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Good Long-term Outcomes after Repair of Chronically Displaced Medial Meniscus Bucket-handle Tears

Iskandar Tamimi^{1,2,3}, Maximiliano Lombardo-Torre⁴, Maria-Josefa Espejo-Reina⁵, Alejandro Espejo-Reina⁵, Enrique Sevillano-Perez^{1,5}, Alejandro Espejo-Baena⁵

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Abstract

Background: Meniscal repair in bucket-handle tears has proven to be effective. However, when such lesions are chronically displaced and adhered to intercondylar soft tissues, their repair may be considered unfeasible. Accordingly, the objective of this study is to show the surgical technique for the reduction and repair of this type of injury and to evaluate the long-term outcomes of such repairs. **Materials and Methods:** We conducted a retrospective case series of eight patients who were identified between 2006 and 2015 and presented with chronically displaced, medial meniscus bucket-handle tears. The bucket-handle tears were reduced, and the medial meniscus was repaired in all cases. The knee was immobilized in full extension and maintained nonweight bearing for 2 weeks. Then, the range of movement was limited from 0° to 90° and kept partially weight bearing for 4 more weeks. **Results:** The mean age of the patients was 27.2 years. The mean time to surgery was 7.12 ± 4.4 months, and the mean follow-up time was 10.0 ± 3.4 years. The average preoperative and postoperative Lysholm score was 58.0 ± 16.2 and 95.9 ± 3.4, respectively ($P = 0.008$). The mean preoperative and postoperative Tegner was 5.5 ± 1.1 and 5.1 ± 1.1, respectively ($P = 0.109$). The average KT-1000 of the participants was 1.2 ± 1.2, and the mean International Knee Documentation Committee was 92.9 ± 5.0. The average Åhlback score at follow-up was 0.83 ± 0.4. **Conclusions:** The treatment of chronically dislocated bucket-handle tears can be successfully achieved by the sequential release and suture of the torn meniscus. Good outcomes and low rates of osteoarthritis were observed at 10-year follow-up. **Level of Evidence:** IV

Keywords: Adherent meniscal tear, bucket-handle tear, chronic, displaced, functional outcome, meniscal repair, meniscus tear

INTRODUCTION

Bucket-handle meniscal tears are longitudinal meniscal tears, in which the less peripheral part of the meniscus migrates to the intercondylar notch, without losing its root insertions. They constitute up to 9%–10% of all meniscal tears; however, their prevalence in the pediatric population is higher (i.e., 20%–26%).^[1,2]

The repair of these injuries is generally complex, and in many cases, a meniscectomy is performed. Bucket-handle tears usually involve a larger volume of meniscal tissue compared with other tear types. Therefore, these types of tears may cause a greater decrease in the cartilage contact area, and a potential increase in the articular peak pressure,^[3,4] which may further aggravate the well-known side effects of meniscectomy.

Meniscal repair in bucket-handle tears has proven to be effective, both from an experimental^[3-5] and a clinical perspective.^[6] However, when such lesions are chronic and displaced, their repair may be considered unfeasible, probably due to the technical difficulties and doubts on their healing potential. Nevertheless, evidence on the best therapeutic approach in these cases is very limited.^[7-9]

Accordingly, the objective of the present work is to show the surgical technique for the reduction and repair of chronically

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displaced bucket-handle tears of the medial meniscus, which may be adhered to the intercondylar soft tissues, and to evaluate the long-term outcomes of this technique. Our hypothesis was that the meniscal repair is a viable option in these cases.

MATERIALS AND METHODS

Study group

This study was approved by the local Ethical Board Committee. A retrospective series of eight patients who came to the senior author's clinic with a chronically displaced bucket handle meniscal tear between 2006 and 2015 were reviewed. The inclusion criteria were patients under 45 years old with a displaced bucket handle tear of the medial meniscus, that were adhered to the intercondylar soft tissues [Figure 1]. The time frame from injury to surgery was ≥ 2 months. All the participants were asked to sign a consent form to participate in this study.

Surgical technique

All patients were subjected to either general or spinal anesthesia and underwent arthroscopic meniscal repair. The patients were placed supine, with the thigh sustained on a leg holder, with a tourniquet. Two or three working portals were made: transpatellar tendon (view portal), anteromedial, and anterolateral (only if necessary). A release of the bucket handle tear was made from the medial femoral condyle or anterior cruciate ligament (ACL) [Video 1]. Then, the edges of the torn meniscus were debrided using a synoviotome (Stryker, Kalamazoo, MI). The instability of the tear was confirmed in all cases. To maintain the reduction, a size 2 suture ultra-resistant (Orthocord, Johnson and Johnson) inside-out suture was placed within the meniscal body using a specific suturing device.^[7] This first suture was used for meniscal traction during the meniscal repair. The anterior part of the meniscus was repaired using an outside-inside technique, whereas the posterior part was sutured using an inside-out technique. Once finished, the stability of the repair was confirmed using a probe. If an associated ACL or posterior cruciate ligament rupture (PCL) was observed, an anatomic reconstruction was performed using the hamstring tendons. Finally, after wound closure and compressive bandaging of the limb, the knee was placed in a knee immobilizer in full extension.

Follow-up

The knee was immobilized in full extension and kept nonweight bearing for 2 weeks. Isometric exercises were initiated from the first postoperative day. The range of movement was limited from 0° to 90° during the first 6 weeks. Patients were kept partially weight bearing for 6 weeks.

Clinical assessment

The functional evaluation was performed using the International Knee Documentation Committee (IKDC) rating, Lysholm score, and Tegner activity level. A clinical and radiological assessment were also performed including KT-1000 and knee X-rays.

Statistical analysis

The statistical analysis was performed using the statistical analysis system IBM SPSS Statistics 20 (IBM Inc., Chicago, IL, USA). Means were presented with their corresponding standard deviations. Differences between preoperative and postoperative outcomes were analyzed using the Wilcoxon test. These differences were considered significant if the two-tailed $P < 0.05$

RESULTS

A total of 10 patients fulfilled our inclusion criteria, however, 2 were lost to follow-up. All the included patients were males, with a mean age of 27.2 years. Seven patients sustained a medial bucket handle tear associated with an ACL injury, and one patient had a PCL tear. The mean time to surgery was of 7.12 ± 4.4 months, and the mean follow-up time was of 10.0 ± 3.4 years [Table 1].

The average preoperative and postoperative Lysholm score was 58.0 ± 16.2 and 95.9 ± 3.4 , respectively ($P = 0.008$). The mean preoperative and postoperative Tegner were 5.5 ± 1.1 and 5.1 ± 1.1 , respectively ($P = 0.109$). The average KT-1000 of the participants was 1.2 ± 1.2 , and the mean IKDC was 92.9 ± 5.0 . The average Ählback score at follow-up was 0.83 ± 0.4 . One patient had a positive Lachman, pivot shift, and anterior drawer following surgery. All patients were subjected

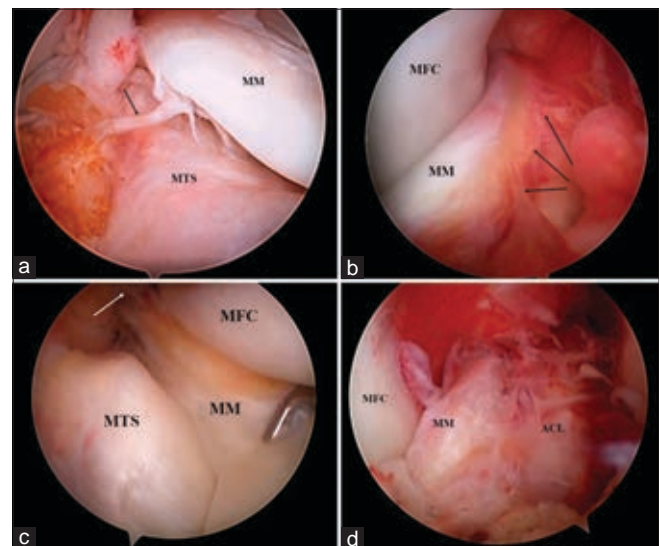


Figure 1: Arthroscopic images of dislocated medial menisci with scar adhesions to neighbouring tissues viewed from the central transtendinous portal. (a) Right knee. Dislocated medial meniscus tear with a thin flange to the torn anterior cruciate ligament (ACL) remnant (Arrow: scar flange). (b) Left knee. Dislocated medial meniscus tear, completely adhered to the ACL in a case of isolated medial meniscus tear (Arrows: scar tissue adhesions from medial meniscus to ACL). (c) Right knee. Dislocated medial meniscus tear with adhesions to the roof of the intercondylar notch (Arrow: adhesions to the roof of the intercondylar notch). (d) Left knee. Dislocated meniscal tear, completely adhered to the ACL, hindering its differentiation from it in a posterior cruciate ligament tear. MM: Medial meniscus, MTS: Medial tibial spine, MFC: Medial femoral condyle, ACL: Anterior cruciate ligament

to a postoperative magnetic resonance imaging scan. In one case, a medial meniscus re-tear was observed after a new trauma 10 years postoperatively. The patient was subjected to a partial meniscectomy of the medial meniscus and to a collagen implantation. However, the amount of meniscal tissue removed was less than it would have been if a meniscectomy was performed during the first surgery. No further complications were observed [Figure 2 and Table 2].

DISCUSSION

The main finding of the present study was that chronic bucket-handle tears of the medial meniscus can be successfully repaired even if reduction of the dislocated meniscus is difficult

because of its adherence to intercondylar soft tissues, achieving good long-term clinical outcomes.

In a recent systematic review and meta-analysis, Costa *et al.* found a 14.8% failure rate following the repair of bucket-handle meniscal tears, with a higher risk of failure for medial meniscal tears and isolated injuries.^[10] On the other hand, in a series of 1353 bucket-handle meniscal tear repairs, Tucker *et al.* found that 20.1% of the patients required further meniscal surgery (4.3% new repair and 12.1% meniscectomy).^[4] Younger age and lower body mass index were identified as risk factors for reoperation, while concomitant ACL reconstruction at the time of bucket-handle meniscus repair reduced that risk.^[4]

Kalifis *et al.* found a failure rate of 33% in 66 patients who were subjected to a bucket-handle meniscal repair, with a mean follow-up of 114 months. However, the presence of degenerative changes was more prevalent in patients with a failed repair. Therefore, the authors recommended meniscal repair in these cases as the chondroprotective effect outweighs the failure rate, especially in young patients.^[11] The present study includes patients, in which the reduction of the bucket-handle tear was particularly difficult due to its adherence to the intercondylar soft tissues. In certain cases, the resection of the neighboring scar tissues was necessary. In our study group, only one re-tear was found, which was treated by partial meniscectomy. However, less meniscal tissue was removed compared to the volume that would have been removed in a potential primary partial meniscectomy of the bucket-handle tear. Although the mean follow-up was relatively long (i.e., 10 years), progression to arthritis was low. Taking all this into account, the authors recommend meniscal repair even in cases, in which the bucket-handle tear is adhered to the intercondylar soft tissues where the reduction technically demanding.^[9,12,13] Some authors recommend performing a cut on the anterior segment of the meniscal tear to facilitate its reduction. In our series, no cuts in the meniscal tissue were required, as mobilization of the bucket handle tears was achieved after its release from the scar tissue and by the use of traction suture.

The main limitations of the present study are its small sample size. However, chronically displaced and adhered bucket-handle meniscal tears are not common. These injuries

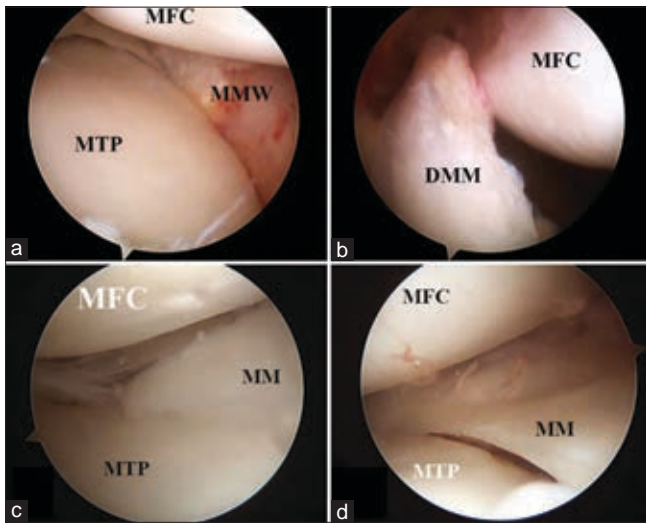


Figure 2: Arthroscopic images of a right knee, showing a displaced bucket-handle medial meniscus re-tear, repaired 10 years previously. We can observe that most of the old tear had healed (a) Medial tibiofemoral compartment with absent medial meniscus, which was dislocated to the intercondylar notch. (b) Dislocated medial meniscus bucket-handle tear, located in the intercondylar notch. (c) View of the new tear on the posterior horn of the medial meniscus 10 years after former suture. (d) View of the correctly healed meniscal body (middle third) of the same meniscus 10 years after former repair. MTP: Medial tibial plateau, MFC: Medial femoral condyle, MMW: Medial meniscus wall, MM: Medial meniscus, DMM: Dislocated medial meniscus

