg Anesth Pain Med*. 2005 Oct;30(5):452–457.
11. Parvizi J, Miller AG, Gandhi K. Multimodal pain management after total joint arthroplasty. *J Bone Joint Surg Am*. 2011 Jun 1;93(11):1075–1084.
12. Kandasami M, Kinninmonth AW, Sarungi M, Baines J, Scott NB. Femoral nerve block for total knee replacement — a word of caution. *Knee*. 2009 Mar 1;16(2):98–100.
13. Lynch J. Prolonged motor weakness after femoral nerve block with bupivacaine 0.5%. *Anaesthesia*. 1990 May;45(5):421.
14. Klasen J, Haas M, Graf S, et al. Impact on postoperative pain of long-lasting preemptive epidural analgesia before total hip replacement: a prospective, randomised, double-blind study. *Anaesthesia*. 2005 Feb 1;60(2):118–123.
15. Pier I, Grant S, Nielsen K, Parker Vail T. *Regional Anesthesia in Hip Surgery*. vol. 441. 2006, 250 p.
16. Alshryda S, Sarda P, Sukeik M, Nargol A, Blenkinsopp J, Mason JM. Tranexamic acid in total knee replacement: a systematic review and meta-analysis. *J Bone Joint Surg Br*. 2011 Dec;93(12):1577–1585.
17. Mullaji A, Kanna R, Shetty GM, Chavda V, Singh DP. Efficacy of periarticular injection of bupivacaine, Fentanyl, and Methylprednisolone in total knee arthroplasty: a prospective, randomized trial. *J Arthroplasty*. 2010 Sep 1;25(6):851–857.
18. Thorsell M, Holst P, Hyldahl HC, Weidenhielm L. Pain control after total knee arthroplasty: a prospective study comparing local infiltration anesthesia and epidural anesthesia. *Orthopedics*. 2010 Feb;33(2):75–80.
19. Tammachote N, Kanitnate S, Manuwong S, Yakumpor T, Panichkul P. Is pain after TKA better with periarticular injection or intrathecal morphine? *Clin Orthop*. 2013 Jun;471(6):1992.
20. Gudmundsdottir S, Franklin JL. Continuous adductor canal block added to local infiltration analgesia (LIA) after total knee arthroplasty has no additional benefits on pain and ambulation on postoperative day 1 and 2 compared with LIA alone. *Acta Orthop*. 2017 Oct;88(5):537–542.
21. Spreng UJ, Dahl V, Hjall A, Fagerland MW, Ræder J. High-volume local

infiltration analgesia combined with intravenous or local ketorolac+morphine compared with epidural analgesia after total knee arthroplasty. *Br J Anaesth*. 2010 Nov;105(5):675–682.
22. Juelsgaard P, Larsen UT, Sørensen JV, Madsen F, Søballe K. Hypotensive epidural anesthesia in total knee replacement without tourniquet: reduced blood loss and transfusion. *Reg Anesth Pain Med*. 2001 Apr;26(2):105–110.
23. Hamilton TW, Athanassoglou V, Mellon S, et al. Liposomal bupivacaine infiltration at the surgical site for the management of postoperative pain. *Cochrane Database Syst Rev*. 2017 01;2. CD011419.
24. Graf BM, Abraham I, Eberbach N, Kunst G, Stowe DF, Martin E. Differences in cardiotoxicity of bupivacaine and ropivacaine are the result of physicochemical and stereoselective properties. *Anesthesiol J Am Soc Anesthesiol*. 2002 Jun 1;96(6):1427–1434.

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Rotational stability after ACL reconstruction using anatomic double bundle technique versus anatomic single bundle technique plus anterolateral ligament augmentation

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ABSTRACT

Background: A residual pivot shift seen in up to quarter of ACL reconstructions using anatomic single bundle (ASB) technique. Light has been thrown on the importance of the Posterolateral (PL) bundle and its role in rotational stability, hence the concept of anatomic double bundle (ADB) reconstruction. Anterolateral ligament (ALL) reconstruction; an added extra-articular procedure, is proposed to be responsible for rotational knee stability. The aim of this study was to assess functional outcomes and rotational stability of the knee after ADB versus ASB reconstruction plus ALL augmentation.

Patients and methods: Between January 2015 and December 2015, a randomized controlled trial (RCT) was conducted on 40 patients suffering from chronic ACL injuries or acute injuries with high grade knee jerk or are high demand athletes. Twenty patients (group A) were treated with ASB ACL reconstruction and ALL augmentation. The other 20 patients (group B) underwent ADB ACL reconstructions. All patients were assessed pre and post-operatively using the Lysholm and IKDC (international knee documentation committee) scores and KT-1000 arthrometer. At the final follow-up, internal rotation kinematics of the knee was assessed using motion analysis in a gait lab.

Results: All were followed-up for a mean of two years. At the final follow-up, there was no statistically significant difference regarding the total Lysholm score, IKDC score and KT-1000 side to side difference; P-values 0.821, 0.732, 0.533 respectively. Group 'A' demonstrated better rotational stability than group 'B' as measured from internal tibial rotation angle with a p-value of 0.001.

Conclusion: ALL augmentation is an added extra-articular procedure that superseded ADB reconstruction in achieveing better knee internal rotation kinematics. Level of evidence: II.

1. Introduction

Techniques for ACL reconstruction are continuously being modified in attempt to restore the native anatomy and kinematics of the knee. The standard anatomical single bundle (ASB) reconstruction yields good results regarding antero-posterior stability, however; it is still questionable in terms of rotational stability.[1] Several studies concluded that ASB fail to confer control of rotational stability and does not reduce risk of knee arthritis.[2]

In the light of better knee rotational stability, several new techniques and procedures are being developed for reconstruction of an ACL that closely resembles the native ACL in anatomy and function. Some proposed a more horizontal graft position (lower femoral tunnel),[3] others added an extra-articular procedure (modified Macintosh). Recently light have been thrown on the ALL and its precise anatomy,[4,5] which contributes to the rotatory stability of the knee.[6–8] Anatomical double bundle (ADB) reconstruction was proposed after biomechanical studies have proven the ACL to be functionally composed of two bundles; anteromedial (AM) and posterolateral (PL). Though it is technically more demanding, a more lengthy procedure and not applicable for individuals with a narrow notch, it is postulated to yield more

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promising results.[3,9] Up to the authors' knowledge, no previous studies compared ADB with ACL plus ALL reconstruction.

2. Patients and methods

After approval of the ethical committee of, a prospective randomized controlled trial (RCT) was conducted from January 2015 till December 2015 to compare the results, IKDC, Lysholm scores and rotational stability of the knee after ASB ACL reconstruction with ALL augmentation versus ADB ACL reconstruction.

A total of 40 patients with ACL injury (chronic injuries or injuries with knee jerk GIII) were included in the study and allocated randomly into one of two groups. An informed consent was obtained from all patients. Twenty patients underwent ASB ACL reconstruction plus ALL augmentation (Group A) while the remaining 20 underwent ADB ACL reconstruction (Group B). All patients with acute ACL injuries with a knee jerk GIII or a lower jerk grade in a highly demanding athlete and chronic ACL injuries, whether isolated or associated with meniscal injuries were included in the study. Patients with bilateral ACL injuries, revision cases, those with associated ligamentous tears and patients with severe osteo-arthritis were excluded.

2.1. Patient demographics

The patients' age ranged from 15 to 42 years with a mean of 25.78. Mean age for group 'A′ was 24.9 (standard deviation (S.D.) of ±7.2, range 15–37 years. Mean age for Group 'B′ was 26.6 (S.D. ± 7.2 ranging from 18 to 42 years). Group 'A′ included 17 males (85%) and 3 females (15%). In group 'B′ all 20(100%) patients were males and none were females. In group 'A′, 14 (70%) had sustained injury to the right knee while 6 (30%) had their left knee injured. In group 'B′, 13 (65%) had right knee injury, while 7 (35%) suffered a left knee injury. Six (30%) out of 20 in group 'A′ were professional athletes as compared to 5 (25%) out of 20 patients in group 'B'.

Mean time from injury to surgery in group 'A′ was 8.8 months ± 21.2 while in group 'B′ it was 10.0 months ± 10.6; p-value was 0.874 (NS). Twenty-five patients have sustained a non-contact injury while only 15 had direct contact trauma.

2.2. Pre-operative evaluation

Clinical evaluation; History taking for the mode and time of trauma, giving way, knee pain, knee swelling, locking, limping and previous interventions. Full knee examination was done in the outpatient clinic. Lysholm knee score and IKDC score were done for all patients.

Radiographic evaluation; Plain radiographs in the AP and Lateral views and MRI were the studies used in all cases.

2.3. Operative details and procedure

All surgeries were performed in the supine position, under general (in 20 patients) or spinal anesthesia (in the other 20 patients). A post was placed at the side of the operating table to abut the thigh facilitating valgus maneuvering during arthroscopic examination of the medial compartment. Routine examination under anesthesia (EUA) was performed as the first step for all patients. The grade of knee jerk was noted and documented. A tourniquet cuff connected to a digital timer was secured over the proximal thigh. The limb was exsanguinated and the cuff inflated to a pressure of approximately 350 mmHg (200 mmHg above the systolic pressure). The anatomic landmarks for the ALL were identified and marked with a marker pen for group 'A′ patients. The whole limb was then sterilized with povidone iodine and draped.

2.3.1. Graft harvesting

In both group 'A′ and 'B′, harvesting of the hamstring tendons (semi-T and Gracilis) was performed in the figure-of-four position through a small oblique incision. A closed striper was used to harvest the tendons one following the other, after they were freed from the connections.

2.3.2. Arthroscopic procedure

Diagnostic knee arthroscopy (DKA) was performed as a routine step in all cases. Any meniscal lesions were treated prior to ACL reconstruction, either by performing partial menisectomy or meniscal repair.

2.3.3. Tunnel placement and drilling

In group A; a C-guide, adjusted to 55°; was used to introduce a single tibial guide wire in the center of the tibial anatomic footprint. The position of the wire is checked and that full extension could be achieved without impingement, followed by drilling of the tunnel. Through accessory anteromedial (AAM) portal, with the knee flexed 120°, a single femoral tunnel is created. This allows its precise placement in the center of the foot print, at the level if the intercondylar ridge just posterior to the bifurcate ridge. First a guide pin is introduced, then the tunnel is drilled corresponding to the graft diameter.

In group B; two tibial and femoral tunnels are created. The AM tunnel is drilled first then separate femoral and tibial PL aimers from the double bundle set available from Smith and Nephew are used to guide placement of the PL femoral (Fig. 1a) and tibial tunnels (Fig. 1b) respectively. On the femoral side, after measurement of the condyle diameter with a depth gauge, the AM tunnel is drilled over a guide pin introduced behind the bifurcate ridge and below intercondylar ridge. A 4.5 mm drill bit is used to drill the entire depth of the tunnel, followed by a 6/7 mm drill bit corresponding to the size of the graft. The PL tunnel is then drilled in the same fashion but anterior to the bifurcate ridge, leaving a 2 mm bony bridge between both tunnels. On the tibial side, the AM tunnel is drilled first over a guide pin placed anterior and medial in the tibial footprint. This is followed by PL tunnel drilling, allowing 1 cm cortical distance to avoid tunnel collision.

2.3.4. Anterolateral ligament (ALL)

This form of extra-articular augmentation was done in group 'A′ only. After drilling of the ACL tunnels, before passage of the ACL graft, femoral and tibial tunnels are created for ALL. The femoral tunnel was drilled over a guide pin introduced just above and posterior to the lateral epicondyle, aiming antero-superiorly to

a

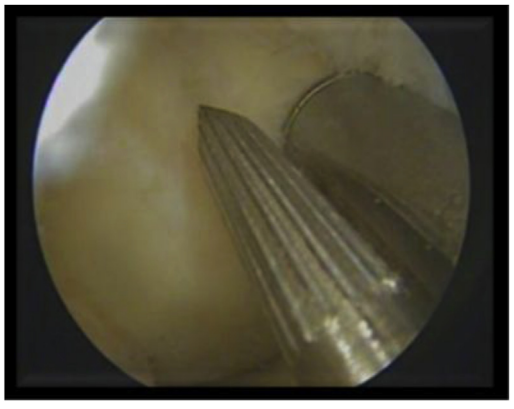

Fig. 1a. Femoral PL aimer used to introduce the guide pin for the PL femoral tunnel after drilling of the AM tunnel.

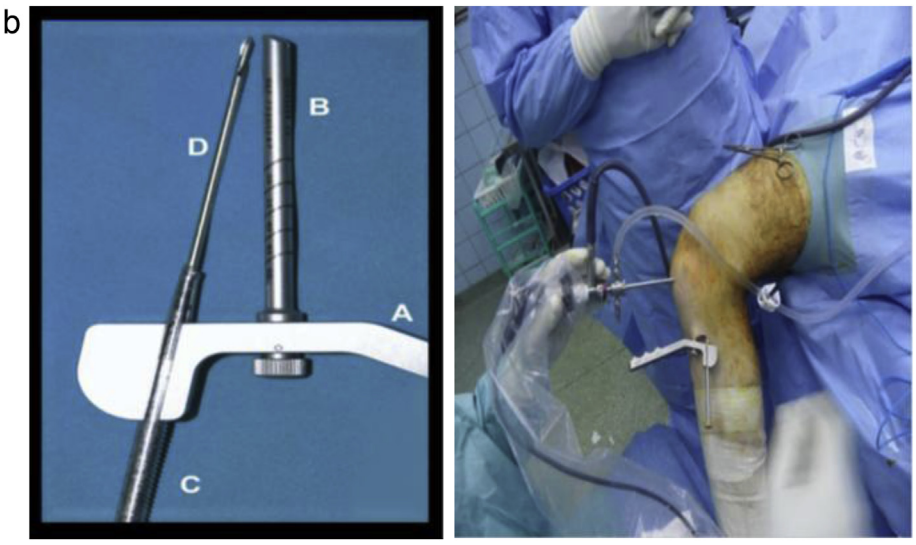

Fig. 1b. PL aimer from the double bundle set provided by Smith and Nephew used to introduce the tibial PL pin.

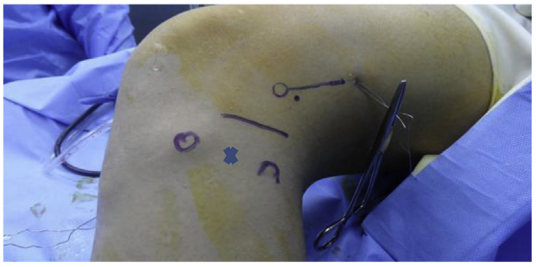

Fig. 2. Landmarks marked with a marker pen for the sites chosen to create tunnels for ALL reconstruction. On the femoral side a point is chosen just above an behind the lateral epicondyle. On the tibial side a point is chosen 7 mm below the joint line midway between Gerdy's tubercle and the head of fibula.

avoid collision with ACL tunnel. The tibial tunnel was drilled halfway between the fibular head and the Gerdy's tubercle, 7 mm below the joint line (Fig. 2).

2.3.5. Graft preparation

Meanwhile the notch was being prepared and the tunnels drilled, the graft was prepared by an assistant on the back table with help of a graft tensioner. In group A; the tendons were separated; the ST was tripled and prepared as the ACL graft. The "G" was doubled and prepared as the ALL graft. In group B; Here the ST is prepared into the AM bundle. The graft size and length are then measured. The "G" is prepared into the PL bundle in the same manner but is usually smaller in diameter.

2.3.6. Passage and fixation of the grafts

In group A; both ACL and ALL grafts are fixed with bio-screws on tibial and femoral sides, starting with ACL graft first. In group B; the PL bundle is shuttled first an fixed in extension, followed by the AM bundle which is fixed in 90° flexion. Both bundles are fixed with an endo-button on the femoral side and bio-screws on the tibial side. The bundles are parallel near full extension, but are crossed in flexion.