Table 1: Clinical features of 8 bucket handle tears

Case	Gender	Age (years)	Side	Type of injury	Time to surgery (months)	Treatment	Follow-up (years)
1	Male	17.0	Left	PCL + MM BHT	3	PCL + MM repair	6
2	Male	34.0	Left	ACL + MM BHT + LM	12	ACL reconstruction + MM and LM repair	6
3	Male	29.0	Right	ACL + MM BHT + LM root	12	ACL reconstruction + MM repair + LM root reinsertion	6
4	Male	25.0	Right	ACL + MM BHT	12	ACL reconstruction + MM repair	14
5	Male	28.0	Left	ACL + MM BHT	8	ACL reconstruction + MM repair	12
6	Male	28.0	Left	ACL + MM BHT	3	ACL reconstruction + MM repair	11
7	Male	35.0	Right	ACL + MM BHT	5	ACL reconstruction + MM repair	13
8	Male	22.0	Right	ACL + MM BHT	2	ACL reconstruction + MM repair	12

F: Female, MM: Medial meniscus, LM: Lateral meniscus, ACL: Anterior cruciate ligament, BHT: Bucket handle tear, PCL: Posterior cruciate ligament

Table 2: Pre- and postoperative clinical evaluation of 8 bucket handle tears

Case	Preoperative lysholm	Preoperative tegner	Postoperative lysholm	Postoperative tegner	KT-1000	Lachman	Anterior drawer	Pivot shift	IKDC	Ahlback
1	39.0	7.0	96.0	7.0		-	-	-	90.0	
2	42.0	6.0	100.0	6.0	0	-	-	-	94.0	1
3	41.0	4.0	100.0	4.0	3	+	+	+	100.0	1
4	85.0	7.0	95.0	6.0	1	-	-	-	96.0	1
5	63.0	4.0	95.0	4.0		-	-	-	96.0	
6	70.0	5.0	91.0	5.0	1	-	-	-	85.0	1
7	75.0	6.0	99.0	4.0	2	-	-	-	96.0	1
8	56.0	5.0	91.0	5.0	0	-	-	-	86.0	0

IKDC: International Knee Documentation Committee

are usually sutured in the acute phase, and untreated displaced cases are rare. Moreover, the treatment of adhered chronic injuries is usually partial meniscectomy, and the cases presented in this study which include adherent chronic injuries that were subjected to a meniscal repair, are extremely rare. Finally, the take-home message of this study is that chronic, displaced and adherent tears, can still be liberated and sutured, achieving good clinical outcomes. However, future systematic reviews could be useful to add insight on the management of these injuries.

CONCLUSIONS

The treatment of chronically dislocated bucket-handle tears can be successfully achieved by the sequential release and suture of the torn meniscus, even when there is an adherence to the intercondylar soft tissues. Good outcomes and low rates of osteoarthritis were observed at 10-year follow-up.

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Conflicts of interest

There are no conflicts of interest.

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Relationship between the Articular Cartilage Thickness of the Patella and Trochlea in Trochlear Dysplasia Compared to Normal Knees

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Abstract

Introduction: Anterior knee pain is not an uncommon problem. A plethora of pathologies can cause anterior knee pain. Patellofemoral maltracking (trochlear dysplasia) is not an uncommon cause of anterior knee pain in adolescents and young adults. **Aim:** We hypothesize that there is an alteration of articular cartilage of the patella and trochlea in trochlear dysplasia. **Materials and Methods:** Magnetic resonance images of 86 knee joints were reviewed independently by two musculoskeletal radiologists. Standard magnetic resonance imaging (MRI) sequences were used in this study. Based on the Dejour classification for trochlear dysplasia, the patients were divided into normal, Type A, B, C, and D. The articular cartilage thickness of the patella and trochlea was measured and compared between the groups. **Results:** Out of the 86 MRI scans of the knees which were reviewed, 32 patients were male and 54 were female. The mean patient age was 21.9 years (range = 10–40). Sixty-six knee joints had trochlear dysplasia, with 15 patients classified into Dejour Type A, 13 in Type B, 31 in Type C, and 7 in Type D. There was no significant difference in the articular cartilage thickness of the lateral facet of the patella between all groups (ANOVA $F = 1.43$, $P = 0.23$). **Conclusion:** There was no significant difference in the articular cartilage thickness in the lateral facet of the patella and trochlea in patients with normal knee joints compared to those with trochlear dysplasia of Type A–D.

Keywords: Articular cartilage, magnetic resonance imaging, patella morphology, trochlear dysplasia

INTRODUCTION

Trochlear dysplasia is an important anatomical abnormality in symptomatic cases of patellar instability. It is characterized by abnormal morphology of the trochlea due to a shallow trochlear angle and depth, together with a small medial facet.^[1] The trochlear groove forms the part of the femoral articular surface of the patellofemoral joint. Patellar stability is affected by its morphology and depth, especially during flexion and extension of the knee joint.^[2] Numerous studies have been conducted about trochlear morphology and the surgical management of this condition, but limited attention has been given to the corresponding patellar morphology.^[3,4]

Trochlear dysplasia can be categorized according to the Dejour classification on lateral radiograph and sectional imaging (Type A, B, C, and D).^[5] This condition can be treated surgically with a procedure called trochleoplasty,

aiming to create a recentralized groove, correcting the trochlear depth abnormality, and stabilizing the patella into the groove.^[6] It is indicated for symptomatic patients with recurrent patellar instability, which has failed conservative management. The morphology of the patella and its cartilage thickness may have implications for the surgical management of trochlear dysplasia, particularly when addressing the impact of trochlear dysplasia on patellar tracking and joint function.^[7]

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The authors have seen anecdotal cases of hypertrophy of articular cartilage of the lateral facet of the patella and trochlea in patients with trochlear dysplasia. This study assessed the alteration of the articular cartilage thickness of the patella and trochlea in trochlear dysplasia compared to normal knee joints. The authors hypothesized that there would be increased cartilage thickness in the trochlea and patella's lateral facet in trochlear dysplasia compared to those without this condition.

MATERIALS AND METHODS

Local ethical committee approval was obtained. Magnetic resonance (MR) images of 86 consecutive patients who presented with anterior knee pain were reviewed over 1 year. The patients (<40 years of age) were referred for magnetic resonance imaging (MRI) of knee joints from the specialist knee clinic of the same hospital for anterior knee pain. There were 32 male and 54 female patients. Their mean age was 21.9 years (range = 10–40). Standard MRI sequences were used, including coronal and axial high-resolution intermediate weighted fat-suppressed images (TR 3660, TE 90, slice thickness 3 mm, matrix 512 × 50, field of view [FOV]-12), axial STIR (TR/TE 5500/60, slice thickness 5 mm, matrix 512 × 45, FOV-15), and sagittal proton-density (TR/TE 2000/14, slice thickness 3 mm, matrix 512 × 50, FOV-18). The images were acquired on 3T MRI, Ingenia Elition, Philips Healthcare, Best, Netherlands. The MRI images were reviewed independently by two musculoskeletal radiologists and one of these radiologists re-reviewed the cases after an interval of 1 week for intraobserver reliability. The MR images of the knee joints were categorized into normal, Type A, B, C, and D based on the Dejour classification. Any disagreement was discussed until a consensus was achieved.

Measurement

The articular cartilage thickness of the patella and trochlea was measured at approximately 2 cm proximal to the subchondral bone of the lateral femoral condyle. The axial images were scrolled at this level to identify the image with the maximum thickness of the patella and trochlea [Figure 1]. The thickness of the medial and lateral facets of both trochlea and patella were calculated at the midpoint of each facet [Figure 2]. Due to the variations of cartilage thickness between different individuals, we standardized the measurement of the cartilage thickness of each participant by deducting the thickness of the medial facet of the articular cartilage from the lateral facet. The value obtained from this measurement was then compared with those obtained from other participants. This was done to minimize the errors from comparing the absolute value of the thickness between the patients. Therefore, the mean value may be negative if the medial facet is thicker than the lateral facet [Figure 1].

Statistics

The data were analyzed using the SPSS software version 24 (Statistical Package for the Social Sciences, IBM, SPSS Inc. Armonk, New York). Descriptive statistics were performed for each group. ANOVA test was used to compare the means

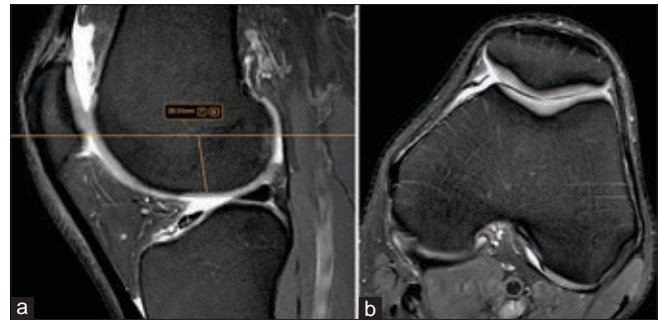


Figure 1: Sagittal (a) and axial (b) PDFS of the knee showing level for measurement of the thickness of articular cartilage of lateral and medial facet of trochlea and patella. PDFS: Proton density fat suppressed

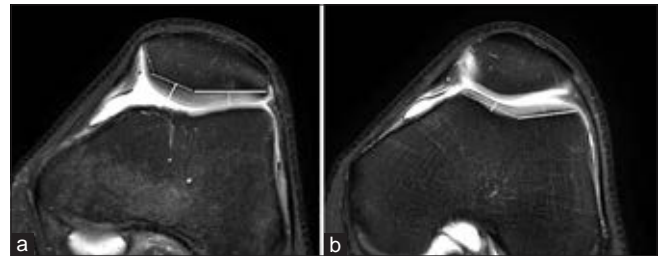


Figure 2: Axial PDFS (a and b) showing the thickness of the articular cartilage of medial and lateral facet of the patella (a) and trochlea (b)

between the patient groups (normal knees vs. knees with trochlear dysplasia Type A-D). Cohen's Kappa was used to analyze intra- and interobserver variability. $P < 0.05$ was considered to be statistically significant in this study.

RESULTS

Of the 86 MRIs of the knee joints in this study, there were 20 normal knee joints and 82 knee joints with trochlear dysplasia. Based on the Dejour classification, 15 knee joints were classified into Type A, 13 into Type B, 31 into Type C, and 7 into Type D, respectively [Table 1].

There was no significant difference demonstrated in the thickness of the articular cartilage of the patella or trochlea between the patients with normal knee joints and those with trochlear dysplasia ($F = 1.43$, $P = 0.23$) and ($F = 1.96$, $P = 0.107$), respectively [Tables 2 and 3]. Intra and interobserver reliability was good with a kappa of 0.8.

DISCUSSION

The patellar morphology of knees with underlying trochlear dysplasia has only been sparsely reported in the literature. To the best of our knowledge, this is the first study solely focusing on the thickness of the articular cartilage of the patella and trochlea in trochlear dysplasia and how they compare with a control group of normally shaped trochlea. In our study population, there was no significant difference in the thickness of the articular cartilage of the patella or trochlea between the normal knee joints and those in patients with trochlear dysplasia of all subtypes.

Table 1: Demographics of patients in each cohort

	Normal	Type A - TD	Type B - TD	Type C - TD	Type D - TD
<i>n</i>	20	15	13	31	7
Average age	13.3	25	24.2	24	26.4
Maximum age	20	39	37	40	38
Minimum age	12	12	13	10	14
Male	10	4	6	12	0
Female	10	11	7	19	7

Table 2: Statistics of difference between the lateral and medial facets of the patella in each cohort

	Normal	Type A - TD	Type B - TD	Type C - TD	Type D - TD
<i>n</i>	20	15	13	31	7
Mean	0.2	-0.7667	-2.9154	-0.9177	-4.5929
SD	0.3277	3.0742	7.3006	6.7697	5.1634

SD: Standard deviation

Table 3: Statistics of difference between the lateral and medial facets of trochlea in each cohort

	Normal	Type A - TD	Type B - TD	Type C - TD	Type D - TD
<i>n</i>	20	15	13	31	7
Mean	0.4	-0.72	1.3692	-0.7268	2.8686
SD	0.5563	3.3388	4.2824	3.7281	7.1658

SD: Standard deviation

The articular cartilage thickness of the patella in patients with trochlear dysplasia may not differ significantly compared to individuals with a normal knee joint due to several reasons. For instance, age and degenerative changes may be contributing factors affecting the patella cartilage thickness over time, often decreasing its thickness with age with degenerative conditions such as osteoarthritis. Hence, the thinning may not be exclusively linked with trochlear dysplasia.^[8] In addition, there may be natural variation in patella cartilage thickness, which varies naturally among individuals, even in normal populations, which may not be exclusively related to the presence or absence of trochlear dysplasia.^[9] Furthermore, in some cases of trochlear dysplasia, the anatomical abnormalities in the femoral trochlear groove may be relatively mild, and these subtle variations may not exert a significant impact on patella tracking and loading, which can result in similar patella cartilage thickness to those individuals with normal knee joints.^[10,11] Hence, the implications for patellar cartilage thickness may be variable and not necessarily a defining feature of this condition.