2.4. Post-operatively

Patients stay in the hospital for one or two nights, in the ward, where they receive intravenous antibiotics, cryotherapy, antiedematous modalities, anticoagulation and start static quadriceps exercises. Patients were discharged on oral antibiotics (3rd generation cephalosporin), anticoagulation and analgesics for 1 week. Full weight-bearing is allowed aided by 2 crutches for balancing. After 1 week, aspiration was done in cases of moderate or severe effusion. After 2 weeks, one crutch is discarded and at 1 month post-operative, weight bearing is allowed without crutches.

Physiotherapy was started, following the accelerated rehabilitation program for 6 months. Flexion is limited to 90° in cases of meniscal repair. At the final follow-up at 2 years, patients were assessed using the Lysholm, objective IKDC scores and KT-1000 instrumented Lachman. Rotational stability was assessed in gait lab using computerized kinematic analysis.

2.5. Statistical methods used

The statistical analysis was done using SPSS v22.0 IBM statistical package for social sciences & Microsoft Office 2013. The significance level was set at $p < 0.05$ & marked with S, while highly statistical significance was set at $p < 0.01$ & marked with HS. The statistical insignificance was set at $p > 0.05$ & marked by NS. The categorical data were subjected to descriptive analysis using frequency & percentage while for the scale data mean & standard deviation SD was used. Tests for inferential statistics & correlation were Chi Square test, independent *t*-test, paired *t*-test & Wilcoxon Rank test for paired results.

3. Results

Mean operative time in group 'A' was 95 min ranging from 70 to 120 min. Group 'B'; 120 min (range 90–170 min), statistically significant with P-value 0.004. The mean blood loss was negligible. The mean follow-up was 2 years (24 months) ranging from 22 to 26 months. In group 'A' 3 patients (15%) had meniscal repairs, while 9 (45%) had partial meniscectomies (PM). In group B there were 3 (15%) meniscal repairs and 8 (40%) had PM.

3.1. Subjective outcomes (Lysholm score)

Pre-operatively: *In group A*; none had an excellent score (95–100). One patient (5%) had a good score (84–94) while 6 (30%)

had a fair score (65–83) and 13 (65%) had a poor score (<64). *In group B*; none of the patients had an excellent score (95–100). Three (15%) had a good score (84–94), while 5 (25%) had a fair score (65–83) and 12 (60%) had a poor score (<64). Post-operatively: *In group A*; 7 patients (35%) had an excellent score (95–100). Twelve (60%) had a good score (84–94) while only one (5%) had a fair score (65–83) and none of the patients had a poor score (<64). *In group B*; 10 patients (50%) had an excellent score (95–100). Seven (35%) had a good score (84–94) while 3 (15%) had a fair score (65–83) and none of the patients had a poor score (<64). No statistically significant difference existed between both groups neither pre nor post-operatively with p-values of 0.521 and 0.331 respectively.

3.2. Objective outcomes

3.2.1. IKDC score

All patients were scored for these items before and after the surgery. Four grades were determined for each group: *Grade A = normal, Grade B = nearly normal, Grade C = abnormal and Grade D = severely abnormal* (Table 1).

3.2.2. KT-1000 instrumented Lachmann

There was no statistically significant difference between both groups regarding post-operative anterior translation measured by KT-1000 arthro-meter in the sound and injured limbs and side to side difference (Table 2).

3.2.3. Rotational stability

It is measured as internal tibial rotation angle for the injured and sound limbs in each group. Then the side to side difference was calculated. There is a statistically significant difference regarding internal tibial rotation angle measured in the operated limb and with side to side difference between group A and B, with a better outcome in group A; p-values 0.011 (S) and 0.001 respectively (Table 3).

Table 1
Showing pre-operative and post-operative objective IKDC scores in group 'A' and 'B'.

IKDC parameter	Pre-operatively		Post-operatively Final follow-up	
	Group A	Group B	Group A	Group B
Effusion				
A: none	13 (65%)	11(55%)	18 (90%)	18 (90%)
B: mild	4 (20%)	6 (30%)	2 (10%)	2 (10%)
C:moderate	3 (15%)	2 (10%)	None	None
D: severe	None	1 (5%)	None	None
Motion deficit				
Lack of Extension (EXT.)				
A: <3°	11 (55%)	12 (60%)	18 (90%)	15 (75%)
B: 3–5°	6 (30%)	4 (20%)	2 (10%)	4 (20%)
C: 6–10°	3 (15%)	3 (15%)	none	1 (5%)
D: > 10°	None	1 (5%)	none	None
Lack of flexion (flex.)				
A: 0–5°	10 (50%)	9 (45%)	18 (90%)	18 (90%)
B: 6–15°	3 (15%)	5 (25%)	1 (5%)	1 (5%)
C: 16–25°	7 (35%)	4 (20%)	1 (5%)	1 (5%)
D: >25°	None	2 (10%)	None	None
Ligament examination:				
Lachmann:				
A:0–2 mm	None	None	15 (75%)	16 (80%)
B:3–5 mm	1 (5%)	1 (5%)	4 (20%)	2 (10%)
C:6-10	14 (70%)	8 (40%)	1 (5%)	2 (10%)
D:>10	5 (25%)	11 (55%)	None	None
Pivot shift test:				
A:equal	None	None	18 (90%)	16 (80%)
B: glide(+)	1 (5%)	2 (10%)	2 (10%)	3 (15%)
C:clunk(++)	3 (15%)	5 (25%)	None	1 (5%)
D:Gross(+++)	16 (80%)	13 (65%)	None	None
Functional test (one leg hop test)				
A: ≥ 90%	None	None	16 (80%)	15 (75%)
B: 89-76%	2 (10%)	2 (10%)	3 (15%)	3 (15%)
C: 75-50%	5 (25%)	7 (35%)	1 (5%)	2 (10%)
D: <50%	13 (65%)	11 (55%)	None	None

Table 2
KT-1000 injured side, sound side and side to side difference in both groups post-operatively.

KT-1000	Group A Mean ± SD	Group B Mean ± SD	P
Injured	4.6 ± 1.59	4.1 ± 1.59	0.3 NS
Sound	3.5 ± 1.2	2.9 ± 1.1	0.1 NS
Difference	1.1 ± 0.8	1.3 ± 1.3	0.5 NS

Table 3
Results for internal tibial rotation angle in the injured and sound limbs and side to side difference for group A and B.

Variable	Group A Mean ± SD	Group B Mean ± SD	95%CI		P
			Upper	Lower	
Injured	−13.8 ± 3.1	−17 ± 4.6	5.6	0.6	0.01 S
Sound	−11.8 ± 3.1	−11.9 ± 2.9	2.1	−1.8	0.8 NS
Difference	2 ± 1.17	5 ± 2.7	−1.6	−4.4	0.001 HS

3.3. Complications

In group A, according to IKDC score; four suffered *compartment pathologies*; 3 were grade "B", moderate changes in the lateral compartment and one patient was grade "C"; moderate changes with mild pain in the medial compartment after a partial meniscectomy (PM) for MM. Two patients suffered pain in the graft harvest site. In group 'B'; Two patients had mild *Harvest site pathologies* (graded B); in the form of intermittent medial pain. Only 1 patient suffered moderate pathology in the form of mild superficial infection that was successfully managed by debridment and IV antibiotics. Three patients had *compartment changes;* two had crepitations of the medial compartment, graded "B". One patient suffered crepitations of anterior and medial compartments with mild pain; graded "C". In one patient the tibial AM tunnel was a little anterior causing the graft to impinge at the roof of the notch. This required notchoplasty in the same session and early strict extension exercises. The patient was able to achieve full range of motion at final follow-up.

4. Discussion

Residual positive pivot shift especially among patients with a high grade knee jerk, chronic tears and highly demanding athletes; led surgeons approach such cases a little bit differently from the currently widely accepted concept of ASB ACL reconstruction.[10–12] Pivot shift is a multi-planar movement combining anterior translation and rotational elements. It is debatable as to which element contributes more to this complex movement in ACL deficient knees.[13–15] ***Zaffagini et al*** suggests that 20–25% of poor outcome following ACL reconstruction is due to poor internal rotational stability,[16] which is the key to the positive knee jerk post-operatively. Several in vivo and in vitro studies have demonstrated the inability of single bundle reconstructions to restore the rotational stability.[17–19] Increased laxity is associated with higher chance of meniscal, chondral injuries and secondary osteoarthritis; resulting from more abrupt motion and poorly fitting joint surfaces.[20–22] Another important issue; is lack of instruments and tools to quantify and assess the complex kinematic ligament

stability and rotation in vivo.

Extra-articular procedures have been suggested to achieve better control of rotational stability[23,24]; however, scar, morbidity and overloading the lateral compartment with subsequent arthritic changes are worrisome complications.[25] The ALL; is a new anatomically discovered lateral knee structure, proposed to be responsible for rotational knee stability.[4,5,7] It is however still debatable whether this is true ligament or a condensation of the capsule and whether it is capsular or purely extra-capsular.[26] Objective and subjective outcome of both methods requires comparison along with assessment of rotational knee stability. Subjective scores and knee tests limit our ability to truly gauge differences between ACL reconstruction techniques.[27,28]

The results of the current study are comparable with those of two clinical trials; ***Feretti et al*** and ***Monaco et al***, who suggest that the PL bundle does not confer more rotational stability.[29,30] The mean KT-1000 side to side difference in ADB reconstructions of this study are similar to ***T.P. Branch et al***; although, they relied on robotic knee testing system.[31] They were slightly greater than ***Hofbauer et al***[32] and lower than ***Plaweski et al***.[33] ***Hofbauer et al*** and ***Plaweski et al*** used computer navigation to assist accurate and precise tunnel placement,[32] and to quantify AP laxity using Lachman testing. Despite relying on computer navigation for quantifying knee kinematics in their study, the results in this study were superior to ***Plaweski et al***. It is also important to note that our analysis of AP stability was at the final follow-up, providing a good reflection of the patient's functional outcome after re-habilitation. In the studies of ***Hofbauer et al*** and ***Plaweski et al***, measurements taken intra-operatively at time "0"; omit the role of rehabilitation, complications and time which affects the overall functional outcome. Studies suggest that grafts used, lengthen with time.[34]

In this study that ASB + ALL (group A) had a slightly better reduction of anterior translation as compared to ADB reconstruction indicated by a lower side to side difference with respect to KT-1000 measurements in group 'A′ as compared to group 'B′, this is consistent with both ***Zaffagini et al***[35] and ***Monaco et al***.[24] However, it was not found to be statistically significant.

With respect to pivot shift; in this study patients treated with ASB + ALL reconstruction showed better correction of the pivot shift as compared to those treated with ADB. This is different from the findings of ***Zaffagini et al***,[35] however; this was not statistically significant, possibly due to our small sample size. ***Monaco et al***[24] reported better control on internal tibial rotation with extra-articular procedures compared to DB reconstruction. The results in this study are consistent with their findings.

After the precise description of ALL in anatomic and biomechanical studies, light have been thrown on its importance as a secondary knee restraint. Several cadaveric studies evaluated the role of the ALL in control over knee rotational stability. ***Matthew T. Rasmussen*** et al. studying cadaver knees in ***2015***; found a minimal contribution of the ALL to anterior tibial translation, but an important role in resiting internal rotation. They also reported a minimal role of the ACL in resisting internal rotation.[36] It is however, argued in other studies in vitro, that the ALL played minimal role in rotational stability. Cadaveric studies may ignore the fact that functional and biomechanical properties of tissues vary in vitro compared to in vivo.

Several cadaveric studies have recently highlighted the importance of the ilio-tibial band and claim that it is the main stabilizer of the knee in the face of internal rotational force.[29,37] It is important to note that in cadaver knees, soft tissue properties change as compared to in vivo. Secondly, cadavers usually belong to the geriatric population; we believe this poses an element of bias because the biomechanical properties change with age. Thus; results of cadaveric studies cannot be implied to young individuals who sustain injuries of the ACL. More clinical trials are required to study the role of ALL reconstruction of rotational stability of the knee in young human subjects and to compare ALL reconstruction with the ITB augmentation.

The strength of this study lies in being a randomized controlled trial. To the authors' knowledge, it is the first study to compare ADB ACL reconstruction with ASB and ALL reconstruction. We relied on computerized motion analysis in gait lab to assess the internal tibial rotation angle. However; we believe our weaknesses include the small sample size and that AP translation was measured using KT-1000 arthrometer with inter and intra-observer bias.

5. Conclusion

ASB reconstruction plus ALL augmentation supersedes ADB reconstruction in achieving better internal rotational knee kinematics, however; it did not demonstrate superior functional outcomes. ASB plus ALL augmentation showed a significantly shorter operative time as compared to ADB reconstruction, lower risk for intra-operative complications and hence would be chosen over ADB reconstruction. Recent literature and cadaveric studies consider the ilio-tibial band (ITB) the important secondary stabilizer to AP translation and rotational stability. They advocate ITB tenodesis as an added extra-articular augmentation to achieve better rotational stability. Controlled clinical trials are needed to compare outcomes with ALL versus ITB tenodesis.

Declaration of interest

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References

1. Tiamklang T, Sumanont S, Foocharoen T, Laopaiboon M. Double-bundle versus single-bundle reconstruction for anterior cruciate ligament rupture in adults. *Cochrane Database Syst Rev*. 2012 Nov 14;11:CD008413.
2. Ingham SJM, de Carvalho RT, Martins CAQ, et al. Anterolateral ligament anatomy: a comparative anatomical study. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(4):1048–1054.
3. Steiner M. Anatomic single-bundle ACL reconstruction. *Sports Med Arthrosc*. 2009;17(4):247–251.
4. Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. *J Anat*. 2013 Oct 1;223(4):321–328.
5. Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA. The anterolateral ligament. *Bone Joint Lett J*. 2014 Mar 1;96(3):325–331.
6. Vincent JP, Magnussen RA, Gezmez F, et al. The anterolateral ligament of the human knee: an anatomic and histologic study. *Knee Surg Sports Traumatol Arthrosc*. 2012 Jan 1;20(1):147–152.
7. Helito CP, Demange MK, Bonadio MB, et al. Anatomy and histology of the knee anterolateral ligament. *Orthop J Sport Med*. 2013 Dec 1;1(7), 2325967113513546.
8. Parsons EM, Gee AO, Spiekerman C, Cavanagh PR. The biomechanical function of the anterolateral ligament of the knee. *Am J Sports Med*. 2015 Mar;43(3):669–674.
9. Ho J, Gardiner A, Shah V, Steiner ME. Equal kinematics between central anatomic single-bundle and double bundle anterior cruciate ligament reconstructions. *Arthroscopy*. 2009 May;25(5):464–472.
10. Galway HR, MacIntosh DL. The lateral pivot shift: a symptom and sign of anterior cruciate ligament insufficiency. *Clin Orthop Relat Res*. 1980 Mar 1;147:45–50.
11. Tashman S, Collon D, Anderson K, Kolowich P, Anderst W. Abnormal rotational knee motion during running after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2004 Jun 1;32(4):975–983.
12. Ristanis S, Stergiou N, Patras K, Vasiliadis HS, Giakas G, Georgoulis AD. Excessive tibial rotation during high-demand activities is not restored by anterior cruciate ligament reconstruction. *Arthrosc J Arthrosc Relat Surg*. 2005 Nov 30;21(11):1323–1329.