The patella cartilage thickness may have implications on the surgical management of trochlear dysplasia, particularly when managing the impact of this condition on patella tracking and joint mechanics. The surgical management of trochlear dysplasia often involves procedures for patellar realignment,

including trochleoplasty where the shape of the trochlea groove is altered or tibial tubercle osteotomy (TTO), which changes the position of the patella tendon attachment on the tibia.^[7] The surgical management will depend on the severity or grading of trochlear dysplasia, the morphology, and the individual anatomy of the knee joint.^[12] In instances where the articular cartilage of the patella is relatively thick and healthy, the operating surgeon may have more flexibility to perform trochleoplasty or TTO, as the patella may withstand the realignment without much concerns about excessive damage to the articular cartilage. In addition, thicker cartilage may provide a better cushioning effect and protection during the postoperative period reducing the risk of cartilage damage during the healing process, allowing more aggressive postoperative rehabilitation.^[13] Besides, surgical approaches may also focus on cartilage restoration or replacement in cases of reduced patella cartilage thickness or damage, including microfracture, autograft, or allograft chondrocyte implantation.^[14] In these cases, thicker cartilage may offer a more favorable substrate for cartilage restoration procedures increasing the chance of successful outcomes.^[15]

Furthermore, trochlear dysplasia and its aberrant biomechanics may also affect the thickness of the trochlear cartilage. Elevated levels of stress and abnormal biomechanics within the dysplastic trochlear groove might result in uneven degeneration of the cartilage, which over a period of time, would cause thinning and permanent damage to the articular cartilage.^[16] The degree of cartilage degradation and damage, and the impact of trochlear dysplasia on cartilage thickness might vary among individuals and are influenced by factors such as the severity of the dysplasia, individual anatomy, and activity levels.^[11]

In summary, patella and trochlear cartilage thickness may affect the surgical management of trochlear dysplasia by influencing the choice of surgical techniques, the possibility of cartilage restoration, the feasibility of the realignment procedure, and the postoperative rehabilitation plan. Nevertheless, in clinical and surgical practice, orthopedic surgeons consider multiple factors, including patient history, imaging, symptoms, and overall joint health, when assessing and managing patients with trochlear dysplasia to develop an individualized surgical strategy for patients with this condition. Patellar and trochlear cartilage thickness is an important consideration and is just one aspect of the broader clinical picture that influences treatment decisions.

Limitations of this study include its retrospective nature and possible selection bias. All patients in this series were referred from the specialist knee clinic who presented with anterior knee pain. Therefore, the proportion of patients with trochlear dysplasia in our series is relatively high as they were sampled from symptomatic patients. In comparison, the prevalence of trochlear dysplasia in the general population is approximately 6%, but it has been found in up to 85% of those with recurrent patellar instability.^[17] There was also a relatively small number of patients in the Type D category in

this study (8 patients). Besides, this study was only designed to analyze the radiographic findings and relationship of the patella and trochlea cartilage thickness and trochlear dysplasia without considering patients' clinical signs and symptoms related to the condition. We propose that further research may be conducted to support our findings in this study.

CONCLUSION

This study demonstrated no significant difference in the thickness of the articular cartilage of the patella and trochlea in patients with normal knee joints compared to those with trochlear dysplasia of all subtypes on MRI scans.

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Conflicts of interest

There are no conflicts of interest.

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The Adductor–Rectus Angle: A Novel Magnetic Resonance Imaging Measurement in Healthy Adult Individuals

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Abstract

Background: Groin pain is a complex musculoskeletal condition, causing significant difficulty in its diagnosis and management. The stability of the anterior pelvis is maintained by the formation of a complex fibrous aponeurotic plate by the rectus abdominis and adductor longus tendons. It is, therefore, vital to have a comprehensive understanding of this condition to guide appropriate management. We aimed to measure the adductor–rectus angle (ARA), which is the angle between the rectus abdominis and adductor longus tendon to establish a normal range in a diverse group of healthy individuals on magnetic resonance imaging (MRI) with the aim of investigating its possible association with the occurrence of athletic pubalgia. **Materials and Methods:** A retrospective cross-sectional study assessed the ARA in 100 asymptomatic normal healthy individuals who had undergone an MRI of the pelvis. The participants were categorized based on gender and divided into three age groups: under 40, between 40 and 60, and above 60 years. Descriptive statistics were calculated for each group and were followed by a one-way analysis of variance to identify any significant differences between these groups. **Results:** The mean ARA in the entire study cohort was $135.543^\circ + 6.4814^\circ$. The ARA did not differ significantly among different age groups or genders. **Conclusion:** The ARA helps to evaluate pelvic muscles' alignment and offers valuable insights into the force applied to the fibrous aponeurotic plate. This information could potentially aid in identifying athletes at risk of sports hernias and inform the development of personalized treatment strategies.

Keywords: Adductor–rectus angle, biomechanics, fibrous aponeurotic plate, groin pain, magnetic resonance imaging, novel measurement

INTRODUCTION

Groin pain is a prevalent complaint among athletes, accounting for approximately 5%–20% of all sports-related injuries.^[1] This discomfort can either manifest as a single acute traumatic event or develop progressively due to repetitive microtrauma. The implications can be severe, potentially curtailing an athlete's ability to perform and even precipitating the premature end of their professional career if left untreated. Although various terminologies are used to describe groin pain, the term “core injury” has recently been widely accepted. “Core injury” includes a range of musculoskeletal issues within the anterior part of the pelvis, particularly those related to the pubic symphysis and adjacent tendons and muscles.^[2]

The pubic symphysis is a complex region that serves as the attachment point for abdominal flexors and thigh adductors and plays a vital role in maintaining the stability and functionality of the core musculature. One of its key components is the

fibrous aponeurotic plate. Formed from merging the bilateral rectus abdominis and adductor longus tendons. This structure is instrumental in stabilizing the anterior pelvis. However, injuries to this fibrous plate are relatively common and are characterized by pain and limited mobility.^[3]

The orientation of the adductor and rectus muscle fibers play a critical role in modulating the amount of torque exerted on the fibrous aponeurotic plate by both muscles during their contraction and could be a predisposing factor for the

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early onset of “core injury.” Therefore, our study aimed to determine the angle between these muscles, also known as adductor–rectus angle (ARA), in a healthy adult population using magnetic resonance imaging (MRI) and establish the normal range of this angle across different age groups and genders.

This study introduces a new MR parameter – the ARA, which is the angle formed between the adductor longus and rectus abdominis. Our study aims to address this knowledge gap by measuring the normal range of ARA in a diverse group of healthy individuals on MRI and establish a consensus on what constitutes a standard value for this angle among different age groups and sexes. By conducting a thorough analysis of average ARA values in healthy subjects, we aim to demonstrate the relevance of the ARA for musculoskeletal diagnosis and its potential as a predictive tool for identifying athletes prone to pubalgia. We also aim to establish a baseline for future studies on core injuries, ultimately leading to improved patient outcomes and optimal functional recovery.

MATERIALS AND METHODS

Study design

This retrospective cross-sectional observational study was conducted over 1 year period.

Statement of ethics

Institutional review board and ethics committee approval were obtained. The informed consent was waived due to the retrospective design of the study. Patient confidentiality was strictly maintained, and all data were deidentified to ensure anonymity.

Inclusion and exclusion criteria

Inclusion criteria included adult individuals who underwent an MRI pelvis at our center for any indication other than core injury/anterior pelvic pain. Exclusion criteria included imaging evidence of pathology affecting the pubic region, pelvic trauma, motion and metallic image artifacts, postoperative changes, and the presence of complaints related to groin pain or anterior pelvic pain.

Data collection

The data collection and analysis encompassed examining historical data from our institute’s radiology database for MRI pelvis images. After applying inclusion and exclusion criteria, 100 MRI pelvis were collected from our institute’s imaging database. The process adhered to strict confidentiality measures, and data were stored securely in compliance with institutional regulations.

Image analysis

Diagnostic MRI pelvis images were meticulously reviewed by a fellowship-trained musculoskeletal radiologist with over 10 years of experience and a musculoskeletal radiology fellow. A coronal proton density-weighted sequence was used for analysis. Images were acquired on 3T MRI, Ingenia Elition,

Philips Healthcare, Best, the Netherlands. Demographic details of patients, encompassing age and gender, were systematically recorded. Standardized criteria were employed to maintain consistency across the image assessments.

Adductor–rectus angle measurement

Rectus abdominis axis

The rectus axis line was drawn along the midpoints of two lines, A and B. Line A was drawn at 2 cm proximal to the pubic insertion of the rectus abdominis by joining its medial and lateral margins. Line B was drawn 3 cm cranial to Line A, between the medial and lateral margins of the rectus abdominis. A third line joining the midpoints of Line A and Line B constituted the rectus abdominis axis.

Adductor longus axis

The adductor longus axis was drawn along the tendon of the adductor longus tendon.

Adductor–rectus angle

ARA was defined as the angle formed at the intersection of the rectus abdominis axis, and the adductor longus axis was labeled the ARA [Figures 1 and 2].

Two readers performed measurements to assess for interobserver reliability and one reader repeated measurements after an interval of 2 weeks for intraobserver reliability.

Statistical methods

Data were collected, entered in a Microsoft Excel sheet, and analyzed using STATA (Stata statistical software: Release 18, StataCorp LLC, USA). The cohort was divided into two groups based on gender and was further subdivided based on age range (<40 years, 40–60 years, and more than 60 years). Descriptive statistics of the different groups were performed. One-way analysis of variance was used to determine whether differences between groups were significant. $P < 0.05$ was considered statistically significant.

RESULTS

Our study analyzed 100 pelvic MRIs and measured the bilateral ARAs. An average of the bilateral ARA measurements was used for calculation. The study cohort consisted of 44 males and 56 females. Among the males, 14 individuals were under 40 years of age, 20 were between 40 and 60 years, and 10 were over 60 years. Among the females, 12 individuals were under 40 years of age, 16 were between 40 and 60 years, and 28 were over 60 years.

The mean ARA in the entire study cohort was $135.543^\circ \pm 6.4814^\circ$. The mean ARA in males was $135.76^\circ \pm 6.39^\circ$, and among females was $134.35^\circ \pm 5.75^\circ$. The ARA did not differ significantly between genders.

The mean ARA was $135.1538^\circ \pm 5.697^\circ$ in the under 40 years age group, $135.697^\circ \pm 6.8533^\circ$ in the 40–60 age group, and $135.697^\circ \pm 6.8533^\circ$ in the over 60 age group [Table 1]. The ARA did not differ significantly among different age groups.



Figure 1: Schematic showing the measurement of the adductor-rectus angle which is the angle between the rectus abdominis axis and adductor axis, i.e., 180-adductor angle – rectus abdominis angle

	Male	Female	<40	40–60 years	>60 years
Maximum	149	145	143	149	144
Minimum	122	120	120	122	120
Median	138	135.5	135.5	136.5	136
SD	6.39	5.75	5.7	6.75	5.7
SEM	0.94	0.78	1.11	1.15	0.9

SD: Standard deviation, SEM: Standard error of mean

There was good intra- and interobserver reliability with a kappa of 0.8.

DISCUSSION

Sports-related groin pain (SRGP) is a common sports injury that can have severe implications for an athlete’s career, as it can limit their ability to perform in competitions and may even lead to premature termination of their professional journey.

The complexity of the anterior pelvis and groin’s anatomy may contribute to the existing confusion regarding the pathoanatomy and treatment modalities for athletic pubalgia. This intricacy often poses challenges in accurately diagnosing and effectively managing this condition.^[4]

The challenges in diagnosing and treating groin injury are partly due to a lack of consensus among researchers and clinicians regarding the functional anatomy of the area and the vast array of diagnostic terms used.^[5] Patients suffering from SRGP are often diagnosed with conditions such as osteitis pubis, adductor tendinopathy, sportsman’s hernia, Gilmore’s groin, or muscular disorders related to the iliopsoas, rectus abdominis, and adductors. In the intricate region of the pubic symphysis, our study primarily focused on the rectus abdominis and adductor longus tendon, which blend to form a fibrous aponeurotic plate, which is the most crucial structure that stabilizes the anterior pelvis.^[6] Injury to this

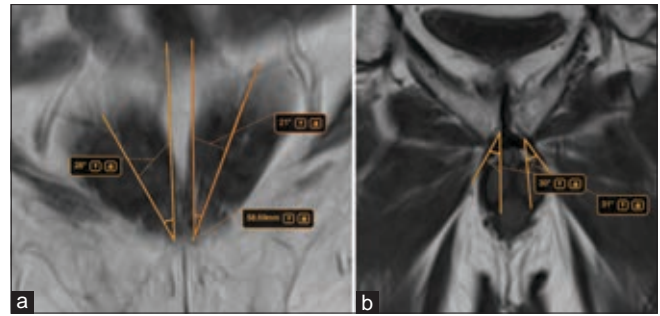


Figure 2: Coronal proton density (a and b) showing measurement of adductor-rectus angle. 180-28-30 = 122° on right and 180-21-31 = 128° on left

fibrous plate is the most common cause of “core injury.” The rectus abdominis generates superoposterior tension during core rotation and extension, whereas the adductors produce inferoanterior tension. This tangential opposition, coupled with the broad attachment of the aponeurosis, is crucial for the stability of the anterior pelvis. Any disruption or injury to either component can lead to abnormal biomechanical forces on the opposing component, resulting in instability of the muscular core. This instability is often associated with many of the lesions observed in athletic pubalgia. Therefore, maintaining the integrity of these muscular components is essential for preventing such injuries and ensuring optimal athletic performance.^[7]

The anatomical, radiological, and surgical literature has not previously described the normal ARA. The mean ARA in the entire study cohort was 135.543° + 6.4814°, and there was no statistically significant difference in the ARA between the genders and among various age groups. This study is the first of its kind, in which the ARA is measured in a healthy adult population using MRI, and a normal range is established across different age groups and genders.

This pioneering research lays the groundwork for future investigations into the role of ARA in the onset and progression of “core injury.” Further large-scale studies can be conducted to observe variations of this angle in patients exhibiting “core injury” symptoms, which could serve as an early indicator of athletes at risk for athletic pubalgia.

CONCLUSION

The adductor-rectus angle introduces a new dimension in assessing pelvic muscle orientation and indirectly assesses the torque on the fibrous aponeurotic plate. The ARA emerges as a promising MR parameter with potential implications for predicting and understanding athletic pubalgia. Early identification of at-risk athletes based on ARA measurements could facilitate targeted preventive interventions and personalized treatment strategies.

Limitations

The angle was measured in normal healthy individuals and no attempt was made to compare this with patients having athletic

pubalgia. Further studies are warranted to validate the ARA as a prognostic tool and to elucidate the underlying biomechanical mechanisms linking ARA with pubalgic pathology.