13. Benjaminse A, Gokeler A, van der Schans CP. Clinical diagnosis of an anterior cruciate ligament rupture: a meta-analysis. *J Orthop Sports Phys Ther*. 2006 May;36(5):267–288.
14. Kaplan N, Wickiewicz TL, Warren RF. Primary surgical treatment of anterior cruciate ligament ruptures. A long-term follow-up study. *Am J Sports Med*. 1990 Jul 1;18(4):354–358.
15. Kocher MS, Steadman JR, Briggs KK, Sterett WI, Hawkins RJ. Relationships between objective assessment of ligament stability and subjective assessment of symptoms and function after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2004 Apr 1;32(3):629–634.
16. Zaffagnini S, Bignozzi S, Martelli S, Imakiire N, Lopomo N, Marcacci M. New intraoperative protocol for kinematic evaluation of ACL reconstruction: preliminary results. *Knee Surg Sports Traumatol Arthrosc*. 2006 Sep 1;14(9):811–816.
17. Mae T, Shino K, Miyama T, et al. Single–versus two–femoral socket anterior cruciate ligament reconstruction technique: biomechanical analysis using a robotic simulator. *Arthrosc J Arthrosc Relat Surg*. 2001 Sep 30;17(7):708–716.
18. Aglietti P, Giron F, Cuomo P, Losco M, Mondanelli N. Single-and double-incision double-bundle ACL reconstruction. *Clin Orthop Relat Res*. 2007 Jan 1;454:108–113.
19. Yagi M, Wong EK, Kanamori A, Debski RE, Fu FH, Woo SL. Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction. *Am J Sports Med*. 2002 Sep 1;30(5):660–666.
20. Schmitt LC, Rudolph KS. Influences on knee movement strategies during walking in persons with medial knee osteoarthritis. *Arthritis Care Res*. 2007 Aug 15;57(6):1018–1026.
21. Dayal N, Chang A, Dunlop D, et al. The natural history of anteroposterior laxity and its role in knee osteoarthritis progression. *Arthritis Rheum*. 2005 Aug 1;52(8):2343–2349.
22. Jonsson H, Riklund-Åhlström K, Lind J. Positive pivot shift after ACL reconstruction predicts later osteoarthrosis 63 patients followed 5–9 years after surgery. *Acta Orthop Scand*. 2004 Jan 1;75(5):594–599.
23. Terry GC, Hughston JC, Norwood LA. The anatomy of the iliopatellar band and iliotibial tract. *Am J Sports Med*. 1986 Jan;14(1):39–45.
24. Monaco E, Labianca L, Conteduca F, De Carli A, Ferretti A. Double bundle or single bundle plus extraarticular tenodesis in ACL reconstruction? *Knee Surg Sports Traumatol Arthrosc*. 2007 Oct 1;15(10):1168–1174.
25. Zaffagnini S, Bruni D, Russo A, et al. ST/G ACL reconstruction: double strand plus extra-articular sling vs double bundle, randomized study at 3-year follow-up. *Scand J Med Sci Sports*. 2008 Oct 1;18(5):573–581.
26. Musahl V, Rahnemai-Azar AA, van Eck CF, Guenther D, Fu FH. Anterolateral Ligament of the Knee, Fact or Fiction?
27. Jacobs CA, Christensen CP. Correlations between knee society function scores and functional force measures. *Clin Orthop Relat Res*. 2009 Sep 1;467(9):2414–2419.
28. Noyes FR, Grood ES, Butler DL, Malek M. Biomechanical concepts. *Clin Orthop Relat Res*. 1980 Jan 1;146:84–89.
29. Monaco E, Maestri B, Labianca L, Speranza A, Kelly MJ, Ferretti A. Navigated knee kinematics after tear of the ACL and its secondary restraints: preliminary results. *Orthopedics*. 2010 Oct 1;33(10):87–93.
30. Ferretti A, Monaco E, Labianca L, De Carli A, Maestri B, Conteduca F. Double-bundle anterior cruciate ligament reconstruction a comprehensive kinematic study using navigation. *Am J Sports Med*. 2009 Aug 1;37(8):1548–1553.
31. Branch TP, Siebold R, Freedberg HI, Jacobs CA. Double-bundle ACL reconstruction demonstrated superior clinical stability to single-bundle ACL reconstruction: a matched-pairs analysis of instrumented tests of tibial anterior translation and internal rotation laxity. *Knee Surg Sports Traumatol Arthrosc*. 2011 Mar 1;19(3):432–440.
32. Hofbauer M, Valentin P, Kdolsky R, et al. Rotational and translational laxity after computer-navigated single-and double-bundle anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2010 Sep 1;18(9):1201–1207.
33. Plaweski S, Grimaldi M, Courvoisier A, Wimsey S. Intraoperative comparisons of knee kinematics of double-bundle versus single-bundle anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2011 Aug 1;19(8):1277–1286.
34. Ellison AE. The pathogenesis and treatment of anterolateral rotatory instability. *Clin Orthop Relat Res*. 1980 Mar 1;147:51–55.
35. Zaffagnini S, Bruni D, Russo A, et al. ST/G ACL reconstruction: double strand plus extra-articular sling vs double bundle, randomized study at 3-year follow-up. *Scand J Med Sci Sports*. 2008 Oct 1;18(5):573–581.
36. Zaffagnini S, Bruni D, Russo A, et al. ST/G ACL reconstruction: double strand plus extra-articular sling vs double bundle, randomized study at 3-year follow-up. *Scand J Med Sci Sports*. 2008 Oct 1;18(5):573–581.
37. Kittl C, El-Daou H, Athwal KK, et al. The role of the anterolateral structures and the ACL in controlling laxity of the intact and ACL-deficient knee. *Am J Sports Med*. 2016 Feb;44(2):345–354.

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Tensile strength comparison between hamstring tendon, patellar tendon, quadriceps tendon and peroneus longus tendon: A cadaver research

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ABSTRACT

Knee ligament injury is a frequent occurrence. Ligament reconstruction using tendon graft is the best therapy recommendation in the case of severe knee ligament injury. Tendon graft that is oftenly used are hamstring tendon, patellar tendon (BPTB), quadriceps tendon and peroneus longus tendon have been proposed as tendon graft donor. Biomechanically, tensile strength from tendon graft is the main factor that greatly contributes to the success of ligament reconstruction procedure. Numerous researches have been done to calculate tensile strengths of hamstring and patellar tendon, but there has not been a research done yet on the comparison of the tensile strengths of peroneus longus tendon, hamstring, patellar tendon and quadriceps tendon. This research will strive to record the tensile strengths of peroneus longus tendon, hamstring, patellar tendon and quadriceps tendon as well as their comparison. Population of this research is 6 cadavers that have met the exclusion and inclusion criterias. From population above, 48 samples are retrieved and further divided into 4 groups. 12 samples for quadriceps tendon group, 12 samples for hamstring group, 12 samples for peroneus longus tendon group and 12 samples for patellar tendon group. Tensile strength measurement will then be done on each tendon by clamping both ends of examined tendon, then pulled on one side until tendon ruptures. Results are then read with a tensile tester. Tensile strength of peroneus longus tendon is not significantly different in comparison to hamstring tendon ($p > 0,05$). Whereas when compared to patellar and quadriceps tendons, peroneus longus and hamstring tendons have tensile strengths that are significantly higher ($p < 0,05$). Peroneus longus tendon have the highest tensile strength in comparison to the other three, followed by hamstring, quadriceps, and patellar tendons respectively.

1. Introduction

Muscles, tendons, and ligaments are soft tissues that often get injured. Injury frequently happens during exercise but daily activities may also cause injuries. Sprain, strain, and contusion, as well as tendinitis and bursitis are soft tissue injuries that happens most often. This type of injury may have a long recuperation time, even though given a proper handling.[1] According to general population data, prevalence of knee injury is 500 to 400.000.[2] There are operative and non-operative therapy choices for cases of multiple ligament injury.[3] Operative actions are divided into two, repair and reconstruction. Ligament reconstruction with tendon graft.[4]

As of now, multiple ligament reconstruction and on the knee have been done frequently that an alternative choice for donor tendon is required for such procedures.[4] There are three main modalities for autografts: hamstring tendon, bone-patellar tendon– bone (BPTB), and quadriceps tendon.[4] As of now, quadriceps tendon grafting is currently considered as a second choice

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even though clinical studies have shown good results and low donor morbidity rate.[1] Another choice for autograft that can be considered as a new alternative is the peroneus longus tendon. Studies have shown that the peroneus longus tendon does not have an effect on walking disorder does not affect ankle stability, meaning it may be used as a choice for autograft in ligament reconstruction procedures.[1]

Mechanically, tensile strength of tendon graft is a factor that greatly contributes to the success of ligament reconstruction. Lengthening of tendon does not only depend on the amount of force it receives, but also how long the force acts on it. This dependency on time can be described through two phenomena, Creep (tissue lengthening dependency on time when given constant tension) and Stress relaxation (observed decrease in stress in response to the same amount of strain generated in the tissue).

Tendon is also strain-rate dependent, where increase in mean lengthening will result in a more rigid tendon. Different anatomical locations, biomechanical environments, and biochemical environments will have different biomechanical properties as well.[6] Numerous researches have been done to calculate tensile strengths of hamstring and patellar tendon. From previous researches, it is known that tendons from flexor muscles and upper and lower extensor have a higher Young Modulus and ultimate tensile stress in comparison to tibialis dan peroneus tendons.[7] Extensor muscles tendons' tensile strength is higher than that of flexor muscles tendons', even though difference in value is not statistically significant.[8] From the comparison of tibialis tendon and peroneus tendon, the highest to lowest ultimate stress value is owned by peroneus longus tendon, tibialis anterior and tibialis posterior respectively. And from these results it is given that there is no significant difference between each tendon.[9]

However, there is no research done yet on the comparison of peroneus longus tendon, hamstring, patellar tendon and quadriceps tendon. This research will strive to uncover the tensile strengths of peroneus longus tendon, hamstring, patellar tendon and quadriceps tendon as well as their comparison.

1.1. Research methods

This research is an experimental research that is performed to find out the tensile strengths of hamstring tendon, patellar tendon, quadriceps tendon and peroneus longus tendon.

Population of this research is 6 cadavers from Forensic Medicine Installation Dr .Saiful Anwar, Malang. From population above, 48 samples are retrieved and further divided into 4 groups. 12 samples for quadriceps tendon group, 12 samples for hamstring group, 12 samples for peroneus longus tendon group and 12 samples for patellar tendon group. Collection of hamstring tendon, patellar tendon, quadriceps tendon and peroneus longus tendon will be done to each cadaver.

Tensile strength measurement will then be done on each tendon by clamping both ends of examined tendon, then pulled on one side until tendon ruptures. Results are then read with a tensile tester in Machine Laboratory of Technical Faculty Brawijaya University.

2. Result

The measurements that have been done shows the following results. (Fig. 1) A normality examination is done using the Kolmogorov-Smirnov method to determine whether or not the spread of data is considered to be normal. The normality test returns with a significance value (p) of 0,221, which concludes that the data used have a normal spread of distribution (Table 1). Then the homogenization of the data obtained from the previous test is analyzed using the homogenity of variance test (Levene's test) to determine whether or not the data utilized have the same variances. Results from the tests have shown a value of significance of 0,350 which can be concluded that the data utilized have a homogeneous spread and can be used for the ANOVA test (Table 2). One Way Anova is done to test whether there is a meaningful and significant difference between each group. Based on the analysis result of ANOVA, a value of 0.000 of p for Tensile Strength, meaning there is a significant difference between each group. Which means there are significant differences in influence between groups (Table 3). To find the difference, further test is done using Tukey method, with the results as shown below (Table 4). Based on the Tukey test results, it is shown that there is no significant difference between Hamstring and Peroneus Longus groups, whereas difference between Hamstring and Peroneus Longus with Patellar dan Quadricep is significant. Patellar tendon does not have a significantly different result when compared with Quadriceps tendon.

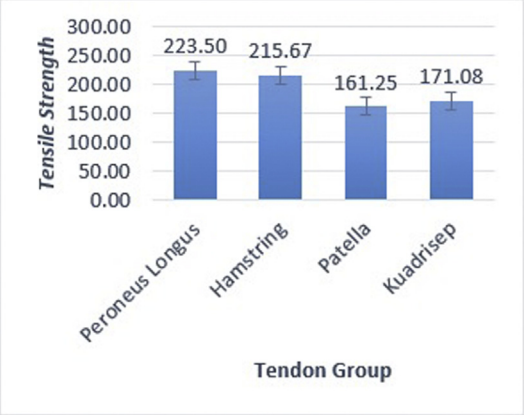

Fig. 1.

Table 1
Normality test.

		Tensile Strength
N		48
Normal Parameters[a,b]	Mean	192.8750
	Std. Deviation	29.96,922
Most Extreme Differences	Absolute	.151
	Positive	.112
	Negative	-.151
Kolmogorov-Smirnov Z		1.049
Asymp. Sig. (2-tailed)		.221

[a] Test distribution is Normal.
[b] Calculated from data.

Table 2
Test of homogeneity of variances.

Levene Statistic	df1	df2	Sig.
1.122	3	44	.350

Table 3
One way anova test.

	F	p
Tensile Strength	73,467	0,000

Table 4
Tukey test.

Group		p	Info
Peroneus Longus	Hamstring	0.435	Significant
	Patella	0.000	Significant
	Kuadrisep	0.000	Significant
Hamstring	Patella	0.075	Not Significant
	Kuadrisep	0.000	Significant
Patellar	Kuadrisep	0.240	Not Significant

3. Discussion

Peroneus longus provides the best tensile strength as seen in several experiments. Zhao and Huangfu found that with the anterior half of the peroneus longus tendon (AHPLT) having enough length and strength to be effective as an autograft choice in ACL reconstruction.[10]

The study by Shi et al. showed that the main tensile strength of both peroneus longus tendons and hamstring tendons was four times higher than the original ACL while the main tensile strength of the double strand peroneus longus tendon was comparable to in vitro. Four-strained hamstring tendon. In their experience, they found the diameter of the double strand of Peroneus longus is usually between 8 and 9 mm and the length of the peroneus longus tendon is about 30 cm from the myotendinous junction to its insertion, making it clinically effective in width and length.[10]

In the Kerimoglu experiment also showed the maximum tensile load of one peroneus longus tendon was 1950N, although the age of the corpse they used was 70 years.[11] The tensile strength of the hamstring veins did not differ significantly as seen in the experiments Shi et al. Meanwhile there are many corruption options for ruptured anterior cruciate ligament (ACL) ligament with special consideration of injuries and certain patients that need to be made during preoperative planning. The most frequently described and used techniques for index procedures are bone-patellar-bone autograft and quadrupled, or four-strand, harmstring autograft.[10]

The Patella tendon autografts have become the most popular choice of grafts because of their strength characteristics, ease of harvest, rigid fixation, bone for bone healing and favorable clinical results.[12]

The average main tensile strength and the average stiffness of normal ACL are 1.725 N and 182 N/mm, respectively. Bone-patellar tendon graft (14 mm) has a tensile strength of 168% and almost four times normal ACL stiffness. Semitendinosus and gracilis tendons provide 70% and 49% of the reported normal ACL strength, respectively. This makes the tensile strength of the second hamstring tendon, compared to the patellar tendon graft bone.[12]

In the hamstring tendon autograft, with a medial harvest, it can damage the saphene nerve and potentially cause medial knee joint instability if the ACL rupture is accompanied by a grade III injury of the medial collateral ligament (MCL). Postoperative varus or valgus instability due to collateral ligament injury can compromise graft resistance.[10]

In a Hamstring graft, there is also a significant variability in small-diameter HT and graft is a potential risk factor for failure of ACL reconstruction. It has been recommended that the diameter of the transverse graft for reconstruction is at least 8 mm which can be difficult with Hamstring alone while maintaining sufficient length.[10]

From tensile strength results of quadriceps tendon, patellar tendon, hamstring tendon, and peroneus longus tendon, it is shown that the Hamstring and Peroneus Longus groups do not have a significant difference, but Hamstring and Peroneus Longus have a significant difference in comparison to Patellar dan Quadricep. Patellar tendon also does not have a significant difference in comparison to Quadriceps tendon.

These results help to explain that even though mean tensile strength of peroneus tendon is a little bit higher than that of hamstring, tensile strengths of both tendons are statistically similar. Whereas when compared to patellar and quadriceps tendon, peroneus longus tendon has a significantly higher tensile strength. Similar values of tensile strengths of peroneus longus and hamstring tendons show that both of them are biomechanically similar.

4. Conclusion

Tensile strength of peroneus longus tendon is not significantly different in comparison to that of hamstring tendon. Whereas in comparison to patellar and quadriceps tendons, peroneus longus tendon has a significantly higher tensile strength.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jajs.2019.02.003.

References

1. Buchanan CI, Marsh RL. Effects of exercise on the biomechanical, biochemical and structural properties of tendons. *Comp Biochem Physiol Mol Integr Physiol*. 2002;133:1101–1107.
2. Bollen S. Epidemiology of knee injuries: diagnosis and triage. *Br J Sports Med*. 2000;34:227–228.
3. Moatshe G, Chahla J, LaPrade RF, et al. *Diagnosis and Treatment of Multiligament Knee Injury: State of the Art Journal of ISAKOS: Joint Disorders & Orthopaedic Sports Medicine Published Online First:*. 08 March 2017. https://doi.org/10.1136/jisakos-2016-000072.
4. Koga H, Zaffagnini S, Getgood AM, et al. JISAKOS Epub ahead of print. doi: 10.1136/jisakos-2017-000136
6. Biau D, Katsahian S, Nizard R. Hamstring tendon autograft better thanbone-patellar tendon-bone autograft in ACL reconstruction - a cumulativemeta-analysis and clinically relevant sensitivity analysis applied to previously published analysis. *Acta Orthop*. 2007;78(5):705–707.
7. Patricia LB, Norman LB. Ultimate tensile strength of fetal and adult human tendons. *J Biomech*. 1970;3(2):181–184.
8. Kraeutler MJ, Bravman JT, McCarty EC. Bone-patellar tendon-bone autograft versus allograft in outcomes of anterior cruciate ligament reconstruction: a meta-analysis of 5182 patients. *Am J Sports Med*. 2013;41(10):2439–2448.
9. Andrew C, Waligora BS, Norman A, Johanson MD, Hirsch Bruce Elliot. PhD *Clinical Anatomy of the Quadriceps Femoris and Extensor Apparatus of the Knee*. 2009 Dec;467(12):3297–3306. Published online 2009 Aug 19.
10. Shi Fu-Dong, Hess Daniel Edward, Zuo Jin-Zeng, Liu Shi-Jie, Wang Xue-Chen, Zhang Yong, Meng Xiao-Guang, Cui Ze-Jun, Zhao Shao-Ping, Li Chang-Jiang, Hu Wan-Ning. Peroneus longus tendon autograft is a safe and effective alternative for anterior cruciate ligament reconstruction. *J Knee Surg*. 2018. https://doi.org/10.1055/s-0038–1669951.
11. Kerimoglu S, Aynaci O, Saracoglu M, Aydin H, Turhan AU. Anterior cruciate ligament reconstruction with the peroneus longus tendon. *Acta Orthop Traumatol Turcica*. 2008;42(1):38–43.
12. West RV, Harner CD. Graft selection in anterior cruciate ligament reconstruction. *J Am Acad Orthop Surg*. 2005;13:197–207.

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Accuracy of Schottle's point location by palpation and its role in clinical outcome after medial patellofemoral ligament reconstruction

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ABSTRACT

Introduction: Medial patellofemoral ligament (MPFL) reconstruction is performed for the recurrent patellar dislocation (RPD). The crux of sound clinical results depends upon accurate placement of the graft at or within the 7-mm circle of Schottle point (acceptable position) over the femur. Most studies recommend the location of Schottle's point using intraoperative fluoroscopy or seldom by clinical palpation. We conducted a clinical study to understand the accuracy of locating Schottle's point by clinical palpation and its effect on outcome after MPFL reconstruction.

Method: 30 patients with RPD were included in this retrospective study after MPFL reconstruction. Post-operative CTscan was performed to locate the position of the femoral tunnel using Servien grid criteria and Schottle's point location. The clinical outcome was assessed using Lysholm and Kujala Scores at the end of a minimum of two years.

Results: 30 patients (11 male, 19 female) with a mean age of 24.8 years (range, 16–45 years) were followed for a mean of 42 months (range, 24–96 months). Mean Kujala score improved from 53.8 to 91.5 ($p = 0.0001$), and Lysholm score improved from 59.0 to 93.3 ($p = 0.0001$) in all 30 patients. Post-operative CT assessment revealed 19 patients (63.3%) had a tunnel in an acceptable position and 11 patients (36.7%) in an unacceptable position. Eight of the eleven unacceptable tunnels were placed in the anteroposterior direction, and three in superior-inferior direction. However, there was no significant difference between the Lysholm and Kujala scores of patients with acceptable versus unacceptable tunnels.

Conclusion: Placement of the femoral tunnel over the medial femoral condyle by the palpatory method is accurate in close to 2/3rd of the cases only whereas rest 1/3rd may fall outside the acceptable position. Hence, it is recommended to confirm the placement of femoral tunnel with intraoperative fluoroscopy at the acceptable position to avoid error.

Level of study: Retrospective case series, level IV.

1. Introduction

Since Ellera Gomes stressed the importance of MPFL reconstruction in 1992 for recurrent patella dislocation,[1] it is increasingly performed to prevent such recurrences and improve the clinical outcome.[2–6] The clinical outcome after MPFL reconstruction depends upon many factors such as the location of femoral and patella tunnels,[7] trochlear dysplasia,[8,9] static versus dynamic reconstruction,[10] graft tension,[11] flexion angle of graft fixation[12] and associated cartilage lesions. A major factor which affects the patellofemoral kinematics is the location of the femoral tunnel over medial femoral condyle (MFC). A malpositioned femoral tunnel can lead to altered patellofemoral mechanics,

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increased medial facet compressive forces and medial patella arthrosis.[13,14] Hence, one of the key factor to a successful MPFL reconstruction lies with the restoration of the isometric property of MPFL, and this goal is achieved by the anatomic placement of the graft over the MFC.[15–17]

The optimal position of the femoral tunnel at the MFC is still debatable as various studies suggest different landmark for attachment of MPFL for isometry restoration such as over the medial epicondyle,[18,19] adductor tubercle[20–22] or anterior to the medial epicondyle.[23,24] However, most authors conclude that it lies over a dimple between the adductor tubercle and medial epicondyle more specifically proximal and posterior to ME and distal and anterior to AT which is also known as 'Nomura point'[25–30] and it possesses the isometric properties.[16,31,32] However, Blatter et al. suggested that the landmark for MPFL origin over MFC could be patient specific.[33]

The identification of such landmarks over the MFC during the surgery could be done by fluoroscopy or clinical palpation. The most common fluoroscopic method used to locate 'anatomic, native' MPFL attachment over MFC is the one described by Schottle et al. who concluded that the "MPFL insertion over MFC could be reproducibly identified using intra-operative fluoroscopy at a point 1.3 mm anterior to the posterior cortical line extension, 2.5 mm distal to a perpendicular line intersecting the origin of the posterior medial femoral condyle, and 3 mm proximal to a perpendicular line intersecting the posterior point of the Blumensaat line", and all these points were within a circle of 5 mm diameter.[34] Servian et al. expanded the '5-mm circle' to '7-mm circle' as "acceptable tunnel position" over MFC because most tunnel diameters at MFC are of 7 mm.[35]

In comparison to radiographic landmarks, the clinical palpation of designated anatomical landmarks for the placement of MPFL over MFC depends upon the experience of the surgeon and how well the palpation of Adductor tubercle (AT) and medial epicondyle (ME) could be executed. Further, the bony landmarks are covered with soft tissues making it difficult to palpate. This may lead to inaccurate graft placement over the MFC.[36] Whichever method, fluoroscopy or palpatory, is used to locate the area over MFC to attach graft for MPFL reconstruction; the good outcome is dependent upon how close it is to the anatomical insertion of MPFL restoring isometry.[37]

We hypothesize that the accuracy of clinical palpation by an experienced surgeon is similar to that of the fluoroscopic method and it will lie within the acceptable limits described by Servian et al.[35] Secondly, the placement of the tunnel outside the acceptable zone will affect the clinical outcome as compared to accurately placed ones.

2. Material and method

This study was approved by institutional review board which constituted the retrospective evaluation of patients with recurrent patellar dislocation (RPD) who underwent MPFL reconstruction by Christiansen patella dual tunnel technique.[38] From 2010 to 2013, a total of 38 patients were operated for MPFL reconstruction and were included in the study. A total 30 patients were finally included in the study with a minimum follow-up of two years. Eight patients were excluded either due to lack of acceptable postoperative imaging, or they did not turn up for minimum follow-up period required. Inclusion criteria were patients with recurrent patellar dislocation who had magnetic resonance imaging (MRI) proven MPFL tear and tibial tubercle-tibial tuberosity (TT-TG) distance less than 20 mm. Patients with TT-TG interval greater than 20 mm, those who underwent distalisation or medialization procedure of tibial tuberosity, Dejour type 3 and 4 trochlear dysplasia, patellofemoral arthritis, patients with open physis, patients with multi-ligament injury and periarticular fractures were excluded from the study.

Each patient had undergone a standard preoperative detailed clinical evaluation to confirm the diagnosis of the RPD. MRI was performed to confirm the tear in MPFL, type of trochlear dysplasia and TT-TG interval assessment. Postoperatively, each patient underwent plain radiograph (anteroposterior and true lateral) and computed tomography (CT) scan with 3-dimensional reconstruction accurately locate the tunnel over the MFC.

Surgical technique: All the surgeries were performed by a single senior surgeon who had experience in patella reconstructive surgery for more than seven years. After appropriate anesthesia, standard part preparation and draping, the diagnostic arthroscopy was performed. The status of patellar cartilage was documented, and the loose body was removed, if any. The meniscal and cartilage lesions were treated as per standard protocol. After diagnostic arthroscopy, the ipsilateral semitendinosus graft was harvested with standard technique. The two ends of graft were prepared by running baseball sutures using no.5 Ethibond sutures (Johnson and Johnson, USA). The MPFL reconstruction was performed by the technique described by Christiansen et al. using two transverse patella tunnel.[38] Then, a 2 cm long incision was made over the skin of superior two-third of the lateral border of the patella. Subcutaneous tissue and deeper lateral retinaculum were incised linearly to expose the lateral border of the patella. Then, two 4.5 mm parallel transverse patellar tunnels were drilled from lateral to the medial border of the patella. Then, another incision was made over the medial border of the patella to expose the medial ends of the tunnels. Next, a one-inch long incision was made over the MFC between ME and AT. Subcutaneous tissue and deep fascia were sharply incised along the lines of skin incision. The ME and AT were palpated, and its center point was felt and visually confirmed. A 2.0 mm guide wire was placed over the center point and was drilled towards the superolateral direction to exit from the superolateral cortex of the femur. Then, 7.0 mm cannulated femoral reamer was used to drill the near cortex only.

Then; the ST graft was looped around the two patellar tunnel, and two free limbs of ST graft were passed between the second and third layer of the knee on the medial aspect. Further, the two limbs were passed via the femoral tunnel keeping the knee in 30^0 flexion, and the graft was fixed in the femoral tunnel with a 7×25 mm bioabsorbable interference screw. The knee was extended back to check the adequacy of graft tension. An adequately tensioned MPFL graft allows one to two quadrants of lateral patellar movement possible. Then, the knee was moved passively to full range of flexion to confirm that the graft fixation is not tight to prevent full flexion. The wounds were closed in layers. Three patients underwent lateral release too.

Rehabilitation: All patients underwent standard rehabilitation in the form of gradual knee mobilization in hinge brace, quadriceps strengthening exercises, and progressive weight bearing. Return to sports was allowed after 5–6 months when patient achieved full range of motion (ROM) and strength.

Postoperative radiographic assessment of femoral tunnel: Each patient underwent postoperative plain radiograph (anteroposterior and lateral) and a CT scan to assess the placement of tunnel on the standard Schottles' point. Though Schottle stated that all the points of MPFL attachment were within the circle of 5 mm diameter, we considered circle diameter as 7 mm as a reference because the standard femoral tunnel diameter was 7 mm as described by Servian et al. method.[35] All the tunnels lying within this range were considered to be adequate (SPA). A mal-positioned tunnel was considered anywhere outside this circle (SPU) of 7 mm diameter. Fig. 1 depicts the relationship of three landmarks (AT, ME, and MPFL

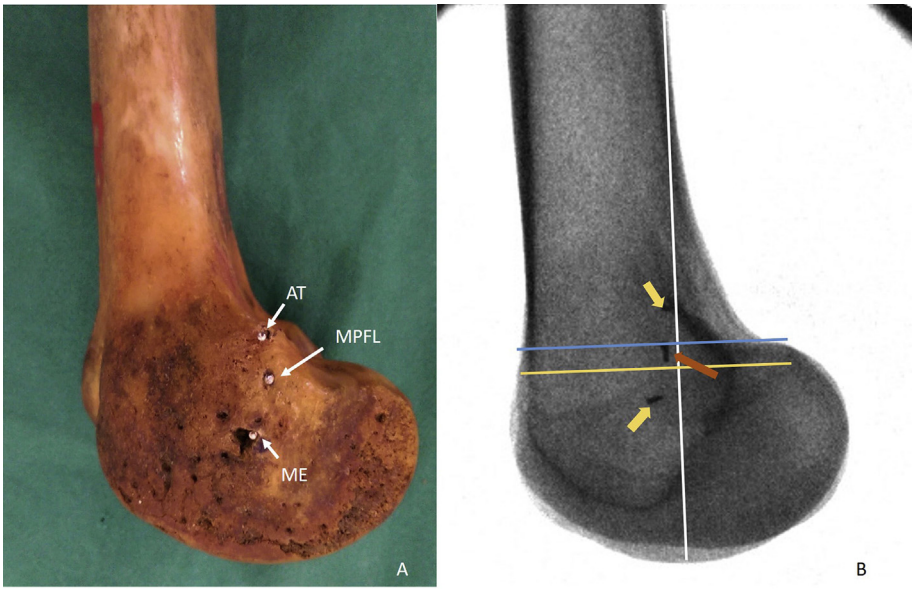

Fig. 1. (A,B): Figure 1A shows the landmarks on the medial femoral condyle of right cadaveric femur specimen where the centre of MPFL is attached in the middle of the AT and ME. Figure 1B shows the lateral radiographic image of the same cadaveric femur with lines drawn to indicate Schottle's point. The Schottle point is indicated by deep orange arrow while AT and ME by yellow arrows. AT, Adductor tubercle; ME, Medial epicondyle; MPFL, Medial patellofemoral ligament.

center) over the cadaveric femur specimen and adjoining radiograph. All images were displayed on imaging software provided by InstaRISPACS for assessment of various parameters. All the outliers (SPU) were plotted on the standard X-ray and CT scan concerning their distance from Schottle's point (Fig. 2). Further, the Servian grid was 1 × 1 cm square was superimposed over the image with outlier points (SPU) to assess how many were in an anteroposterior

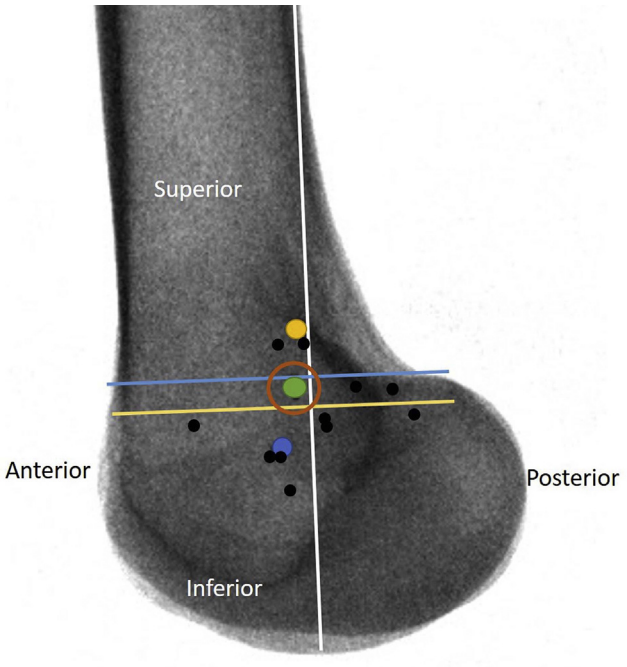

Fig. 2. Lateral radiographic image of the femur plotted with the all eleven outliers (black circles). Yellow circle indicates AT, Blue circle indicates ME and green circle shows Schottle's point. The 7 mm wide brown circle indicates maximum permissible acceptable position for a tunnel. Three lines (white, blue and yellow) used to draw Schottle point. AT, adductor tubercle; ME, medial epicondyle.