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Conflicts of interest

There are no conflicts of interest.

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Graft Maturity Assessment by Magnetic Resonance Imaging and its Relation with Functional Scores after Anterior Cruciate Ligament Reconstruction with Hamstring Graft

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Abstract

Background/Objectives: Anterior cruciate ligament (ACL) reconstruction is a common procedure performed in orthopedic surgery. There are many methods to evaluate the functional outcome postoperatively, but no single reliable method exists to assess graft maturity. The purpose of this research is to evaluate graft maturity by magnetic resonance imaging (MRI) and its relation with functional outcome at the end of 6 months and 12 months. **Materials and Methods:** MRIs were performed on 32 patients who underwent ACL reconstruction at 6 and 12 months following surgery. The measurements were made of the background, posterior cruciate ligament, and signal intensity of the graft. The calculation of the signal noise quotient (SNQ) was done. The correlations between the international knee documentation committee (IKDC) at 6 and 12 months and the SNQ values at 6 and 12 months were assessed. **Results:** After 6 months, the mean SNQ value was 3.8953 ± 2.6561 , and after 12 months, it was 2.6013 ± 1.7337 . In addition, the mean IKDC was 43.3 preoperatively, 52.8125 ± 9.24728 at 6 months' follow-up and 70.6875 ± 8.32578 at 12 months' follow-up. The 12-month SNQ values showed a significant decrease, according to RMANOVA ($F[1,62] = 6.50871, P = 0.01316$). Conversely, the IKDC scores at 12 months demonstrated a statistically significant rise ($F[1,62] = 66.03667, P < 0.001$). **Conclusion:** MRI is a reliable investigation to assess the graft maturity. In our study, hamstring graft demonstrated superior maturity at 12 months as compared to 6 months' postsurgery. There was a noteworthy inverse relationship between graft SNQ and IKDC scoring. MRI assessment at 6 months and 12 months is desirable to know graft's maturity and helps to modify the rehabilitation protocol.

Keywords: Anterior cruciate ligament reconstruction, hamstring graft, international knee documentation committee score, signal/noise quotient

INTRODUCTION

The volume of patients undergoing anterior cruciate ligament (ACL) reconstruction has steadily increased in recent years and despite all the recent advances, there has been varying degree of complications and recurrent instability following ACL reconstruction. Even though there are numerous ways to evaluate the results of ACL reconstruction postoperatively, there is no single reliable method to evaluate the graft maturity.^[1]

The clinical and functional outcome assessments for evaluating the results of ACL reconstructions are many like arthrometry of the knee and questionnaires such as international knee documentation committee (IKDC) scores. Even though these evaluation methods have shown beneficial in numerous studies, these are the indirect measures of graft health or integrity and

may not accurately detect graft incorporation, healing, or failure. Furthermore, there does not seem to be agreement on which test, or set of tests, is the best for assessing the outcome after ACL reconstruction.^[2,3]

Therefore, the clinical evaluation of ACL reconstruction done alone is unreliable. Muscle strength and functional

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stability alone should not be the only criteria for returning to physically demanding activities such as sports. The graft's magnetic resonance imaging (MRI) evaluation postoperatively is an additional assessment technique. Numerous research examining MRI evaluation have come to the conclusion that it is a dependable diagnostic technique for assessing the various parameters related to ACL graft evaluation, including graft healing, maturation, and position, as well as potential problems or re-injury. "With MRI we can also assess the graft signal integrity, correct tunnel placement, tunnel widening and problems with fixation devices that could compromise the surgical outcome and potentially predict the failure of the surgery."^[4,5] Although MRI of the graft can be done at different points of time, grafts are best evaluated at 6–12 months postsurgery when the remodeling process happens, as it is during this period, grafts are most vulnerable to damage and failure.^[6]

Furthermore, early assessment of graft maturity may aid in the prediction of future clinical outcomes and in tailoring the rehabilitation regimen in accordance with the graft's maturity rather than using a predetermined regimen that may result in graft failure. This period is also the most commonly recommended time for returning to high demand activity such as sports and preinjury status. Therefore, performing an MRI at different intervals, such as 6 months and 12 months postoperatively will help assess the graft incorporation and pick up any features suggestive of graft failure or delay in healing.

By calculating the signal/noise quotient (SNQ) of the graft on MRI, graft maturity can be quantitatively analyzed. A reduction in the physical characteristics of the reconstructed graft was indicated by an increase in the intensity of the MRI signal. Very few studies have evaluated the early predictive significance of graft maturity on clinical outcomes, despite the large number of studies on MRI evaluation of the reconstructed graft at various postreconstruction periods.^[7,8] We could be able to infer some final clinical conclusions from this data. Thus, to explore any possible correlation between MRI-based graft maturity and the functional outcomes as determined by IKDC scores during the initial year following ACL reconstruction, we designed this study.

MATERIALS AND METHODS

The local ethical committee approved this study, and it was carried out in compliance with the 1964 Helsinki Declaration's amended 2008 ethical guidelines. Before the commencement of the study, all patients provided written and informed consent. This prospective, retrospective, and observational study was conducted by the Department of Orthopedics at a tertiary referral center from September 2018 and December 2020 among the patients admitted with an ACL tear. The inclusion criteria of the subjects were as follows: (1) isolated ACL injury in active young individuals, (2) patients aged 18–50 years, (3) hamstrings graft as ACL graft, and (4) suspensory fixation (Endo button) at femoral side and aperture

fixation (screw) at the tibial tunnel. The exclusion criteria were as follows: (1) fixation methods other than mentioned in the inclusion criteria, (2) ACL injury in individuals with osteoarthritis, (3) ACL avulsion fractures and multi-ligament injuries, (4) revision ACL reconstruction, and (5) ACL injury in individuals with concurrent lower limb long bone fractures.

The study comprised 32 patients in total. The patients' ages ranged from 16 to 43 years, with a mean age of 30.40 ± 7.68 . Hence, the activity demands of the patients were similar.

Surgical procedure

Anatomic single-bundle ACL reconstruction using 5-strand double looped hamstring autograft was performed on all patients using the similar technique. The ACL footprints on the tibia and femur were recognized. Afterward, an inside-out femoral tunnel was drilled using femoral reamers. Using a cannulated drill and a commercially available tibial guide, the tibial tunnel was made at the footprint center. The graft was secured on the tibial side using an aperture fixation (Bio-screw, Zimmer) and the femoral side using a suspensory fixation (Endo button-Closed Loop, Smith and Nephew). With a knee flexion of 15° – 20° with tension of 30 N, the graft was fixed with the bioscrew.^[9] The graft tension was determined by the ConMed graft tensioning system.

A physiotherapist performed rehabilitation at our hospital. All patients followed similar rehabilitation protocol for 6 months. Every patient had a follow-up knee score assessment and a MRI at 6 and 12 months.

Magnetic resonance imaging scan and image analysis

Thirty-two patients who underwent ACL reconstruction underwent MRI scan using 1.5T (GE healthcare, USA) at 6 and 12 months' follow-up. Sagittal and coronal images were obtained with T2-weighted turbo spin-echo/fast spin echo imaging with slice thickness of 5 mm. Proton density-fat saturation imaging and short-tau inversion recovery images were also obtained. One experienced musculoskeletal radiologist performed the analysis and was blinded for the surgery: MRI time interval, graft type, type of fixation, and also the clinical condition of the patient assessed using IKDC score. The evaluation of the grafts was centered on signal intensity (SI) and overall morphology. The measurement of the SI was done at 3 areas within the graft: Adjacent to femoral insertion, middle, and adjacent to tibial insertion. After averaging the data from the three sites, the graft's final intensity was determined. The SI of the background (approximately 1 cm anterior to the inferior pole of patella) and posterior cruciate ligament was measured [Figures 1 and 2]. The following formula was used to estimate the SNQ of the graft:

$$\text{SNQ} = \frac{(\text{signal of ACL graft} - \text{signal of PCL})}{\text{signal of background}}$$

When the SNQ values are less it means, the graft is healed and matured better with less water content. The signs of graft failure were assessed such as discontinuity in the graft and



Figure 1: Measurement of signal intensity (SI) at 6 months using magnetic resonance imaging. (a) SI of anterior cruciate ligament (ACL) graft near the femoral insertion (b) SI of ACL graft in the middle (c) SI of ACL graft near the tibial insertion (d) SI of intact posterior cruciate ligament (e) SI of background

increase in SI. Graft maturity was represented by SNQ. There is a direct correlation between the period following surgery and the graft's MRI appearance at different time intervals.

Following the MRI that same day, a thorough evaluation was performed by a skilled orthopedic surgeon. The surgeon and the radiologist evaluating the MRI images were blinded to each other. To assess the clinical results, a subjective functional evaluation of the IKDC score was conducted. The test had 10 questions, seven of which were related to symptoms, two to sports activity, and one to function. The summary of the study design is depicted in Figure 3.

Statistical analysis

The statistical analysis was conducted using the SPSS software for Windows (Version 20.0, IBM Corporation, Armonk, NY). $P < 0.05$ was designated as the significance level. The data were presented as the mean and standard deviation for the purpose of description. Repeated-measures analysis of variance was performed to evaluate the indices (SNQ values and IKDC scores) between the 6th and the 12th months (RMANOVA). The Pearson correlation analysis (r) was utilized to determine the association between SNQ values and IKDC scores. The correlation coefficients are classified as strong when they are over 0.5 and as moderate when they are between 0.3 and 0.5. With a 95% confidence interval (95% CI), an intra-class correlation coefficient was used to assess intra-observer and inter-observer variation in SI. $P < 0.05$ was used to determine the statistical significance.

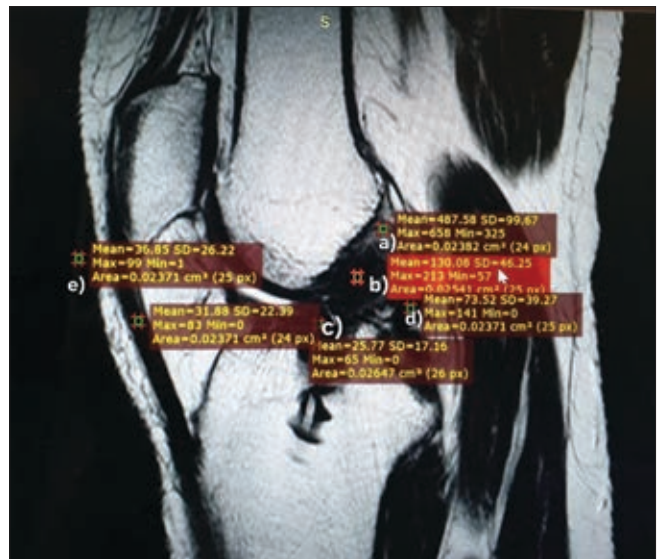


Figure 2: Measurement of signal intensity (SI) at 12 months using the magnetic resonance imaging. (a) SI of anterior cruciate ligament (ACL) graft near the femoral insertion (b) SI of ACL graft in the middle (c) SI of ACL graft near the tibial insertion (d) SI of intact posterior cruciate ligament (e) SI of background

RESULTS

The final study included 32 individuals in total. The study population's mean age was 30.4 years; the lowest age was 16 years and the highest age was 43 years [Table 1]. Among them, 23 were male's (71.9%) and 9 were female's (28.1%), 19 cases (59.4%) were right side knee. Among the study population, the most common mechanism of injury was road traffic accidents followed by other mechanisms of injury [Table 2]. None of the patients had any infection. During the follow-up, none of the patients had any laxity in their knee joints. In follow-up MRI, there were no signs of graft re-tear or graft failure in any of the patients.

At 12 months' follow-up, the mean value of SNQ was 3.8953 ± 2.6561 at 6 months and 2.6013 ± 1.7337 . In addition, the mean IKDC score was 43.3 preoperatively, 52.8125 ± 9.24728 at 6 months' follow-up, and 70.6875 ± 8.32578 at 12 months' follow-up [Table 1].

The results of the RMANOVA showed that at 12 months, the SNQ values were significantly less than those measured at 6 months ($F [1,62] = 6.50871, P = 0.01316$), whereas the IKDC scores at 12 months were substantially more than those at 6 months ($F [1,62] = 66.03667, P < 0.001$). To find the association between SNQ and IKDC, the Pearson correlation analysis (r) was used. The correlation coefficients are classified into strong when they are over 0.5 and as moderate when they are between 0.3 and 0.5. The results of the Pearson correlation analysis showed a strong inverse relationship between the IKDC scores at 6 months ($r = -0.682, P = 0.001$) and 12 months ($r = -0.4068, P = 0.0211$) and the SNQ values. Hence, the SNQ and IKDC scores at 6 months were highly correlating. Moreover, the values of IKDC

Table 1: International knee documentation committee score and signal noise quotient value at 6 months' and 12 months' follow-up

	<i>n</i>	Minimum	Maximum	Mean ± SD
Age	32	16.00	43.00	30.4062±7.6805
Weight	32	53.00	87.00	68.1875±9.83226
Height	32	163.00	187.00	170.3438±6.10980
BMI	32	15.20	31.30	23.5719±3.64879
IKDC score at 6 months' follow-up	32	42.00	72	52.8125±9.24728
IKDC score at 1-year follow-up	32	52.00	84.00	70.6875±8.32578
SNQ value at 6 months' follow-up	32	0.6	8.50	3.8953±2.6561
SNQ value at 1-year follow-up	32	0.52	6.2	2.6013±1.7337

BMI: Body mass index, IKDC: International knee documentation committee, SNQ: Signal noise quotient, SD: Standard deviation

Table 2: Etiology of anterior cruciate ligament injury in our patients

Cause of injury	Frequency (%)
RTA	18 (56.3)
Sports injury	7 (21.9)
Self-fall	7 (21.9)
Total number of patients	32 (100)

RTA: Road traffic accidents

obtained at 12 months and SNQ obtained at 6 months were also highly negatively correlating ($r = -0.718, P = 0.001$) [Figures 4 and 5]. The SI of ROI showed great intra- and inter-observer agreement (0.997: CI 0.993–0.998 and 0.994: CI 0.987–0.997, in that order).

DISCUSSION

Early necrosis, revascularization, and religamentization occurs in the hamstring graft soon after ACL reconstruction.^[1] The reconstructed graft becomes more mature once this process is completed.^[10] When the graft reaches maturity, it will be prepared for fresh loading demands, enabling the athlete to get back to their activities. By this, graft maturity influences the clinical results.^[11] Better the graft maturity, better the clinical results.^[12] Our study's key finding is that, compared to a 6-month postoperative MRI scan, the mean SNQ at 12 months was lower, suggesting a higher level of graft maturity at the latter time. In addition, we have seen an improvement in the IKDC score after 12 months as opposed to 6. These findings helped us to deduce that increased graft maturity is associated with better clinical results. These findings coincide with a similar study conducted by Li Q *et al.*^[13] Hence, early evaluation of graft maturity helps to study the behavior of the graft. In people who need to get back to sports at the earliest, measuring SNQ will help us to know the maturity of the graft and also give us the route map for rehabilitation further. If the graft is mature with low SNQ, we can help the sports person to resume his game under guidance. If the SNQ is high, we should delay resuming sports activity, until the graft is sufficiently matured. Although most of the times, muscle strength and neuromuscular control would have been achieved by

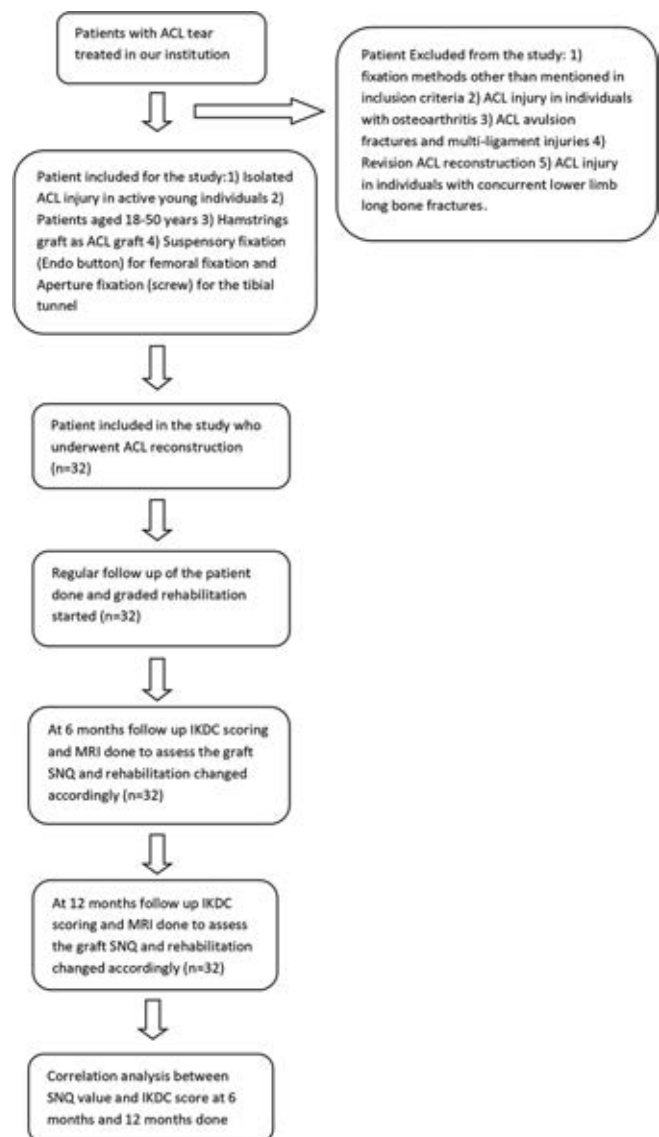


Figure 3: Flowchart depicting the study design and patient selection process

6 months, repeat MRI guides us to know status of the graft and avoids excessive load on the immature graft which eventually delay healing and ends up in re-tear/failure.^[14] MRI also provides adequate prognostic value for the persons

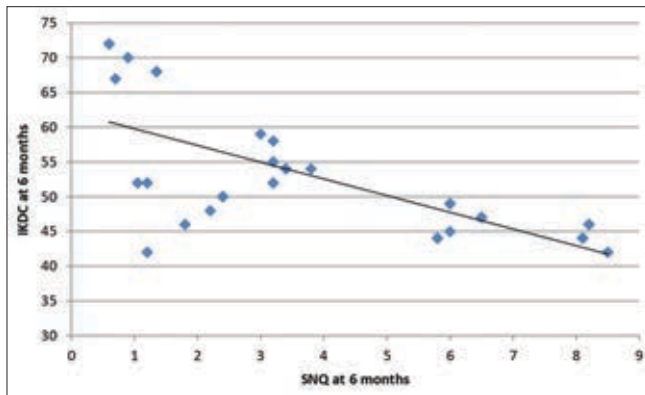


Figure 4: Scatter plot distribution of association between signal noise quotient and international knee documentation committee at 6 months

needing monitoring or modified intervention to get adequate results. Our research demonstrated that SNQ is a powerful predictor of functional outcome, and early return to sporting activities can be facilitated by rehabilitation regimens based on SNQ values.

ACL reconstruction has become one of the most common procedures in recent years. Many patients do get back to preinjury status after the surgery, but some doesn't. This may be due to poor technique, improper tunnels, and inadequate graft healing. Graft healing has been gaining attention recently as it influences the final results. With a secondary graft failure incidence of 6–25% in young, active patients, the high re-rupture rate has been a concern for over a decade.^[15,16] To solve this issue, we need a standard reference value in terms of SNQ in MRI to make a decision. Serial MRI is done to find out when the graft's SNQ reaches an stable state that can be connected with maturity.^[17]

Graft failures occur between 6 months and 9 months. Getting a MRI at 6 months and measuring SNQ will help us to know the graft's maturity and whether the person is fit to resume his sporting activities, hence taking the decision clinically and supported by imaging. This will further increase the confidence levels of the sports person and also gives the surgeon if any further modification is necessary in terms of rehabilitation protocols. This study demonstrated a robust correlation between SNQ and functional outcome.

“Many studies have used the SNQ to assess graft maturity via MRI, a method first proposed by Stöckle *et al.*”^[2] Muramatsu *et al.* looked into how autograft and allograft tendons remodelled differently from one another. In this study, “the SNQ of autograft grew at 1 month, peaked at 6 months, and then declined over time, whereas the SNQ of allograft increased at 6 months and peaked at 2 years.”^[3] This suggests that, 2 years after surgery, autograft tendons in ACL restoration may have more mature grafts than allograft tendons. According to the findings of Hofbauer *et al.*'s study, “hamstring tendon autografts should be regarded as immature since, at 6 months, they do not exhibit the same MRI SI as a healthy ACL; however, if a competitive athlete wishes to resume sport after 6 months,

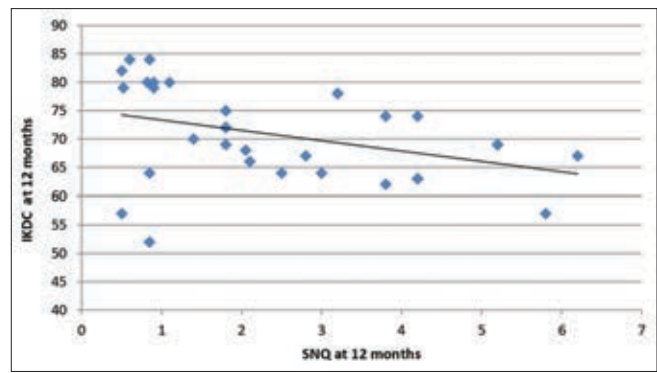


Figure 5: Scatter plot distribution of association between signal noise quotient and international knee documentation committee at 12 months

performing an MRI might be an alternative.”^[4] Weiler *et al.* did extensive research on graft vascularity and biomechanical properties. Based on the MR SI, a substantial negative linear connection was discovered between SNQ and biomechanical parameters. In addition, it was mentioned that the degree of physical activity may have an impact on the graft SNQ value. The Tegner activity score (TAS) indicated a substantial positive link between the Graft SNQ value and physical activity level, while the postoperative period showed a significant negative correlation.^[5] This study supports our results as there is a significant negative correlation with SNQ and postoperative time which was found in our result. Li *et al.*'s study also showed that there was significant positive relation between SNQ and TAS, which is a measure of physical activity.^[6] The association between MRI characteristics (SI) and conventional functional outcomes at early time points, especially in the 1st year following ACL reconstruction, is yet unknown, though.

Li *et al.* showed that a “good graft maturity at the 6-month follow-up point could strongly predict a good clinical outcome at the 12-month follow-up.”^[18] Our study's results also showed a correlation between better clinical outcomes at 12 months after surgery and enhanced graft maturity seen at 6 months postoperatively. These findings suggested that measuring graft maturation early on could be useful in predicting the final clinical result. Anderson *et al.* did a study that used MRI scan for accurately assessing graft healing and to compare different methods of healing augmentation. His study showed that “Graft SI based on MRI has a good linear relationship with the material strength of the ACL auto graft.”^[19]

There are certain limitations in our research. The sample size is small, which may not represent the entire population. We did not measure other parameters such as graft inclination angle, position of the graft which may influence graft healing. We measured IKDC score at 1 year, which is the short-term outcome. A longer follow-up period could be required to validate the study's conclusions. There is not enough information in subjective and functional scores and consensus regarding maturity and stability of the reconstructed graft. More research is required to examine the relationships between SNQ and graft strength. CT scan was not used to

assess the anatomic placement of tunnels, which will influence the result.

Despite these drawbacks, clinicians could find the study's findings intriguing and practically useful because this study will help us to know the extent of graft maturity by MRI when measured in two different time intervals. In addition, it aids in the planning of the patient-specific rehabilitation program that reduces the likelihood of early graft loading, which could lead to re-tear and graft failure.^[20]

CONCLUSION

After ACL reconstruction, MRI is a useful investigation to evaluate the maturity and integrity of the hamstring graft. According to our research, the hamstring graft showed more maturity at 12 months following surgery than it did at 6 months. There was a noteworthy inverse relationship between graft SNQ and IKDC scoring. MRI assessment at 6 months and 12 months is desirable to know the maturity of the graft and help to modify the rehabilitation protocol. During the 1st year following surgery, this study will enable clinicians to assess if the graft has healed sufficiently to allow for a return to sports.

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Conflicts of interest

There are no conflicts of interest.

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Comparison of Intra-articular 0.2% Ropivacaine versus 0.75% Ropivacaine in Acute Pain Treatment after Postoperative Knee Arthroscopy: A Randomized Control Trial

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Abstract

Context: In the realm of orthopedics, knee arthroscopy stands as a prevalent outpatient procedure. Despite the application of diverse pain alleviation techniques, the drawbacks frequently eclipse the advantages. Currently, there exists no consensus regarding the standard analgesic regimen following knee arthroscopy. At present, a unanimous agreement regarding the conventional analgesic regimen subsequent to knee arthroscopy remains elusive. **Aims:** The aim of the study was to evaluate the efficacy of administering 0.75% ropivacaine intra-articularly upon completion of knee arthroscopy for the management of postoperative pain. **Settings and Design:** A controlled, triple-blind clinical trial enrolled 70 participants scheduled for knee arthroscopic surgery due to simple acute meniscal tears and chondral injuries. **Subjects and Methods:** Following randomization, all participants received general anesthesia and a single intra-articular dose (10 mL of either 0.75% or 0.2% ropivacaine) at the conclusion of the surgical procedure. Pain intensity was assessed as “moderate-severe” using a Visual Analog Scale 2 h postropivacaine administration. **Statistical Analysis Used:** Chi-square and logistic regression analyses were employed for the primary objective. **Results:** In the intention-to-treat (ITT) analysis, with no loss of subjects, a significant difference was observed in the occurrence of moderate-to-severe pain between groups (Ropivacaine 0.2% [85.3%] vs. Ropivacaine 0.75% [27.8%], $P < 0.001$). According to the per-protocol analysis, which excluded 19 subjects requiring postsurgery opioids, moderate-to-severe pain was more prevalent in the ropivacaine 0.2% group (Ropivacaine 0.2% [77.3%] vs. Ropivacaine 0.75% [10.3%], $P = 0.001$). **Conclusions:** The utilization of intra-articular 0.75% ropivacaine following knee arthroscopy led to a reduced incidence of moderate-to-severe pain. The number needed to treat was 2 subjects, as demonstrated by both ITT and per-protocol analyses.