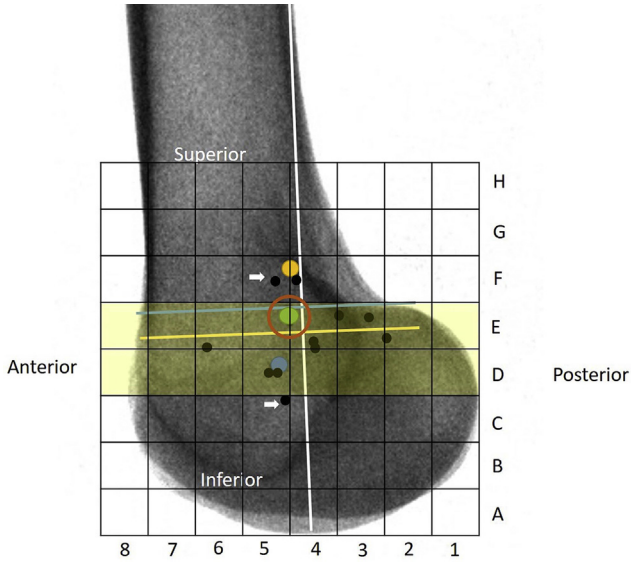

Fig. 3. Lateral radiographic image of the femur plotted with the all eleven outliers (black circles) and a grid of 1×1 cm squares described by Servian et al. The squares shaded in light yellow indicate anteroposterior plane. Yellow circle indicates AT, Blue circle indicates ME and green circle shows Schottle point. The 7 mm wide brown circle indicates maximum permissible acceptable position for a tunnel. AT, Adductor tubercle; ME, Medial epicondyle.

direction or superior-inferior direction (Fig. 3). The horizontal square row of D and E was considered to be anteroposterior in direction, and any square lying elsewhere was superior or inferior.

The preoperative and postoperative data were analyzed using chi-square and paired *t*-test.

3. Results

The final follow-up included 30 patients (11 males and 19 females) with a mean age of 24.8 years (range, 16–45 years). The

mean follow-up was 42 months (range, 24–96 months). Eight had right knee involvement, and 22 had left knee involvement.

At the final follow-up, the mean preoperative Kujala score improved from 53.83 to 91.57 postoperatively ($p = 0.0001$). The mean Lysholm score improved from 59.0 to 93.37 ($p = 0.0001$) [Table 1]. No patient had any recurrence of dislocation or subluxation.

The postoperative radiographic assessment revealed that 19 (63.3%) out of 30 patients had tunnels in the acceptable position (SPA) whereas 11 (36.7%) patients had their tunnels located outside the acceptable limit of Schottle's point (SPU). Fig. 2 demonstrates the location of 11 tunnels which were outside the acceptable limit (SPU). The mean distance of these 11 tunnels from Schottle's point was 11.9 mm (range, 8–24 mm) or approximately 4 mm outside the acceptable circle of 7 mm with Schottle point at center. On superimposing the Servian grid over the tunnels located over the MFC, eight tunnels were mal-positioned in the anteroposterior direction (in the block of D and E) whereas two were in superior and one in an inferior direction (Fig. 3). Fig. 4 illustrates three cases of the malpositioned tunnel on a 3-D CT scan.

However, the Kujala and Lysholm score of patients "within, SPA" and "outside, SPU" did not show any significant difference (Table 2).

4. Discussion

The significant finding from our study states that even in the experienced surgeon's hand, palpatory localization of Schottle's point or anatomical insertion of MPFL is accurate only in two-third cases and a third of tunnels are located outside the acceptable limits. Derived from this study, fluoroscopic guidance is now mandatorily used in our unit by default. However, the tunnels outside the 'currently defined' acceptable limits do not affect the clinical outcomes significantly.[11]

The palpatory method in our series could place only 63.3% tunnels over acceptable area whereas 36.7% cases were in outlier group (SPU). By the palpatory method, Servian et al. reported 70% accuracy in tunnel placement whereas McCarthy et al. reported only 36% of tunnels placed in the acceptable position.[35,39] In a cadaveric study wherein surgeons of varying experience located accurate position by palpatory method; Hershel et al. reported that 29% of all the tunnels were in correct zone, another 47% in less than 5 mm of correct zone and another 23% were complete outliers.[36] Further, Hershel et al. did not find any difference in the tunnel localization by surgeons with different level of expertise. So, in most cases, a third of tunnel placement might remain out of the acceptable zone using palpatory method.

Our series shows that most malpositioned tunnels are in the anteroposterior direction (8 out of 11, 77%) where as only three in the superior-inferior direction. Serivan et al. reported more outliers in proximal (5 out of 10, 50%) in the proximal direction and less in anterior direction (3 out of 10, 30%) on MRI assessment.[35] The mean distance erred in our series using palpatory method was 11.9 mm (approximately 5 mm outside the acceptable circle of 7 mm diameter) whereas McCarthy et al.[39] reported an error of 13.25 mm from Schottle point (approximately 6 mm outside the acceptable circle of 7 mm diameter). This data suggests that the palpatory method remains an inaccurate method to locate the exact tunnel position for MPFL attachment and should be avoided.

Although the fluoroscopic methods described in the literature[34,40] result in the reproducible and acceptable placement of the femoral tunnel for MPFL reconstruction, but fluoroscopy is often routinely not used due to practical reasons, and surgeons often feel confident about their skills of the palpatory method. Further, the accuracy of the palpatory method also depends upon that how well these landmarks (AT or ME) can be palpated with ease. The Adductor tubercle is often well palpated in comparison to medial epicondyle as latter is often flat or like a groove.[29] Also, the area between the ME and AT is often covered with scar tissue due to ruptured MPFL from femoral origin further blunting the palpatory feeling of these landmarks especially ME.

The major factor deciding the outcome after MPFL reconstruction is accurate tunnel placement over the medial femoral condyle[27] and deviation as little as 5 mm from the designated point of MPFL anatomic insertion leads to altered isometric behavior of the graft affecting the outcome.[16,24] Hence, it is our strong recommendation that the positioning of the tunnel should always be confirmed with the intraoperative fluoroscopic method to avoid mal-positioning of tunnels and one should not rely on one's palpatory skills to locate the landmarks for tunnel placement.

The second observation arising out of our study is that although there were 36% "anisometric outliers" but they did not influence the outcome as compared to the 64% of "acceptable isometric position" ones. Similar observations were reported by McCarthy et al. and Servian et al. who did not find any difference between the patients who had mal-positioned tunnel compared to the anatomic tunnel.[35,39] Stephen et al. also suggested that tunnel placement in proximal or distal direction results in a larger effect on isometry as compared to anterior to posterior direction on anatomic MPFL attachment point.[16]

Further, this anomaly may be explained by the fact that still there lies an ambiguity about the precise origin of MPFL and an exact landmark for MPFL attachment on MFC which may contribute to the isometric behavior of the graft.

Apart from the debate over the accurate anatomic location of MPFL, there continues to have disagreement by various authors over the isometric point for the MPFL attachment. Zhang et al. suggested that the most isometric point is located in a triangular area formed by joining the point forming the dome of the Blumensaat line, the point 10 mm inferior to the AT and a midpoint between the AT and ME.[41] Gobbi et al. suggested that placement of MPFL graft directly posterior or distal to ME is 'risky' and should be avoided whereas Smirk and Morris have shown that worst isometric position lies at the Adductor tubercle.[24,31] Blatter et al. suggested that most isometric point showed a non-uniform distribution in subjects.[33] Blatter further suggested that radiographic points lead to worst isometric scores as compared to the surgeon defined ones. Therefore, he suggested that careful intraoperative assessment of isometric behavior of MPFL is important for each patient rather than considering it as a fixed point in the entire population.

Limitations: Although the mid-term results of our study conclude that the clinical outcome is not affected if tunnels are malpositioned in anterior or posterior direction but we do not know the effect of the malpositioned tunnel over the increased patellofemoral pressures in the long term. A longer follow-up may reveal an increased incidence of patellofemoral arthritis.

5. Conclusion

Irrespective of their experience, the surgeons should avoid

Table 1
Mean pre- and post-operative Lysholm and Kujala scores of patients. CI, confidence interval.

	Mean Score	95% CI	P value
Preoperative Lysholm score	59.0	54.11–63.9	0.0001
Postoperative Lysholm score	93.3	91.25–95.5	
Preoperative Kujala score	53.83	41.8–59.86	0.0001
Postoperative Kujala score	91.5	89.96–93.18	

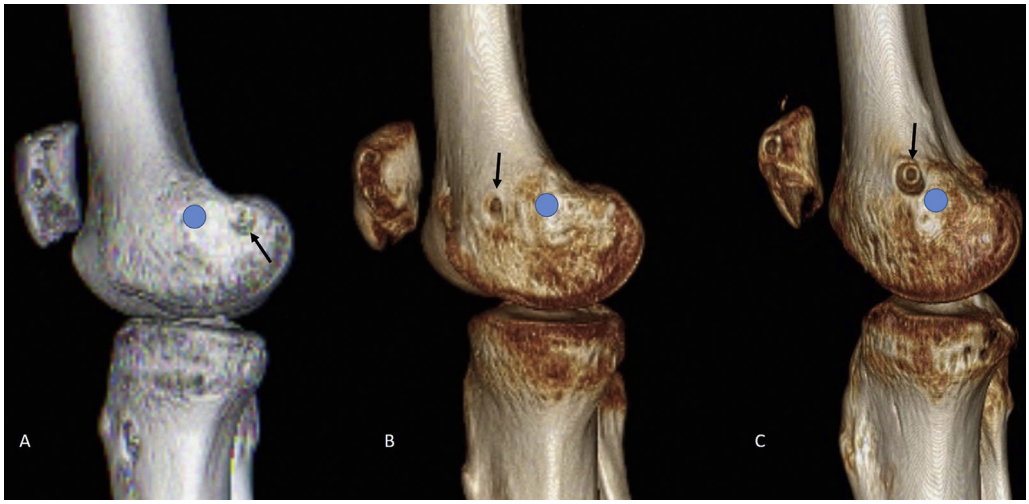

Fig. 4. (A,B and C): 3-D reconstruction of CT scan showing three images with mal-positioned tunnel (black arrow) in posterior (4A), anterior (4B) and superior (4C) direction. Blue circle indicates position of Schottle point.

Table 2
Comparison between postoperative Lysholm and Kujala scores of two groups (SPA and SPU) using Independent sample test. SPA, Schottle's position acceptable; SPU, Schottle's position unacceptable.

	Position of tunnel	Number of patients (N)	Mean Score	± Standard deviation	P value
Postoperative Lysholm score	SPA	19	92.84	6.23	0.51
	SPU	11	94.27	4.67	
Postoperative Kujala score	SPA	19	91.58	3.58	0.98
	SPU	11	91.55	5.55	

palpatory skills alone for the placement of femoral tunnel during MPFL reconstruction as the chances of error in tunnel placement can happen in one-third of all the cases. However, an error in anteroposterior direction could be more forgiving and may not affect the clinical outcome.

Patient declaration statement

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

Conflicts of interest

None.

References

1. Ellera Gomes JL. Medial patellofemoral ligament reconstruction for recurrent dislocation of the patella: a preliminary report. *Arthroscopy*. 1992;8:335–340.
2. Ambrozic B, Novak S. The influence of medial patellofemoral ligament reconstruction on clinical results and sports activity level. *Phys Sportsmed*. 2016;44:133–140.
[3]. Mulliez A, Lambrecht D, Verbruggen D, Van Der Straeten C, Verdonk P, Victor J. Clinical outcome in MPFL reconstruction with and without tuberositas transposition. *Knee Surg Sports Traumatol Arthrosc*. 2017 Sep;25(9):2708–2714.
4. Neri T, Philippot R, Carnesecchi O, Boyer B, Farizon F. Medial patellofemoral ligament reconstruction: clinical and radiographic results in a series of 90 cases. *Orthop Traumatol Surg Res*. 2015;101:65–69.
5. Stupay KL, Swart E, Shubin Stein BE. Widespread implementation of medial patellofemoral ligament reconstruction for recurrent patellar instability maintains functional outcomes at midterm to long-term follow-up while decreasing complication rates: a systematic review. *Arthroscopy*. 2015;31:1372–1380.
6. Valkering KP, Rajeev A, Caplan N, Tuinebreijer WE, Kader DF. An evaluation of the effectiveness of medial patellofemoral ligament reconstruction using an anatomical tunnel site. *Knee Surg Sports Traumatol Arthrosc*. 2017;25:3206–3212.
7. Bicos J, Fulkerson JP, Amis A. Current concepts review: the medial patellofemoral ligament. *Am J Sports Med*. 2007;35:484–492.
8. Hiemstra LA, Kerslake S, Loewen M, Lafave M. Effect of trochlear dysplasia on outcomes after isolated soft tissue stabilization for patellar instability. *Am J Sports Med*. 2016;44:1515–1523.
9. Hopper GP, Leach WJ, Rooney BP, Walker CR, Blyth MJ. Does degree of trochlear dysplasia and position of femoral tunnel influence outcome after medial patellofemoral ligament reconstruction? *Am J Sports Med*. 2014;42:716–722.
10. Rood A, Hannink G, Lenting A, et al. Patellofemoral pressure changes after static and dynamic medial patellofemoral ligament reconstructions. *Am J Sports Med*. 2015;43:2538–2544.
11. Beck P, Brown NA, Greis PE, Burks RT. Patellofemoral contact pressures and lateral patellar translation after medial patellofemoral ligament reconstruction. *Am J Sports Med*. 2007;35:1557–1563.
12. Burrus MT, Werner BC, Conte EJ, Diduch DR. Troubleshooting the femoral attachment during medial patellofemoral ligament reconstruction: location, location, location. *Orthop J Sports Med*. 2015;3, 2325967115569198.
13. Stephen JM, Kittl C, Williams A, et al. Effect of medial patellofemoral ligament reconstruction method on patellofemoral contact pressures and kinematics. *Am J Sports Med*. 2016;44:1186–1194.
14. Elias JJ, Kelly MJ, Smith KE, Gall KA, Farr J. Dynamic simulation of the effects of graft fixation errors during medial patellofemoral ligament reconstruction. *Orthop J Sports Med*. 2016;4, 2325967116665080.
[15]. Sanchis-Alfonso V, Ramirez-Fuentes C, Montesinos-Berry E, Domenech J, Marti-Bonmati L. Femoral insertion site of the graft used to replace the medial patellofemoral ligament influences the ligament dynamic changes during knee flexion and the clinical outcome. *Knee Surg Sports Traumatol Arthrosc*; 2015. https://doi.org/10.1007/s00167-015-3905-0.
16. Stephen JM, Lumpaopong P, Deehan DJ, Kader D, Amis AA. The medial patellofemoral ligament: location of femoral attachment and length change patterns resulting from anatomic and nonanatomic attachments. *Am J Sports Med*. 2012;40:1871–1879.
17. Stephen JM, Kaider D, Lumpaopong P, Deehan DJ, Amis AA. The effect of femoral tunnel position and graft tension on patellar contact mechanics and kinematics after medial patellofemoral ligament reconstruction. *Am J Sports Med*. 2014;42:364–372.

18. Hautamaa PV, Fithian DC, Kaufman KR, Daniel DM, Pohlmeyer AM. Medial soft tissue restraints in lateral patellar instability and repair. *Clin Orthop Relat Res*. 1998:174–182.
19. Reider B, Marshall JL, Koslin B, Ring B, Girgis FG. The anterior aspect of the knee joint. *J Bone Joint Surg Am*. 1981;63:351–356.
20. Conlan T, Garth Jr WP, Lemons JE. Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. *J Bone Joint Surg Am*. 1993;75:682–693.
21. Desio SM, Burks RT, Bachus KN. Soft tissue restraints to lateral patellar translation in the human knee. *Am J Sports Med*. 1998;26:59–65.
22. Tuxoe JI, Teir M, Winge S, Nielsen PL. The medial patellofemoral ligament: a dissection study. *Knee Surg Sports Traumatol Arthrosc*. 2002;10:138–140.
23. Feller JA, Feagin Jr JA, Garrett Jr WE. The medial patellofemoral ligament revisited: an anatomical study. *Knee Surg Sports Traumatol Arthrosc*. 1993;1:184–186.
24. Smirk C, Morris H. The anatomy and reconstruction of the medial patellofemoral ligament. *Knee*. 2003;10:221–227.
25. Nomura E, Inoue M, Osada N. Anatomical analysis of the medial patellofemoral ligament of the knee, especially the femoral attachment. *Knee Surg Sports Traumatol Arthrosc*. 2005;13:510–515.
26. Philippot R, Chouteau J, Wegrzyn J, Testa R, Fessy MH, Moyen B. Medial patellofemoral ligament anatomy: implications for its surgical reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2009;17:475–479.
27. Baldwin JL. The anatomy of the medial patellofemoral ligament. *Am J Sports Med*. 2009;37:2355–2361.
28. LaPrade RF, Engebretsen AH, Ly TV, Johansen S, Wentorf FA, Engebretsen L. The anatomy of the medial part of the knee. *J Bone Joint Surg Am*. 2007;89:2000–2010.
29. Fujino K, Tajima G, Yan J, et al. Morphology of the femoral insertion site of the medial patellofemoral ligament. *Knee Surg Sports Traumatol Arthrosc*. 2015;23:998–1003.
30. Placella G, Tei M, Sebastiani E, et al. Anatomy of the Medial Patello-Femoral Ligament: a systematic review of the last 20 years literature. *Musculoskelet Surg*. 2015;99:93–103.
31. Gobbi RG, Pereira CA, Sadigursky D, et al. Evaluation of the isometry of different points of the patella and femur for medial patellofemoral ligament reconstruction. *Clin Biomech*. 2016;38:8–12.
32. Steensen RN, Dopirak RM, McDonald 3rd WG. The anatomy and isometry of the medial patellofemoral ligament: implications for reconstruction. *Am J Sports Med*. 2004;32:1509–1513.
33. Blatter SC, Furnstahl P, Hirschmann A, Graf M, Fucentese SF. Femoral insertion site in medial patellofemoral ligament reconstruction. *Knee*. 2016;23:456–459.
34. Schottle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. *Am J Sports Med*. 2007;35:801–804.
35. Servien E, Fritsch B, Lustig S, et al. In vivo positioning analysis of medial patellofemoral ligament reconstruction. *Am J Sports Med*. 2011;39:134–139.
36. Herschel R, Hasler A, Tscholl PM, Fucentese SF. Visual-palpatory versus fluoroscopic intraoperative determination of the femoral entry point in medial patellofemoral ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2017;25:2545–2549.
37. Tateishi T, Tsuchiya M, Motosugi N, et al. Graft length change and radiographic assessment of femoral drill hole position for medial patellofemoral ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2011;19:400–407.
38. Christiansen SE, Jacobsen BW, Lund B, Lind M. Reconstruction of the medial patellofemoral ligament with gracilis tendon autograft in transverse patellar drill holes. *Arthroscopy*. 2008;24:82–87.
39. McCarthy M, Ridley TJ, Bollier M, Wolf B, Albright J, Amendola A. Femoral tunnel placement in medial patellofemoral ligament reconstruction. *Iowa Orthop J*. 2013;33:58–63.
40. Redfern J, Kamath G, Burks R. Anatomical confirmation of the use of radiographic landmarks in medial patellofemoral ligament reconstruction. *Am J Sports Med*. 2010;38:293–297.
41. Zhang N, Jiang Z, Wen X, Sugamoto K, Yang C. The triangle zone as a femoral attachment location in medial patellofemoral ligament reconstruction: an in vivo three-dimensional analysis using an open MRI scanner. *Knee*. 2015;22:585–590.

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An in vitro study on the effects of various concentrations of low and high molecular weight hyaluronic acid on human chondrocyte cell metabolism

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1. Introduction

Hyaluronic Acid (HA) also known as hyaluronan is a mucopolysaccharide with alternate N-Acetyl-D-glucosamine and D-glucuronic acid that is found in the synovial fluid of joints.[1] It is a responsible for the viscosity of synovial fluid as it binds to water.[2]. In normal the human joint it is present at a molecular mass of 6–7 x 10^6 Daltons[3] There is a constant secretion of hyaluronic acid by the synovium in the knee joint.[4] It regulates and maintains the joints osmotic pressure as demonstrated by Day et al.[5] HA has been postulated to have feature known as shear dependent viscosity where when shear forces in the joint increase, the viscosity of HA increases forming a thick gel like structure across the joint surface in order to counteract the forces applied to the articular cartilag3.[6] Hyaluronon molecules interact with $CD44^+$ receptors on articular chondrocytes to promote collagen synthesis.[7] HA has been shown to have a role in angiogenesis, where high molecular HA inhibits angiogenesis and low molecular weight induce it in the joint.[8] This may be the reason for reduced vascularity in the articular joints. HA has also been shown to remove free radicals from the joint but the biological significance of this has not been proven as of yet.[9]

Commercially various forms of HA are available from a spectrum of drug manufacturers. In the past it was extracted from rooster combs but manufacture has now moved on to recombinant systems using Streptococcus zooepidemicus and Bacillus subtilus.[10] High and low molecular weight HA are the two forms of the molecule sold by manufacturers (high molecular weight being 6×10^6 Daltons and low molecular being 2×10^6 Daltons).

Hyaluronic acid intra articular injections have documented use in treating osteoarthritis in equine joints in a study done by Balaz et al. in the 1970s.[11] They found that horses had reduced symptomology and did have improved performance with the HA injections. As a part of this study owl monkeys were also subjected to bilateral knee injuries, one knee was kept as a control and injected with saline while the other received serial HA injections. Results showed the joint that received HA was smoother and had better cartilage healing.[11] In vitro studies have shown promise in aiding in chondrocyte metabolism, showing stimulation and increased glycosaminoglycan and DNA synthesis especially in low doses of hyaluronic acid in bovine chondrocytes.[12]

In clinical studies Trigkilidas et al. showed that there was a modest effect of the drug in mild to moderate OA knee showing most effectiveness at 6–8 weeks, at 6 months the effect of the drug was questionable.[13] A Meta analysis of double-blinded, sham-controlled trials with a minimum of sixty patients showed no differences of HA treatment over placebo.[14] A conflict of interest was found in an updated systematic review stating that there was a significant association of conflict of interest in the study and a favourable outcome in HA injections. Studies with no industry affiliations showed no more effectiveness of HA than a placebo injection.[15] Thus there is inadequate evidence and controversial data as to whether HA injections are beneficial treatment in early knee osteoarthrosis.

The purpose of this study was to assess the effects of low and high molecular weight hyaluronic acid on human chondrocytes in vitro and determine whether they potentiate chondrocyte cell metabolism.

2. Material and methods

2.1. Study type- comparative study

2.1.1. Tissue culture and harvest

All procedures were approved under the institutional ethical

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committee and with patient consent. Three osteochondral plugs were harvested during total knee arthroplasty from patients suffering from osteoarthritis scheduled for surgery under sterile conditions.

Chondrocytes were isolated and cultured to passage one and three samples from passage one cultured to passage two.

Passage one and two flasks were seeded with 0.1 mg/ml, 1 mg/ml & 2 mg/ml of High (Hylast One) and low (Synject) molecular weight hyaluronic acid all against control.[12] Cells were then harvested on the 14th day of culture and assessed for cell viability, cell count, CD 44^{+} expression.

2.1.2. Cell viability

20 µl Samples of cell suspension was removed on the 14th day culture and dispensed into a 1.4 ml test tube. A hemocytometer was wiped with 70% isopropyl alcohol and allowed to dry. 20 µl of 0.4% Trypan blue was added to the same test tube and the mixture gently mixed by dispensing with a micropipette. 10 µl of the cell suspension Trypan blue mixture is then transferred to the counting chamber under a cover slip. Stained cell (non viable) and non stained cells (viable) are then counted in 4 squares of the hemocytometer areas at 100× magnification. The percentage of the viable cells is then calculated by dividing the viable cells by total cells and multiplied by one hundred.

Table 1a
Concentration of HMW in cell count.

	cultural stage	Mean	sd	F	P value
Control	P1	4.5733	2.93737	.0.081*	.968
1 µM/ml Pred	P1	4.3700	2.61152		
10 µM/ml Pred	P1	3.9433	2.97147		
100 µM/ml Pred	P1	3.6300	2.61064		
Control	P2	6.2800	1.22784	1.47*	.293
1 µM/ml Pred	P2	5.4433	.59501		
10 µM/ml Pred	P2	4.9500	1.12601		
100 µM/ml Pred	P2	4.5600	1.16202		

*not significant (p; >0.05).

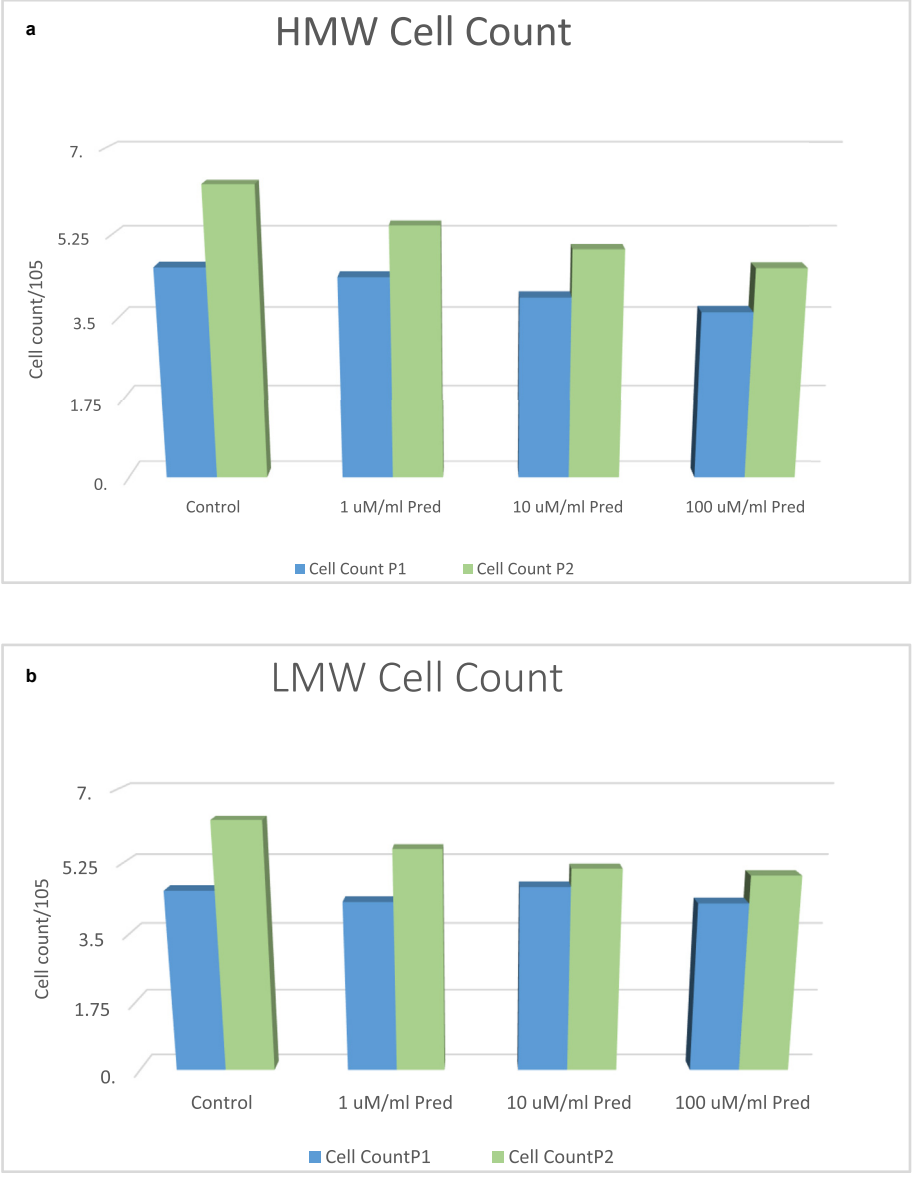


Fig. 1. Graph showing the effect of HMW & LMW HA on cell count.

Table 1b
Concentration of LMW in cell count.

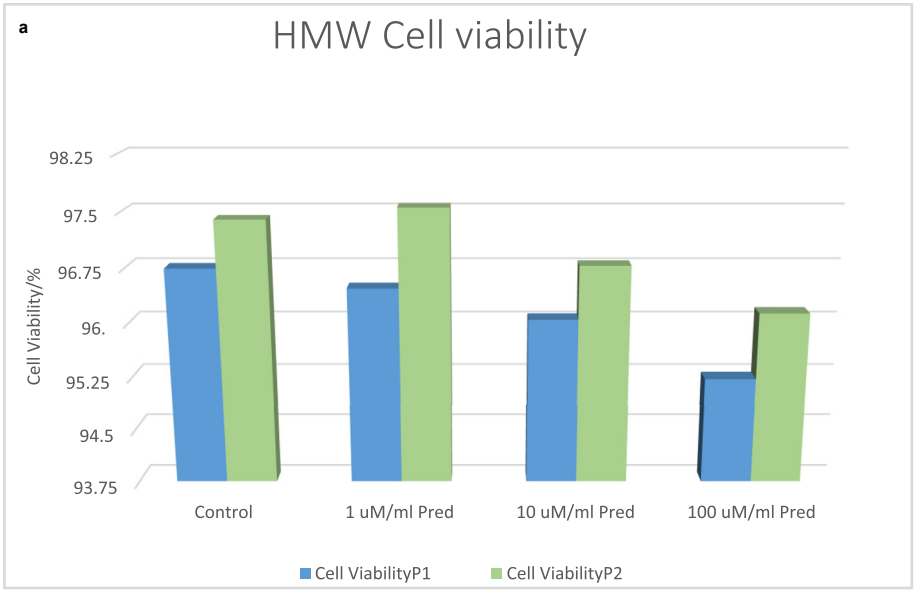
	cultural stage	Mean	sd	F	P value
Control	P1	4.5733	2.93737	.0.015*	.997
1 μM/ml Pred	P1	4.2967	2.61152		
10 μM/ml Pred	P1	4.6633	2.97147		
100 μM/ml Pred	P1	4.2633	2.61064		
Control	P2	6.2800	1.22784	2.12*	.176
1 μM/ml Pred	P2	5.5867	.41885		
10 μM/ml Pred	P2	5.1067	.44456		
100 μM/ml Pred	P2	4.9433	.39107		

*not significant (p; >0.05).

Table 2a
Concentration of HMW in cell viability.

	cultural stage	Mean	sd	F	P value
Control	P1	96.7400	1.64654	.284*	.836
1 μM/ml Pred	P1	96.4700	2.06589		
10 μM/ml Pred	P1	96.0433	2.39529		
100 μM/ml Pred	P1	95.2167	2.44672		
Control	P2	97.3933	1.03549	1.600*	.264
1 μM/ml Pred	P2	97.5533	.23180		
10 μM/ml Pred	P2	96.7767	.50143		
100 μM/ml Pred	P2	96.1300	1.33368		

*not significant (p; >0.05).