Keywords: Acute pain, chondral injury, efficacy, meniscal tear, placebo, ropivacaine

INTRODUCTION

Meniscal tears have an estimated annual incidence of 60–70 cases per 10,000 people^[1] primarily linked to traumatic events or degenerative processes.^[2,3] Anterior cruciate ligament (ACL) injuries occur with a frequency of 13%–20.3%, whereas medial and lateral meniscal tears are less common, with rates of 10.8%–19% and 3.7%–8%, respectively.^[4-6] It has been reported that 51% of individuals with meniscal injuries also exhibit concomitant chondral damage.^[7] Both meniscal and chondral injuries are associated with unfavorable outcomes, such as pain.^[8] According to estimates of surgical procedures associated with higher levels of pain, orthopedic procedures rank second, with median scores exceeding 4 points on the Visual Analog Scale (VAS).^[9]

In 2006, around 6.3 million outpatient orthopedic surgeries occurred in the United States, with approximately one million of these being knee arthroscopies.^[10] Each year, a single surgeon performed a median of 47 of these procedures across teaching, general, and local hospitals.^[11] Following knee arthroscopy, acute postsurgical pain, defined as occurring within a 4-day period after the surgery, has been reported in

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up to 69.2% of patients.^[12] Currently, there are no established guidelines or consensus on the analgesic treatment for elective knee arthroscopy.^[11,13]

Several hospital centers have reported using intra-articular long-acting bupivacaine (54.05%), short-acting lidocaine or prilocaine (with or without adrenaline) (21.62%), morphine (13.51%), and nonsteroidal anti-inflammatory drugs (8.10%), while 2.70% do not employ intra-articular local anesthesia for the treatment of postoperative pain.^[11] Orthopedic surgeons rank fourth among specialists who most commonly prescribe opioids (7.7%) for pain management.^[14]

This is one of the criteria for administration when pain intensity is ≥ 4 as evaluated by the VAS.^[15] Previously, the use of intra-articular 0.2% ropivacaine showed a peak pain at 1.5 h after knee arthroscopy, with a mean value of 4 on the VAS, indicating a lack of effect in at least 50% of subjects.^[16] Knee arthroscopy is a frequent surgical procedure and presents an ideal opportunity to reduce postoperative opioid prescriptions, considering the associated adverse effects such as narcotic addiction.^[17,18] In knee arthroscopy, the impact of intra-articular application of bupivacaine (an analgesic chemically similar to ropivacaine) on the occurrence of moderate-to-severe pain compared to placebo has shown a difference of 39.6% (4.8% vs. 44.4%) in the 2nd h postsurgery.^[19] In addition, complementary analgesia has been required in 65% of patients treated with bupivacaine within the first 8 h postsurgery.^[13] Due to the chemical similarity between ropivacaine and bupivacaine, their analgesic potency has been hypothesized to be equivalent.^[13,16]

However, the efficacy of ropivacaine in managing acute pain in patients undergoing knee arthroscopy has not been evaluated in a homogeneous sample, particularly because it is mainly assessed in a sample of mixed-diagnosis subjects and often in combination with other analgesics.^[15] Nor has its impact on reducing immediate postoperative opioid usage. This study aimed to assess the analgesic effect of intra-articular administration of 0.75% ropivacaine at the conclusion of knee arthroscopy, compared to the use of intra-articular 0.2% ropivacaine (considered as placebo), with the primary outcome being the occurrence of moderate-to-severe pain.

SUBJECTS AND METHODS

All patients diagnosed with an acute meniscal tear who attended the orthopedic and trauma department of the ABC Medical Center, under the care of a single-surgical team, were invited to participate between July 1, 2020, and February 1, 2023. Patients scheduled for elective unilateral knee arthroscopy surgery, who provided informed consent and presented with a simple meniscal tear (lateral or medial) (refers to a longitudinal or radial tear located in the peripheral portion of the meniscus, extending outward. It is small and limited in length, not affecting multiple areas of the meniscus) and a concomitant chondral lesion (classified as < IV according to Outerbridge criteria), were included. Exclusion criteria comprised neuromotor disease (alterations in gait, strength, or

sensitivity), a history of orthopedic knee surgery, addiction, mental illnesses under medical treatment (psychotropics, antidepressants, sedatives), hepatic diseases, allergies to any study medications, eligibility for epidural administration, chronic pain under treatment, or pregnancy or breastfeeding. It was estimated that fewer than 1% of the subjects might experience an event necessitating removal from the study, such as postoperative drainage or any intraoperative event requiring surgery suspension or hindering the intra-articular application of ropivacaine.

Randomization and blinding

Despite selecting a homogeneous patient population to minimize susceptibility bias, the maneuver was randomized (ropivacaine dose: 0.2%/0.75%, allocation ratio 1:1). Simple randomization was conducted using Oxford Minimization and Randomization number-generating software, and the sequence was maintained by a single orthopedic surgeon (ACM), aiming to create a triple-blind study. Both the patient and the administering surgeon of ropivacaine, as well as the outcome evaluator, were blinded to the ropivacaine dose administered to the patient. Upon consenting to participate through signed informed consent, the surgery was scheduled. On the day of the surgery, the surgeon responsible for randomization informed the anaesthesiologist (ROTO) of the planned maneuver for the patient. The anaesthesiologist then prepared the ropivacaine dose and provided it to a surgeon who was unaware of the procedure (ESB/CGT/PMZM), and this surgeon administered it intra-articularly.

Manoeuvre

Knee arthroscopy was performed by two orthopedic surgeons skilled in arthroscopic surgery with a minimum of 10 years of experience. The surgical procedure was deemed to commence with the administration of anesthesia. All patients received general anesthesia with a standardized regimen (Intravenous [IV] midazolam [0.03 mg/kg], IV fentanyl [2 µg/kg], IV lidocaine at 2% [1 mg/kg], and IV propofol [1.5–2 mg/kg]). In all cases, the patients were discharged to the postanesthesia care unit (PACU).

Ropivacaine was administered at the conclusion of the surgical procedure, after the arthroscopic portals had been sutured. The surgeon received infiltration based on randomization results, with either 10 mL of ropivacaine at 0.2% or 10 mL of ropivacaine at 0.75%. The appearance of the application vehicle was identical for all patients, and it was applied by trained physicians using standardized procedures. The infiltration took place, whereas the patient was under anesthesia, directly into the knee joint at the anatomical point near the proximal pole of the patella, beneath the iliotibial band. Following the infiltration, gauze and a simple bandage were applied before the patient was transferred to the PACU and subsequently to the recovery room for the evaluation of surgical outcomes.

Outcome

Assessment of the outcome took place 2 h after the surgery and was overseen by a physician who was blinded to the

procedure (CGT/ESB). The presence of moderate-to-severe pain (primary outcome) was evaluated using the VAS, whereas the patient performed knee flexion and extension. The results were quantitatively recorded and then categorized into “no pain-mild” (0–3 points) and “moderate-severe” (4–10 points) pain levels.

In addition to pain assessment, opioid administration was documented. Patients received a 50 mg dose of tramadol if pain intensity reached ≥ 4 points on the VAS within the first 2 h after surgery. This served as the recorded outcome for opioid usage (secondary outcome). Furthermore, patients’ knee flexion and extension abilities were assessed (secondary outcome: mobility) during the same evaluation. For those unable to perform these movements, the pain experienced during the attempt was measured.

Adverse effects

It was anticipated beforehand that adverse effects could occur in at least 1% of cases. Therefore, patients were closely monitored for the reporting of such effects (hypotension, nausea, vomiting, bradycardia, headache, paresthesia, pruritus, fever, dizziness, tremor, and hypoesthesia) during the initial 2 h after surgery.

Ethics

Before commencing the study, it was submitted to and approved by the Research Committee and Research Ethics Committee of Centro Médico ABC (ABC-20-36). The clinical trial was registered with Clinical trials NCT05807945.

Sample size and statistical analysis

The sample size was calculated to detect a 30% difference in the occurrence of moderate-to-severe pain among patients treated with varying doses of ropivacaine, with an alpha level of 0.05 and a beta of 0.20. This necessitated 68 patients, divided into two groups of 34 each. Anticipated information loss was $< 1\%$, and an additional 2 subjects were included, bringing the total required to 70 subjects. Statistical analysis was conducted using SPSS version 28 (IBM, Armonk, New York, USA). A comparison of outcome incidence between the two groups receiving different doses of ropivacaine was carried out using the Chi-square or Fisher exact test, as necessary. Multivariate analyses were performed through logistic regression analysis, with a significance level set at $P < 0.05$. Furthermore, the multivariate analysis took into account double gradient differences in exposure to different variables between treatment groups.

In the intention-to-treat analysis (ITT), the primary and secondary outcomes were compared between groups, considering the randomization of different doses of ropivacaine. In the per-protocol analysis set (PPS), the incidence of moderate-to-severe pain was compared between groups formed by randomization; however, patients who received opioids within the first 2 h after surgery were excluded. This was conducted to evaluate the effect of using 0.75% ropivacaine without the influence of additional interventions.

When a variable showed significance in the multivariate analysis, the analysis was stratified by the effect-modifying variable. Statistical power for each hypothesis test within each stratum was calculated using the OpEnepi software (Open Source Epidemiologic Statistics for Public Health, version 3.1) for clinical trials.^[20]

RESULTS

Baseline characteristics

During the enrolment period, 96 subjects were invited to participate [Figure 1]; however, only 70 subjects were randomized to receive different doses of ropivacaine. Table 1 illustrates the distribution of baseline characteristics among the subjects in both the ITT analysis and PPS. There were no statistically significant differences in the distributions. However, in the ITT analysis, there were notable differences in exposure gradients concerning the severity of chondral injury (Outerbridge I difference: 23.8%). In the PPS, double gradient differences were observed in variables such as physical activity (active, difference: 18.0%), surgery etiology (Degenerative, difference: 14.0%), and the severity of chondral injury (Outerbridge I difference: 27.9%).

Surgical characteristics

Table 2 shows the distribution of surgical characteristics among treatment groups for both ITT analysis and PPS. No statistically significant differences or double gradient variations were observed.

Primary outcome

There was a significant difference in the incidence of moderate-to-severe pain between groups in both the ITT analysis, with rates of 85.3% versus 27.8%, $P < 0.001$, and in the PPS, with rates of 77.3% versus 10.3%, $P < 0.001$, for the use of ropivacaine at 0.2% and 0.75%, respectively [Table 3].

Table 3 also presents a comparison in opioid requirement before 2 h of ropivacaine application and mobility presence at 2 h postsurgery, with no statistical difference observed.

Adjusted analysis

The application of 0.75% ropivacaine revealed a relative risk (RR) for the occurrence of postoperative moderate-to-severe pain of 0.066 (95% confidence interval [CI]: 0.020–0.219, $P < 0.001$) in the ITT analysis postsurgery. When adjusted, the RR for the 0.75% ropivacaine group was 0.046 (95% CI: 0.009–0.232, $P < 0.001$). For categories II and III of the Outerbridge system, the RR was 20.422 (95% CI: 3.410–122.316, $P = 0.001$) and 21.513 (95% CI: 2.477–186.854, $P = 0.005$), respectively. In the PPS, the use of 0.75% ropivacaine exhibited a RR for moderate-to-severe pain of 0.034 (95% CI: 0.007–0.161, $P < 0.001$). When adjusting for physical activity, the RR for 0.75% ropivacaine was 0.036 (95% CI: 0.007–0.176, $P < 0.001$), and for the presence of physical activity, the RR was 2.813 (95% CI: 0.430–18.381, $P = 0.280$). Adjusting for lesion etiology resulted in a RR of 0.027 (95% CI: 0.005–0.153, $P < 0.001$) for 0.75% ropivacaine

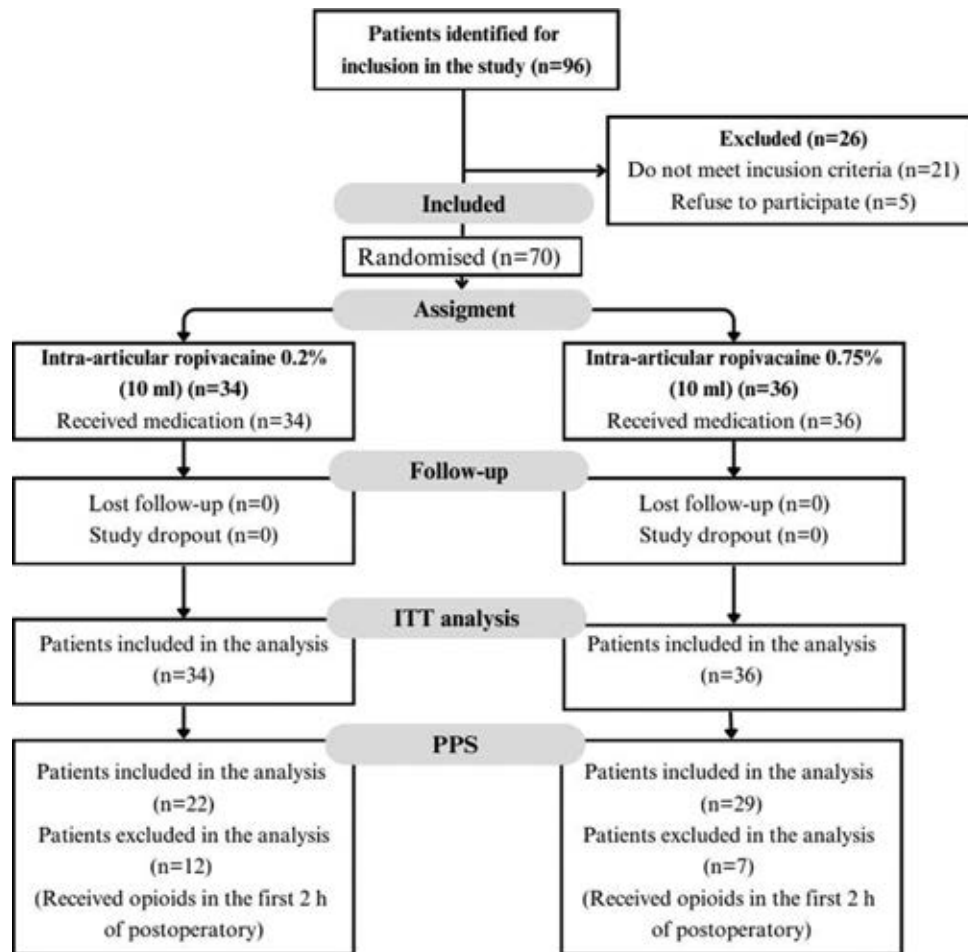


Figure 1: Flowchart of patient recruitment. ITT: intention-to-treat analysis PPS: per-protocol analysis set

use and for degenerative etiology, the RR was 2.403 (95% CI: 0.316–18.259, $P = 0.397$). Adjusted for severity of chondral injury, the 0.75% ropivacaine group showed a RR of 0.018 (95% CI: 0.002–0.173, $P < 0.001$), with RR values of 20.934 (95% CI: 1.973–222.128, $P = 0.012$) for strata II and RR: 2.141 (95% CI: 0.142–32.311, $P = 0.582$) for strata III.