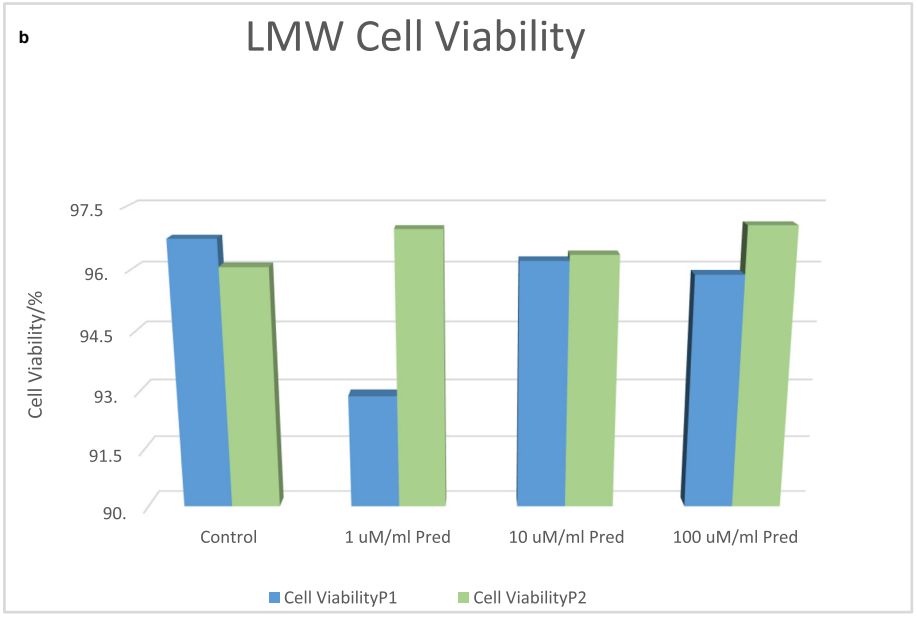


Fig. 2. Graph showing the effect of HMW & LMW HA on cell viability.

Table 2b
Concentration of LMW in cell viability.

	cultural stage	Mean	sd	F	P value
Control	P1	96.7400	1.64654	.858*	.501
1 μM/ml Pred	P1	92.8700	5.11205		
10 μM/ml Pred	P1	96.2100	2.74255		
100 μM/ml Pred	P1	95.8767	2.44396		
Control	P2	96.0600	1.67896	.363*	.781
1 μM/ml Pred	P2	96.9700	.77949		
10 μM/ml Pred	P2	96.3533	1.94747		
100 μM/ml Pred	P2	97.0600	.70292		

*not significant (p; >0.05).

2.1.3. Cell count

Aperture of coulter counter is first flushed. 200 μl of the culture sample is removed from the cell suspension. It is then dispensed in 9.8 ml of cell counting buffer solution. The sample is then poured into an accuvette sample container and then placed on the coulter counter.

The aperture is then immersed into the cell suspension and the counter is then initiated reading taken and recorded.

2.1.4. CD 44^{+} expression

2.1.4.1. Flowcytometry

2.1.4.1.1. Specimen preparation. 100 μl of well mixed specimen brought to room temperature is added to tube. 10 μl of antibody solution is added to the mixture. The sample is then incubated for 30 min in a dark room at room temperature. The cells were then washed twice with BD FACS Flow Solution. The sample was then centrifuged at 1500 rpm for 5 min. The supernatant is then discarded and the pellet suspended in 500 μl of BD FACS Flow solution. The sample is then run through the flow cytometry within one hour and readings recorded. CD44^{+} expression is an indirect method of measuring collagen II synthesis in chondrocytes.[16]

3. Results

3.1. Cell count

Both High molecular weight (HMW) and Low molecular weight

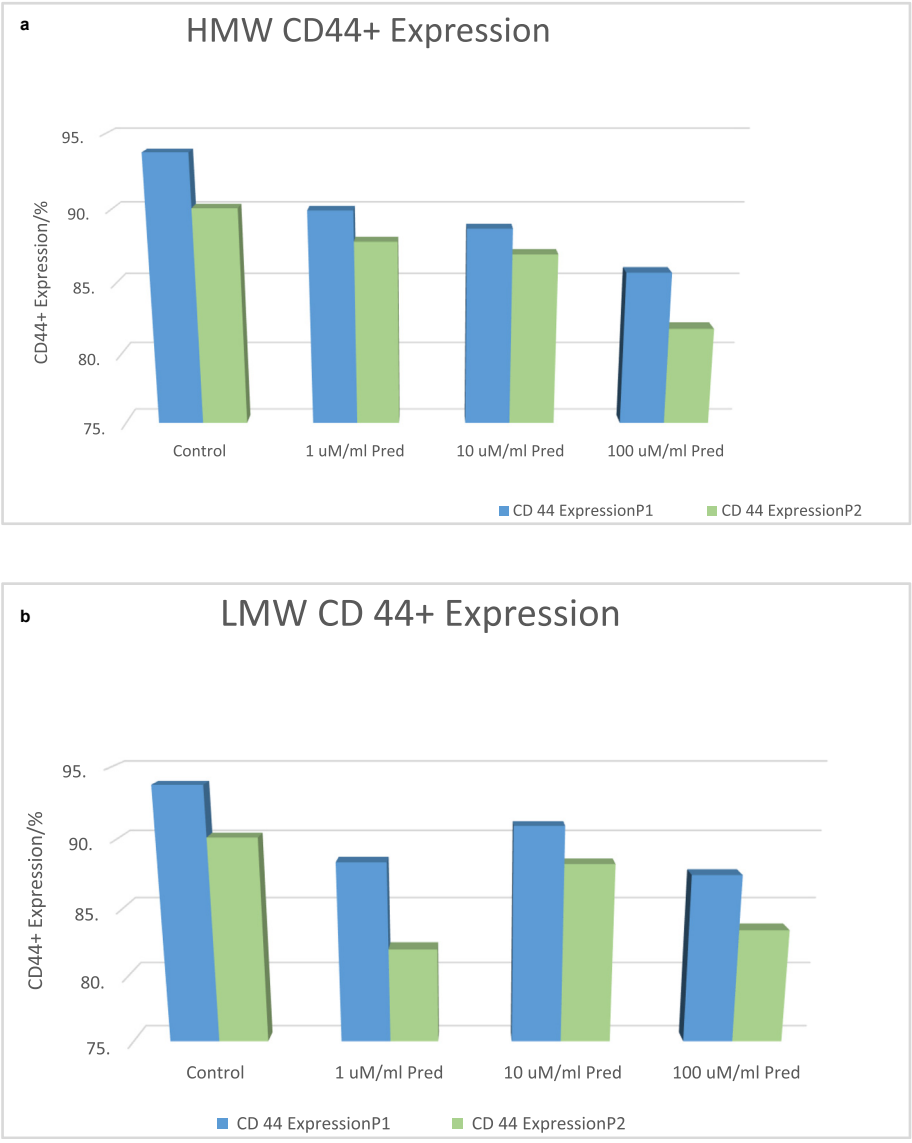


Fig. 3. Graph showing the effect of HMW & LMW HA on CD44 expression.

Table 3a
Concentration of HMW in CD 44 expression.

	cultural stage	Mean	sd	F	P value
Control	P1	93.7933	3.14662	4.457**	.040
1 μM/ml Pred	P1	89.9533	1.93146		
10 μM/ml Pred	P1	88.7333	2.04131		
100 μM/ml Pred	P1	85.7300	3.49309		
Control	P2	90.1000	4.70698	.875*	.493
1 μM/ml Pred	P2	87.8433	5.66224		
10 μM/ml Pred	P2	86.9900	5.08605		
100 μM/ml Pred	P2	81.8267	9.36276		

*not significant (p; >0.05) ** significant (p; <0.05).

Table 3b
Concentration of LMW in CD 44 expression.

	cultural stage	Mean	sd	F	P value
Control	P1	93.7933	3.14662	2.65*	.120
1 μM/ml Pred	P1	88.3433	3.69007		
10 μM/ml Pred	P1	90.9267	1.66692		
100 μM/ml Pred	P1	87.4333	3.25997		
Control	P2	90.1000	4.70698	.783*	.536
1 μM/ml Pred	P2	81.9800	11.1440		
10 μM/ml Pred	P2	88.2267	3.56350		
100 μM/ml Pred	P2	83.4067	8.30456		

*not significant (p; >0.05).

(LMW) HA passages showed a steady decrease in cell count as the concentration of HA increased (Fig. 1a and b). Although the decrease was not statistically significant in both group passages (Tables 1a and 1b).

3.2. Cell viability

Passage 1 in both HMW and LMW showed a decrease in cell viability as the concentration of HA increased but the decrease was not significant. However, in passage 2 both HMW HA and LMW HA demonstrated a slight increase in viability at a concentration of 1 μM/ml although not statistically significant (Fig. 2a and b). At concentrations higher than 1 μM/ml the viability decreased in both groups although not statistically significant (Tables 2a and 2b).

3.3. $CD44^{+}$ expression

In both passages the HMWHA group showed a decrease in $CD44^{+}$ expression and it was statistically significant in HMW HA passage 1 ($p = 0.04$) (Fig. 3a). The LMW HA group showed a decrease in both passages with decreased expression at 1 μM/ml, then a slight increase at 10 μM/ml followed by a decrease again at 100 μM/ml (Fig. 3b) though these changes were not statistically significant (Tables 3a and 3b).

4. Discussion

Our study shows that both HMW and LMW HA have no significant effect on articular human chondrocytes in vitro. There was no potentiation of chondrocyte activity in terms of cell viability, cell count and CD 44^{+} expression. The results showed decreases in viability, count and CD 44^{+} expression though only statistically significant in HMW HA passage one. As our results do not show a uniform statistically significant decrease in all groups it cannot be said that either forms of HA cause toxicity to the chondrocytes. If HA was to increase collagen II synthesis in chondrocytes the $CD44^{+}$ expression would have increased in our study groups.

Literature has shown that lower concentrations of HA have a stimulatory effect on chondrocyte metabolism in bovine chondrocytes[12], but our study did not support such findings. Clinical studies have shown ambiguous results[13–15] with some studies showing benefit. This may be attributed to the physical properties of HA causing an overall improvement in joint health and lubrication. Our study design does not take into account the physical properties of HA where clinical studies allow for the biological and physical property effects to be studied.

From our study results indicate that HA does not have a significant biological role in promoting cartilage health or growth. It does not potentiate chondrocyte metabolism nor is it chondrotoxic. Intra articular HA injections to promote cartilage growth and joint health may not be an effective treatment option.

Limitations we faced in our study were mainly to do with sample size. Also determining the concentration of HA reached within the knee joint during an intra articular injection in a clinical setting, would be beneficial to help decide what concentrations of HA to study. This would involve studying average joint surface area in a defined population and estimation of synovial fluid volume.

5. Conclusion

Both low and high molecular weight hyaluronic acid did not have a beneficial biological effect on human articular chondrocytes. Both neither potentiated chondrocyte metabolism nor did they cause significant chondrotoxicity.

References

1. Necas J, Bartosikova L, Brauner P. J. Kolar Hyaluronic acid (hyaluronan): a review. *Vet Med*. 2008;53(8):397–411.
2. Ogston AG, Stanier JE. The physiological function of hyaluronic acid in synovial fluid; viscous, elastic and lubricant properties. *J Physiol*. 1953;19:244–252.
3. Balazs E, Watson D, Duff I, Roseman S. Hyaluronic acid in synovial fluid. Molecular parameters of hyaluronic acid in normal and arthritic human fluids. *J Arthritis Rheum*. 1967;10(4):357–376.
4. Smith MM, Ghosh P. The synthesis of hyaluronic acid by the human synovial fibroblasts is influenced by the nature of the hyaluronate in extracellular environment. *Rheumatol Int*. 1987;7:113–122.
5. Day TD. Connective tissue permeability and the mode of action of hyaluronidase. *Nature*. 1950;166:785–786.
6. Laurent T, Laurent U, Fraser J. Functions of hyaluronan. *Ann Rheum Dis*. 1995;54(5):429–432.
7. Knudson Cb, Knudson W. *ClinOrthopRelat Res*. 2004 Oct;(427 Suppl): S152–S162.
8. Sattar A, Kumar S, West D. Does Hyaluronan have a role in endothelial cell proliferation of the synovium? *Semin Arthritis Rheum*. 1992;22(1):37–43.
9. Myint P, Deeble D, Beaumont P, Blake S, Phillips G. The reactivity of various free radicals with hyaluronic acid: steady-state and pulse radiolysis studies. *BBA - General Subjects*. 1987;925(2):194–202.
10. Widner B, Behr R, Von Dollen S, et al. Hyaluronic acid production in bacillus subtilis. *Appl Environ Microbiol*. 2005;71(7):3747–3752.
11. Rydell N, Balazs E. Effect of intra-articular injection of hyaluronic acid on the clinical symptoms of osteoarthritis and on granulation tissue formation. *ClinOrthop and Rel Res*. 1971;80:25–32.
12. Akmal M, Singh A, Anand A, et al. The effects of hyaluronic acid on articular chondrocytes. *J. Bone Joint Surg Br*. 2005;87-B:1143–1149.
13. Trigkilidas D, Anand A. The effectiveness of hyaluronic acid intra-articular injections in managing osteoarthritic knee pain. *Ann R CollSurg Eng*. 2013;95(8): 545–551.
14. Jevsevar D, Donnelly P, Brown GA, Cummins DS. Viscosupplementation for osteoarthritis of the knee: a systematic review of the evidence. *J Bone Joint Surg*. 2015;97(24):2047–2060.
15. Printz JO, Lee JJ, Knesek M, Urquhart AG. Conflict of interest in the assessment of hyaluronic acid injections for osteoarthritis of the knee: an updated systematic review. *J Arthroplasty*. 2013;28(8):30–33. e1.
16. Knudson Cb, Knudson W. Hyaluronan and CD44: modulators of chondrocyte metabolism. *Clin Orthop Relat Res*. 2004 Oct;(427 Suppl):S152–S162.

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Convenient three portal technique to remove locked bucket handle medial meniscus tear

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1. Introduction

Bucket handle medial meniscus tear presenting with a locked knee is a condition encountered frequently by arthroscopic surgeons. However these conditions need to be managed urgently to facilitate movement of the knee and mobility of the patient. Most of these tears can be diagnosed accurately on MRI.[1] Treatment options range from repair to menisectomy. Sometimes the tears are not salvageable and need to be removed. Arthroscopic removal is sometimes challenging and can vary from two to three portal techniques.[2,3] Most of the techniques described require adequate valgus force to open the medial compartment to facilitate easy working within the compartment. The technique of removing a bucket handle tear in a locked knee described in this article requires very little assistance and is efficient in terms of time and effort.

2. Technique (Video1)

The viewing portal (Portal 'A') is a vertical high anterolateral portal about 1 cm in length (Fig. 1) just adjacent to the lateral margin of the patellar tendon at the level of the inferior pole of the patella. The locked meniscus is visualized and a horizontal 1 cm long, low far medial portal is made just above the medial meniscus. (Portal 'C') (Fig. 2). A third vertical 1 cm portal is made just medial to the patellar tendon at the level of the inferior pole of the patella (Fig. 1) (Portal 'B'). Using Portal 'A' as a viewing portal, a grasper is introduced through Portal 'B' and the meniscus grasped at its root. A Punch is then introduced through Portal 'C' and the meniscus is cut at its root attachment (Figs. 3 and 4). Then, re positioning the grasper through Portal 'B', the transected end of the meniscus is held and traction applied laterally to bring its body attachment into view which is then cut by a punch introduced through Portal 'C' (Figs. 5 and 6). The meniscus is then delivered outside as a whole through Portal 'B', grasping it from one end (Fig. 7).

Supplementary video related to this article can be found at https://doi.org/10.1016/j.jajs.2019.02.002.

3. Discussion

Bucket handle medial meniscus tears often accompany ACL tears and in our case series all 10 cases using this technique were accompanied with ACL tear that required reconstruction.[4] Tears in the avascular area, degenerative changes in the knee, inability to reduce the tear anatomically and a deformed meniscus are reasons to remove the torn part rather than repairing it.[5]

Arthroscopy of the medial joint can be a challenge in tight knees. Working in the medial compartment not only requires accurate portal placement but also good assistance in terms of a valgus force to open up the medial compartment. Working on the posterior horn is especially difficult if adequate valgus force is not applied. The viewing portal was a vertical high anterolateral portal to avoid injury to the patellar tendon and to double as the viewing portal for the ACL reconstruction. The accessory portal too was made close to the patellar tendon and was thus vertical. In a locked knee where the meniscus is trapped between the femoral and tibial condyles using this technique the root posterior horn junction of the meniscus trapped in the notch is in direct view due to the shear force acting on it by the femoral condyle. Amputating this end

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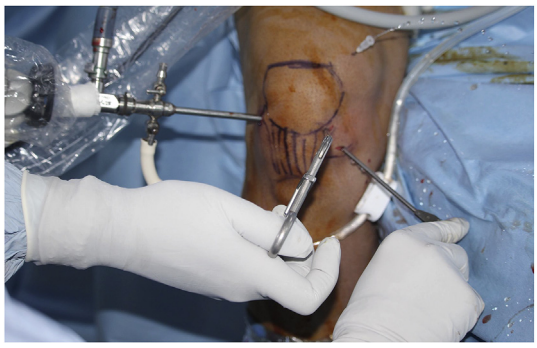

Fig. 1. Portals used.

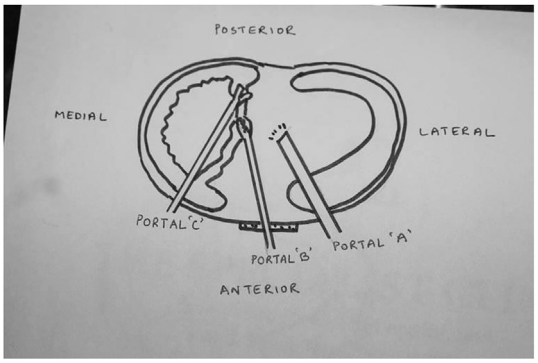

Fig. 4. Illustration of the amputation of the root end of the meniscus with portals used.

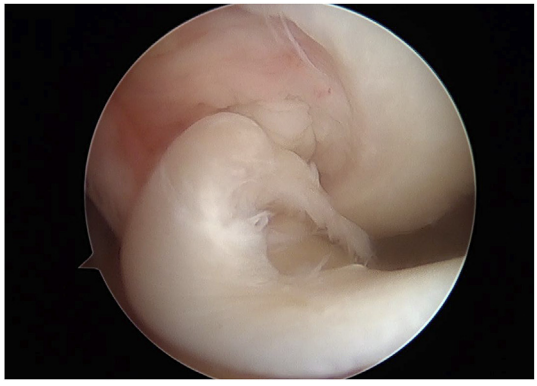

Fig. 2. Locked bucket handle medial meniscus tear.

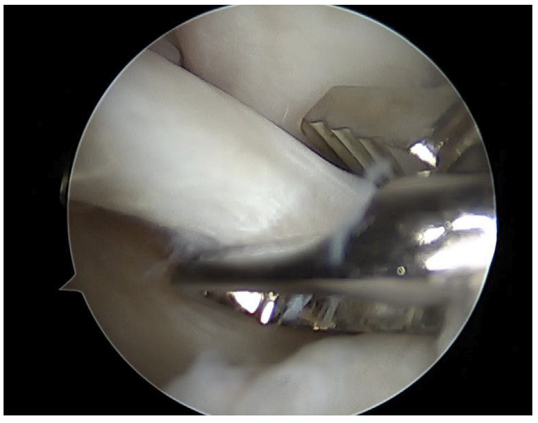

Fig. 5. Cut ends grasped with traction and punch cutting the body end of the meniscus.

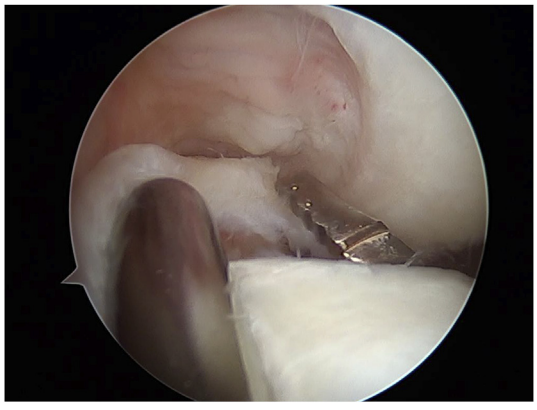

Fig. 3. Meniscus grasped at the posterior horn root junction and punch used to amputate one end.

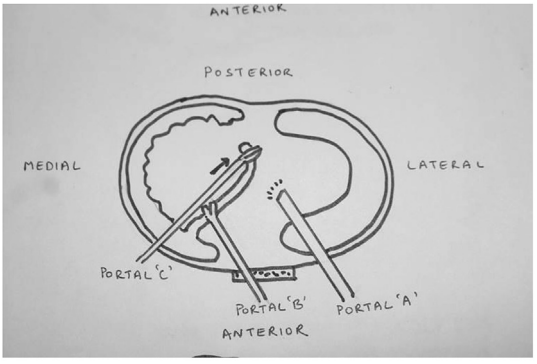

Fig. 6. Illustration of the amputation of the body end of the meniscus with portals used.

should be done carefully to avoid injury to the Posterior cruciate ligament (PCL) and the cartilage on the femoral and tibial condyles. The grasper initially grasps this end, and applying a tractional force brings the torn end into view and can be cut easily with a punch. Once this end is amputated the grasper through the accessory anteromedial portal holds the cut end so that traction can be applied to the meniscus to facilitate visualization of the torn end at body and this does not require any valgus force that is normally required to cut the meniscus from the posterior horn in the standard two portal technique. In comparison to the three portal technique involving a posteromedial portal the technique described is more convenient as it does not involve going into the posterior compartment, that can be more technically challenging. Thus this technique has the advantages of not having to apply excessive valgus to open the medial compartment and can be done

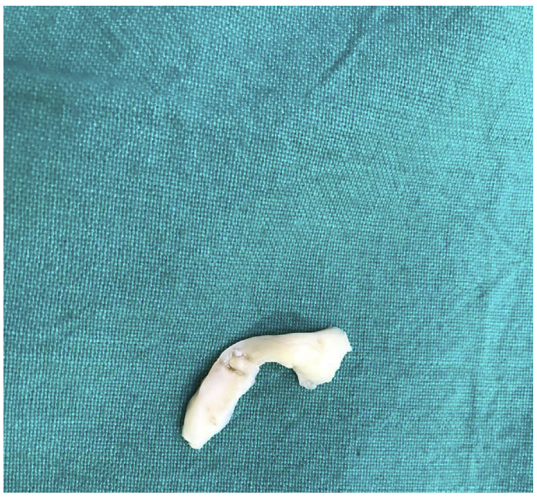

Fig. 7. Amputated medial meniscus as a whole.

with no assistant. However the same does not hold if the meniscus is not locked, in which case valgus force would be required to enter the medial compartment. The same can be applied to lateral meniscus tears as well.

4. Conclusion

The three portal technique described is a convenient alternative to the standard two portal technique and potentially reduces operative time. The frequent association with an ACL tear allows us to use the standard viewing portal in ACL reconstruction while working on the meniscus.

Disclosures

None.

References

1. Dorsay TA, Helms CA. Bucket-handle meniscal tears of the knee: sensitivity and specificity of MRI signs. *Skeletal Radiol*. 2003;32(5):266–272.
2. Ahn JH, Oh I. Arthroscopic partial meniscectomy of a medial meniscus bucket-handle tear using the posteromedial portal. *Arthroscopy*. 2004;20(7):e75–e77.
3. Nakase J, Kitaoka K, Tsuchiya H. Arthroscopic resection of a bucket handle tear of the meniscus: a technical note. *J Orthop Surg*. 2010;18(3):378–381.
4. Binfield PM, Maffulli N, King JB. Patterns of meniscal tears associated with anterior cruciate ligament lesions in athletes. *Injury*. 1993;24(8):557–561.
5. Weiss CB, Lundberg M, Hamberg P. Non-operative treatment of meniscal tears. *J Bone Joint Surg Am*. 1989;71:811–822.

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Technical note

A novel technique for bone debris clearance during anterior cruciate ligament reconstruction

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ABSTRACT

Background: Anterior cruciate ligament (ACL) reconstruction using hamstring graft or bone-patella-bone graft results in the accumulation of bone debris within the knee joint. This has been identified as a causative factor in post-operative complications, including knee effusion and osteophyte generation. This technical note describes a technique aiming to reduce the accumulation of bone debris within the knee joint following ACL reconstruction.

Method: Following creation of the femoral tunnel using a retrograde reamer during ACL reconstruction, the reamer is removed and the femoral tunnel guide left in place. In the attempt to reduce the presence of bone debris, a 20 ml syringe of sterile saline is then injected at high pressure through the guide and femoral tunnel from outside to in.

Results: In our experience, this additional operative step significantly reduced the accumulation of bone debris within the femoral canal during ACL reconstruction.

Conclusions: We conclude that this simple additional step can reduce bone debris left within the joint during ACL reconstruction.

1. Introduction

Anterior cruciate ligament (ACL) reconstruction using hamstring graft or bone-patella-bone graft results in the accumulation of bone debris within the knee joint. This is as a result of drilling the femoral and tibial tunnels into which the graft is placed. The clinical significance of this bone debris is uncertain, but its continued presence in the joint after surgery has been linked to the development of several post-operative complications.[1,3–5]

Imam et al. described a 5-step protocol for debridement of bone debris from the knee joint during ACL reconstruction which significantly reduced the rate of bone debris detected on post operative X-Ray from 69% to 15%.[2] Their technique applied to cases in which the femoral tunnel was created using a retrograde reamer and tibial tunnel created using an anterograde reamer. The graft was positioned in the femoral tunnel using a tightrope technique and in the tibial tunnel using an interference screw. To clear tibial debris, they described insertion of a shaver into the tibial tunnel from outside to in to clear. For clearance of femoral debris, the protocol suggested placement of a shaver at the femoral tunnel aperture using the accessory medial or standard anteromedial arthroscopic portals.

2. Technique

We have found that it is not possible to remove all debris from the retrograde reamed femoral tunnel using this technique (Fig. 1), and propose a simple additional surgical tip which we have found to be successful. Following creation of the femoral tunnel using a retrograde reaming Flipcutter® (Arthrex, Munich, Germany), the Flipcutter® is removed and the femoral tunnel guide left in place. A 20 ml syringe of sterile saline is then injected at high pressure through the guide and femoral tunnel from outside to in (Fig. 2). This dislodges debris within the femoral tunnel into the knee joint where it can then be easily removed using a shaver (Fig. 3). We have found that this reliably removes bone debris from the femoral

Abbreviations: Anterior cruciate ligament, ACL.

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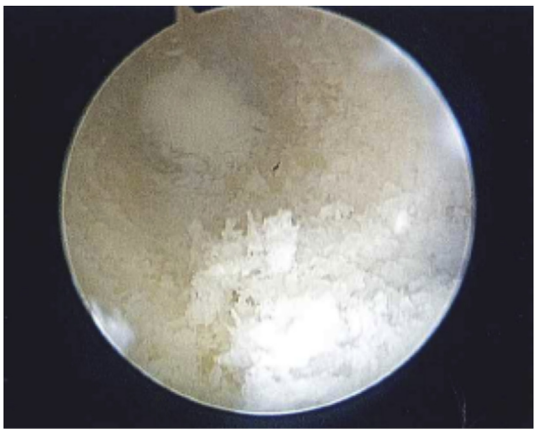

Fig. 1. Femoral tunnel before saline injection.

Fig. 2. Injection of sterile saline into femoral tunnel.

canal. Furthermore this technique can be readily modified for use in the tibial tunnel for reconstruction techniques using a retrograde reamer, and tightrope fixation for both tunnels.

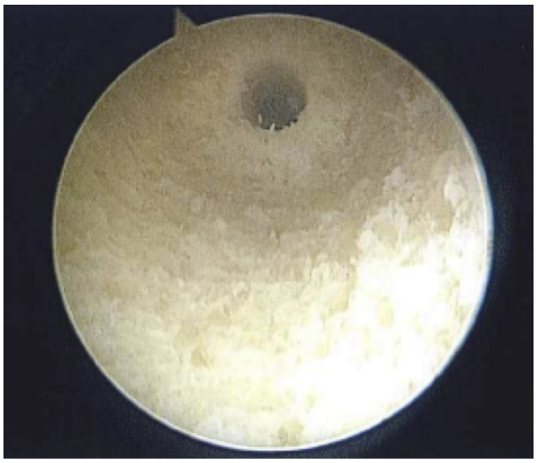

Fig. 3. Femoral tunnel after saline injection.

3. Discussion

It is important that bone debris is thoroughly cleared from the knee joint during ACL reconstruction, as the presence of bone debris within the knee has been associated with several complications. These include persistence of knee effusion post operatively[5] and the generation of osteophytes which can subsequently resulting in a falsely high diagnosis rate of osteoarthritis on X-Ray.[1] It has also been suggested that early tunnel enlargement after ACL reconstruction may be due to bone necrosis and compacted bone debris created during tunnel drilling.[4] Jackson and Shaefer proposed that cyclops lesions were the result of a fibroproliferative process from accumulated bone debris, and dramatically reduced the rate of cyclops lesions in their patients by debriding the tissue at the articular side of the tibial tunnel and avoiding anterior placement of the tunnel.[3]

Imam et al. described a protocol for clearance of bone debris resulting in reduced radiographic detection of bone debris post operatively. This technique is adequate to ensure clearance of debris if a shaver can be directly inserted into both tibial and femoral tunnels as can be done in many ACL reconstruction techniques. However we have found that the technique does not adequately clear bone debris from a tunnel created using a retrograde reamer. We have shown that this technical tip allows thorough clearance of debris from the joint in ACL reconstruction techniques using a retrograde reamer and tightrope fixation. This may further improve rates of debris detection post operatively.

Ethics

The patient was informed that data from the case would be submitted for publication, and gave their consent to images being viewed and published.

Author's contributions

DM and IS innovated and described the technique, identifying it as a surgical tip. EB was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jajs.2018.12.002.

References

1. Hart AJ, Buscombe J, Malone A, Dowd GS. Assessment of osteoarthritis after reconstruction of the anterior cruciate ligament: a study using single-photon emission computed tomography at ten years. *J Bone Joint Surg Br*. 2005;87(11):1483–4187.
2. Imam MA, Abdelkafy A, Dinah F, Adhikari A. Does bone debris in anterior cruciate ligament reconstruction really matter? A cohort study of a protocol for bone debris debridement. *SICOT J*. 2015;1(4):1–4.
3. Jackson DW, Schaefer RK. Cyclops syndrome: loss of extension following intra-articular anterior cruciate ligament reconstruction. *Arthroscopy*. 1990;6(3):171–178.
4. Ugutmen E, Ozkan K, Güven M, Sener N, Altintas F. Early tunnel enlargement after arthroscopic ACL reconstructions. *Acta Orthop Belg*. 2007;73(5):625–629.
5. Wnorowski DC. The fate of intra-articular debris following arthroscopic anterior cruciate ligament reconstruction. *Arthroscopy*. 1997;13(5):620–626.