Stratified analysis

Considering that in both the ITT and PPS multivariate analyses, the most severe chondral injury indicated a higher risk of moderate-to-severe postoperative pain, the effect of ropivacaine dose was stratified by the Outerbridge system [Table 4]. The need for opioids was also higher in subjects in stratum III (Need for opioids in stratum I [1/23, 4.34%], stratum II [10/34, 29.41%], and stratum III [8/13, 61.53%], $P < 0.001$).

DISCUSSION

This research represents the first to uncover the occurrence of moderate-to-severe pain in patients administered a dose of ropivacaine previously deemed safe. Furthermore, it scrutinizes the occurrence of this outcome in subjects given a placebo dose. The findings indicate a notable decrease in the frequency of

moderate-to-severe pain by 57.5% in the ITT analysis (Number Needed to Treat: 2) and 60.0% (Number Needed to Treat: 2) in the PPS, with no adverse effects documented. In previous assessments, when evaluating pain as a continuous score, minimal clinically important differences are regarded as significant when there is a difference of 15 mm (1.5 cm) or more;^[21] in our study, median differences observed for ITT and per-protocol analysis were 20 mm (2 cm) on the VAS scale.

Previously, Kaeding *et al.*^[19] reported a 90% relative gain (OR: 0.10, $P = 0.001$) in pain control during the second postoperative hour with the use of bupivacaine (40 mL at 0.25%) infiltrated in arthroscopic portals compared to saline solution of the same volume. However, the volume infiltrated could be associated with pain presence. According to our results from logistic regression, a similar relative gain was observed of 93.4% (RR: 0.066, 95% CI: 0.020–0.219) and 96.6% (RR: 0.034, 95% CI: 0.007–0.161) in ITT analysis and PPS, respectively, with an administered volume that did not require more absorption time than that used by Kaeding *et al.*^[19] In the treatment of postknee arthroscopy pain, analgesics similar to ropivacaine have been used both in combination and in isolation. Combinations include bupivacaine with morphine, adrenaline, or tramadol;^[22] levobupivacaine with dexmedetomidine;^[23] and prilocaine with

Table 1: Clinical characteristics of patients in the intention-to-treat and per-protocol analyses

Characteristics	ITT analysis			PPS		
	Total (n=70), n (%)	Ropivacaine: 0.2% group (n=34), n (%)	Ropivacaine: 0.75% group (n=36), n (%)	Total (n=51), n (%)	Ropivacaine: 0.2% group (n=22), n (%)	Ropivacaine: 0.75% group (n=29), n (%)
Sex						
Male	19 (27.1)	8 (23.5)	11 (30.6)	16 (31.3)	6 (27.3)	10 (34.5)
Female	51 (72.9)	26 (76.5)	25 (69.4)	35 (72.7)	16 (72.7)	19 (65.5)
Age (years)						
18–35	26 (37.1)	13 (38.2)	13 (36.1)	17 (33.3)	8 (36.4)	9 (31.0)
36–60	44 (62.9)	21 (61.8)	23 (63.9)	34 (66.7)	14 (63.6)	20 (69.0)
BMI (kg/m ²)						
<25 normal	35 (50.0)	17 (50.0)	18 (50.0)	23 (45.1)	10 (45.5)	13 (44.8)
≥25 overweight	35 (50.0)	17 (50.0)	18 (50.0)	28 (54.9)	12 (54.5)	16 (55.2)
Time of evolution of articular cartilage lesions (days)						
<14	59 (84.3)	28 (82.4)	31 (86.1)	41 (80.4)	17 (77.3)	24 (82.8)
≥14	11 (15.7)	6 (17.6)	5 (13.9)	10 (19.6)	5 (22.7)	5 (17.2)
Physical activity						
Sedentary	51 (72.9)	22 (64.7)	29 (80.6)	40 (78.4)	15 (68.2)	25 (86.2)
Active	19 (27.1)	12 (35.3)	7 (19.4)	11 (21.6)	7 (31.8)	4 (13.8)
Etiology of surgery						
Trauma	55 (78.6)	29 (85.3)	26 (72.2)	40 (78.4)	19 (86.4)	21 (72.4)
Degenerative	15 (21.4)	5 (14.7)	10 (27.8)	11 (21.6)	3 (13.6)	8 (27.6)
Outerbridge classification (mm)						
I (0)	23 (32.8)	7 (20.6)	16 (44.4)	22 (43.1)	6 (27.3)	16 (55.2)
II (<0.5)	34 (48.6)	19 (55.9)	15 (41.7)	24 (47.1)	13 (59.1)	11 (37.9)
III (≥0.5)	13 (18.6)	8 (23.5)	5 (13.9)	5 (9.8)	3 (13.6)	2 (6.9)

BMI: Body mass index, ITT: Intention to treat, PPS: Per-protocol analysis set

Table 2: Surgical characteristics of patients in the intention-to-treat and per-protocol analyses

Characteristics (variable)	ITT analysis			PPS		
	Total (n=70), n (%)	Ropivacaine: 0.2% group (n=34), n (%)	Ropivacaine: 0.75% group (n=36), n (%)	Total (n=51), n (%)	Ropivacaine: 0.2% group (n=22), n (%)	Ropivacaine: 0.75% group (n=29), n (%)
Surgery length (min)						
<45	22 (31.4)	13 (38.2)	9 (25.0)	17 (33.3)	9 (40.9)	8 (27.6)
≥45	48 (68.6)	21 (61.8)	27 (75.0)	34 (66.7)	13 (59.1)	21 (72.4)
Tourniquet						
No	8 (11.4)	4 (11.8)	4 (11.1)	5 (9.8)	2 (9.1)	3 (10.3)
Yes	62 (88.6)	30 (88.2)	32 (88.9)	46 (90.2)	20 (90.9)	26 (89.7)

ITT: Intention to treat, PPS: Per-protocol analysis set

adrenaline.^[24] Bupivacaine and levobupivacaine have also been used alone.^[25] However, the effect of 0.5% ropivacaine administered intra-articularly in 30 mL volumes has typically been evaluated starting from 4 h postsurgery,^[15] a timing that does not align with all outpatient procedures. In addition, in a follow-up study of up to 24 h postknee arthroscopy, subjects treated with 0.5% ropivacaine in 30 mL were compared to those receiving 0.5% ropivacaine in 30 mL plus 30 mg of ketorolac. While good pain control was observed in the first 4 h postoperatively for both groups, at 8 and 24 h of follow-up, the ropivacaine plus ketorolac group experienced significantly less pain both at rest and during movement compared to

the ropivacaine-only group.^[26] In this study, opioid use was considered a secondary outcome because it might reflect the presence of moderate-to-severe pain. Previous research has reported a median opioid intake (oxycodone or hydromorphone) of 11.3 pills (range: 0–52) during the acute pain period following knee arthroscopy.^[27] In our study, patients were administered only a dose of tramadol in the 2 h preceding surgery. Nevertheless, the use of ropivacaine did not impact the need for opioids in the overall sample. When considering the baseline condition (severity of chondral injury), subjects categorized in the less severe Outerbridge stratum required opioids infrequently (4.34%). The half-life of fentanyl has

Table 3: Impact on acute postoperative pain in patients in the intention-to-treat and per-protocol analyses treated with 0.2% intra-articular ropivacaine versus 0.75% ropivacaine

Ropivacaine (%)	ITT analysis			PPS	
	Moderate to severe pain, n (%)	Opioid use, n (%)	Mobility, n (%)	Moderate to severe pain, n (%)	Mobility, n (%)
0.2	29/34 (85.3)	12/34 (35.3)	29/34 (85.3)	17/22 (77.3)	20/22 (90.9)
0.75	10/36 (27.8)* [‡]	7/36 (19.4)*	32/36 (88.9) [‡]	3/29 (10.3)* [‡]	26/29 (89.7) [‡]

*Chi-square test, [‡]Fisher’s exact test, [‡]P<0.001. During the initial 2 h following surgery, there were no reported adverse effects. ITT: Median of pain 4 points (IQR: 2–4) in the sample. Median of pain in ropivacaine 0.2% group: 4 points (IQR: 4–5); median of pain in ropivacaine 0.75% group: 2 points (IQR: 2–4), P=0.001. PPS: Median of pain: 2 points (IQR: 2–4) in the sample. Median of pain in ropivacaine 0.2% group: 4 points (IQR: 4–4); median of pain in ropivacaine 0.75% group: 2 points (IQR: 2–2), P<0.001. ITT: Intention-to-treat, PPS: Per-protocol analysis set, IQR: Interquartile range

Table 4: Stratified analysis of the impact on acute postoperative pain in patients in the intention-to-treat and per-protocol analyses treated with 0.2% intra-articular ropivacaine versus 0.75% ropivacaine based on Outerbridge classification

	ITT analysis			Per-protocol analysis		
	No pain-mild, n (%)	Moderate to severe, n (%)	P	No pain-mild, n (%)	Moderate to severe, n (%)	P
Outerbridge I						
Ropivacaine: 0.2%	3 (42.9)	4 (57.1)	0.004*	3 (50.0)	3 (50.0)	0.013 [§]
Ropivacaine: 0.75%	16 (100.0)	0		16 (100.0)	0	
Outerbridge II						
Ropivacaine: 0.2%	1 (5.3)	18 (94.7)	0.004 [‡]	1 (7.7)	12 (92.3)	0.002
Ropivacaine: 0.75%	8 (53.3)	7 (46.7)		8 (72.7)	3 (27.3)	
Outerbridge III						
Ropivacaine: 0.2%	1 (12.5)	7 (87.5)	0.510 [‡]	1 (33.3)	2 (66.7)	0.400 [¶]
Ropivacaine: 0.75%	2 (40.0)	3 (60.0)		2 (100.0)	0	

Statistical power: *83.47%, [‡]82.01%, [‡]5.71%, [§]64.36%, ^{||}87.72%, [¶]4.70% (Fisher’s exact test). ITT: Intention to treat

been described as 90 min, with the peak effect occurring within 2–5 min.^[28] Its analgesic effect during knee arthroscopy could be present before 2 h but not necessarily at the 2-h mark postsurgery.

Regarding mobility, although there was no statistically significant difference between treatment groups, it was present in over 80% of subjects treated with different doses of ropivacaine in the ITT analysis and in 90% of subjects in the PPS. This disparity in mobility percentage between the analyses may be attributed to the retention of subjects who did not require opioids in the PPS, the use of which is influenced by pain intensity. Previous studies have shown that subjects with higher preoperative pain intensity (≥4 points on a scale of 10) more frequently experience more severe pain (≥4 points on a scale of 10), both acutely and chronically.^[12] While our study did not evaluate preoperative pain intensity, which is a limitation, patients were categorized based on the severity of articular cartilage injury, a variable correlated with pain severity.^[14,29] In previous studies, several variables were identified as potentially related to postoperative pain intensity. These included the type of anesthesia used during surgery,^[24] the etiology of the surgery,^[30] the use of a tourniquet during surgery,^[13] and the severity of chondral injury based on the Outerbridge classification.^[29] In our study, the anesthesia process for patients was standardized, eliminating it as a variable that could potentially alter the observed effects. From a clinical perspective, regional anesthetic blocks are effective and long-lasting; however, as invasive procedures,

they carry their indications and risks.^[31,32] Therefore, from an anesthetic standpoint, they are preferred for other types of surgical-orthopedic procedures, such as arthroplasties or fracture osteosynthesis. Arthroscopic procedures, being minimally invasive, are considered less painful. From a methodological perspective, the use of anesthetic blocks would invalidate the evaluation of the isolated effect of ropivacaine on acute pain; hence, it was planned not to use them in the arthroscopy procedure of the present study.

In a prior study involving knee arthroscopy patients under general anesthesia – which aimed to compare the effectiveness of intra-articular administration of bupivacaine alone or in combination with fentanyl or tramadol – the utilization of a tourniquet did not affect the analgesics’ efficacy in controlling postoperative pain.^[13] In our current study, the distribution of tourniquet usage was similar across treatment groups, with differences of <2% in exposure between groups in both the ITT and PPS. In addition, there were no statistical differences found in the distribution of surgery etiology between treatment groups, and multivariate analysis did not demonstrate relevance to the presence of moderate-to-severe pain. As physical activity can be linked to the onset of knee pain, it was considered a potential modifier variable.^[2,3] However, its distribution among the groups receiving different doses of ropivacaine did not exhibit a statistically significant difference. Its inclusion in multivariate analyses did not demonstrate relevance regarding moderate-to-severe pain.

It is worth noting that among subjects with Grade I chondral injury, only one out of 23 (4.34%) was excluded from the analysis because he/she needed opioids for pain treatment within the first two postoperative hours. However, among those classified as Outerbridge II, 10 out of 34 (29.41%), and Outerbridge III, 8 out of 13 (61.53%), required tramadol during the same timeframe. A more severe cartilage injury might indicate a diminished ability to control pain, as a positive correlation between opioid consumption and the severity of articular cartilage injury has been observed.^[29] Therefore, individuals with the most severe articular cartilage damage may necessitate a different treatment approach compared to those with Outerbridge I lesions.

The stratified analysis revealed an expected variation in moderate-to-severe pain according to the proposed hypothesis. In the ITT analysis, there was a significant absolute gain of 30% among subjects with Outerbridge Grade I, indicating a 57.1% difference in pain frequency between treatment groups, with statistical significance ($P < 0.05$) and power of 83.47%, this finding suggests that the 0.75% ropivacaine dose is effective in reducing pain for these patients. In Outerbridge II, a 48% absolute difference was observed, also with statistical significance ($P < 0.05$) and a power of 82.01%, which indicates less efficacy in pain control compared to the stratum with a less severe chondral injury. However, in Outerbridge III, the difference was 27.8%, with $P = 0.510$ and a low statistical power of 5.71%, likely due to the small sample size. In the PPS, absolute differences in moderate-to-severe pain incidence within Outerbridge strata I, II, and III were 50.0%, 65.0%, and 66.7%, respectively, with statistically significant values for strata I and II.

The results of our study should be reproducible within its proposed context but limited to subjects with concomitant chondral and meniscal injuries. It is crucial to highlight this subgroup, as it is anticipated that 51% of subjects with a primary diagnosis of meniscal tear also have both conditions, excluding ACL injury, owing to the fact that ACL reconstruction (by drilling femoral tunnel and tibial tunnel) results in increased pain.^[7] Examination of previous studies, including those beyond knee arthroscopies, allowed us to identify potential biases avoided in our study that may influence the frequency of the main outcome (moderate-severe pain). First, we excluded subjects who might require a major procedure alongside knee arthroscopy, and we adjusted the administration technique to avoid causing pain due to a significant increase in knee volume.^[15,26] Finally, there is concern about the possible chondrotoxic effect of combining different analgesic treatments.^[33] In *in vitro* studies, a chondrotoxic effect has been found following the exposure of tissue specimens to lidocaine, bupivacaine, and ropivacaine, with the latter affecting chondrocytes the least, or showing no effect at all at concentrations lower than 0.2%.^[34] Ropivacaine's chemical composition compared to similar substances such as bupivacaine theoretically indicates a lower frequency of side effects.^[35-37] In our study, no adverse effects were reported in

the first two postsurgery hours. Reports from the US Food and Drug Administration indicate adverse effects occurring in over 1% of cases; however, these reports encompassed various surgical procedures, including caesareans and nonorthopaedic procedures.^[38] Therefore, the absence of adverse effects associated with ropivacaine in the context examined in this study is plausible, although our study's scope was limited by the short follow-up time.

Until now, the efficacy of ropivacaine in treating postoperative knee arthroscopy pain had not been confirmed, despite its frequent use in orthopedic settings. Intra-articular administration of 0.75% ropivacaine at the end of knee arthroscopy resulted in a reduction in the frequency of moderate-to-severe pain (VAS values ≥ 4), with only 2 subjects requiring treatment to prevent such pain events, as analyzed through ITT and per-protocol analysis.

CONCLUSIONS

Given that the difference in the frequency of moderate-to-severe pain is 57.5% between the group treated with 0.75% intra-articular ropivacaine and the placebo group, these findings could aid in the establishment of more standardized analgesic protocols following knee arthroscopy, potentially enhancing postoperative pain management practices. Subjects with less severe articular cartilage injury may benefit more from a treatment regimen incorporating a single intra-articular analgesic like ropivacaine.

Enhanced pain management with reduced opioid usage can lead to better overall patient outcomes and may increase patient satisfaction.

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Conflicts of interest

There are no conflicts of interest.

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Assessing Chat Generative Pre-training Transformer's Proficiency in Identifying, Diagnosing, and Managing Orthopedic Fractures

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Abstract

Background: The exploration of Chat generative pre-training transformer's (GPT's) applications in medicine is gaining momentum, with artificial intelligence, particularly ChatGPT, showing promise in enhancing orthopedic care. ChatGPT can assist clinicians by providing relevant information based on patient symptoms, medical history, and radiological findings, aiding in differential diagnosis, and suggesting appropriate imaging modalities. This study focuses on evaluating the effectiveness of ChatGPT-4 in diagnosing and managing common orthopedic fractures. **Methods:** This study involved inputting a diverse set of fracture images into the ChatGPT-4 model. The process commenced by prompting ChatGPT with four questions: "What does the radiograph show?" The second prompt instructed ChatGPT with the actual diagnosis, followed by inquiries on how a clinician should manage the condition and potential complications. All generated responses underwent grading by two authors (musculoskeletal radiologist and orthopedic trainee), utilizing a 5-point Likert scale. Intraclass correlation coefficient (ICC) analysis measurements were performed to assess inter-rater reliability. Descriptive statistical analysis was then employed to provide a comprehensive summary of the study's findings. **Results:** ChatGPT demonstrated limitations in identifying diagnoses based on inputted X-ray images. However, it excelled in providing comprehensive information about fracture management and potential complications. There was excellent interobserver reliability with a kappa of 0.9. **Conclusion:** Our study underscores the utility of ChatGPT as a valuable tool for aiding in the management of common fractures, offering a comprehensive overview of diagnosis, management, and potential complications. The findings highlight its potential role as a supplementary resource in orthopedic practice.

Keywords: Artificial intelligence, diagnosis, orthopedics, X-rays

INTRODUCTION

The chat-generative pre-training transformer (GPT) language model, developed using advanced deep learning techniques by Open Artificial Intelligence (AI), is the part of the generative pretraining transformers (GPTs) family and stands as one of the most extensive publicly available language models.^[1] Trained on a large dataset, ChatGPT excels in understanding human language intricacies and generating relevant responses. Its growing use in health care and medical research, particularly within health-care systems, is noteworthy for its potential to enhance accuracy, efficiency, and process speed.^[2,3]

The exploration of ChatGPT's applications in medicine is gaining momentum.^[3-5] In the field of medical education, it

proves valuable for students, doctors, nurses, and health-care professionals by providing updates and facilitating clinical skills assessments.^[3]

In trauma and orthopedics, where challenging cases arise, patient education and compliance are crucial for overall

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patient outcomes. AI, especially ChatGPT, shows promise in enhancing orthopedic care.^[2,4,6] Its capabilities extend to supporting patient information exchange, providing clinical decision support, and improving patient communication and education.^[4,7-9] As a potential clinical decision-support tool in orthopedics, ChatGPT can assist clinicians in providing relevant information based on patient symptoms, medical history, and radiological findings, aiding in differential diagnosis and suggesting appropriate imaging modalities.^[4,9,10]

With an aging population, an increase in common orthopedic fractures is expected, bringing more complex injuries through the door. AI technology may be used in the future to assist with the management of such injuries. This study focuses on evaluating the effectiveness of ChatGPT-4 in diagnosing and managing common orthopedic fractures, including distal radius fractures, neck of femur fractures, and ankle fractures. The goal is to aid medical students and junior doctors in understanding and potentially guiding them in the management of these injuries.

METHODS

This study involved inputting a diverse set of radiographic fracture images into the ChatGPT-4 model. The radiographic images were taken from our radiology database in our orthopedic trauma center. The fractures included an undisplaced extra-articular distal radius fracture, a dorsally displaced and comminuted distal radius fracture, an intertrochanteric (extracapsular) comminuted neck of femur fracture, bilateral intracapsular neck of femur fractures, and two Weber B, AP images of ankle fracture X-rays.

The process commenced by prompting ChatGPT with the question, “What does the radiograph show?” This initial prompt aimed to assess the model’s ability to identify and recognize the presented images. Subsequently, a second prompt instructed ChatGPT to specify the actual diagnosis, focusing on particular instances like an undisplaced distal radius fracture. This step aimed to evaluate the model’s diagnostic capabilities.

Following the identification and diagnostic phases, the study delved into practical aspects by posing questions related to fracture management (“How should a clinician manage this?”) and potential complications (“What are the complications?”). These inquiries sought to explore ChatGPT’s understanding

of treatment approaches and its ability to recognize associated complications. The prompts can be seen in Table 1.

To systematically assess ChatGPT’s performance, all generated responses underwent rigorous grading by two authors – a consultant musculoskeletal radiologist and an orthopedic trainee – utilizing a 5-point Likert scale. The latter was graded from 1 as a “very poor” response, 2 as poor, 3 as neutral, 4 as good, and a score of 5 as an “excellent” response. To gauge the agreement between the two reviewers, interclass coefficient measurements were performed. Descriptive statistical analysis was then employed to provide a comprehensive summary of the study’s findings.

RESULTS

In the first prompt, “What does the radiograph show?” ChatGPT successfully identified the X-rays of the involved limbs. However, the AI model faced challenges in providing accurate diagnoses for the six images presented. Instead, it consistently indicated that the images were normal, with no obvious pathologies identified. Both readers scored 1 for this.

Moving to the second prompt, where ChatGPT was provided with the diagnosis based on the X-ray findings, the model demonstrated proficiency in breaking down and explaining the diagnosis in detail. The readers scored an average of 4 for this prompt.

In response to the third prompt – “How should a clinician manage this?” – ChatGPT exhibited success in offering a comprehensive, step-by-step approach. The model described the management of individual fractures in a manner easily understandable by junior doctors or medical students. It systematically outlined treatment options, encompassing initial assessment, imaging, surgical management, diverse surgical modalities, postoperative care, rehabilitation, follow-up, and long-term management for each fracture. The average score by the readers for this prompt was 4.5.

For the final prompt – “What are the complications?” – ChatGPT once again provided a comprehensive description of potential complications associated with each type of injury. The model highlighted intraoperative, early postoperative, and late postoperative complications, offering a thorough understanding of the multifaceted nature of complications across different stages of injury management. Both readers scored 5 for this prompt. There was excellent interobserver reliability between the two readers with a kappa of 0.9 [Figure 1 and Table 2].

DISCUSSION

This study highlights that while ChatGPT may not accurately describe X-ray findings, it demonstrates competence in providing a comprehensive analysis of inputted fractures, covering their basic clinical and surgical management, as well as potential complications when prompted. Notably, the model presents this information in a comprehensible, straightforward,

Table 1: Different prompts provided to chat generative pre-training transformer-4

ChatGPT prompt

What do the radiographs show?

How should a clinician/I manage this injury?

What is the ideal surgical management of this injury?/fracture

What are common complications in the management of these fractures?

GPT: Generative pre-training transformer



Figure 1: Anteroposterior radiograph of ankle showing Weber B fracture of lateral malleolus

and organized manner, making it accessible for junior doctors and medical students seeking guidance in managing common injuries.

In the context of medical education in the UK, where there is a clear lack of undergraduate orthopedic experience, entering an orthopedic or accident and emergency block can be particularly challenging.^[11] This is especially true given that common adult fractures, such as distal radius and proximal femur fractures, are prevalent. Distal radial fractures are identified as the most common adult orthopedic fracture, while hip fractures alone account for nearly 76,000 cases annually in the UK.^[12-14] Ankle fractures are also frequent presentations in emergency departments. Timely and appropriate management of these injuries is crucial for optimal patient outcomes and rehabilitation. This underscores the potential significance of AI technology, like ChatGPT, in aiding junior doctors faced with limited orthopedic experience, providing a valuable resource for understanding and managing common injuries effectively.^[2-5,9,15]

In recent years, advancements in technology have significantly impacted orthopedic practices, with the incorporation of AI systems showing considerable promise in enhancing patient care and overall outcomes.^[15] Within this field, ChatGPT emerges as a valuable clinical decision-support tool, offering clinicians information based on patient symptoms, medical history, and radiological findings, particularly useful in differential diagnoses.^[7,16,17] The model's capabilities extend to suggesting diagnostic tests and appropriate imaging modalities for further evaluation.^[16,17] Orthopedic practice stems from evidence-based guidelines and clinical experience.^[18,19] AI technologies, like ChatGPT, streamline this process by assisting clinicians in creating extensive medical literature and providing updated therapeutic suggestions tailored to the patient's specific characteristics and condition.^[5,6] This optimization contributes to refining treatment plans, ensuring adherence to evidence-based practices, and minimizing variability in clinical decisions.^[2,4,5,7] Beyond clinical applications, AI can serve as a

Table 2: Example of the answers received by chat generative pre-training transformer 4 for ankle fracture

What does the radiograph show

ChatGPT: This radiograph shows a lateral view of the ankle, including the distal ends of the tibia and fibula, the talar dome, and the calcaneus. The joint spaces between the tibia, fibula, and talus, as well as between the talus and calcaneus, are visible. There appears to be no obvious fracture or dislocation. The bones show normal density and the soft tissue structures are not visibly swollen. The overall alignment of the ankle joint appears to be maintained. However, it is important to note that interpretation of radiographs should be performed by a medical professional, as there can be subtle signs of injury or disease that require clinical correlation

The management of an undisplaced fracture of the lateral malleolus typically involves several steps and considerations

- **Immobilization:** An undisplaced fracture usually requires immobilization to allow the bone to heal properly. This can be accomplished with a cast or a walking boot. The period of immobilization can vary but is typically around 4–6 weeks
- **Weight-bearing status:** The clinician must decide whether the patient can bear weight on the affected limb. In the case of an undisplaced fracture, partial weight-bearing or full weight-bearing may be allowed as tolerated with the protection of a boot or cast
- **Pain management:** Pain control is important for patient comfort and to facilitate mobilization. This can include the use of over-the-counter pain medication such as acetaminophen, ibuprofen, or other pain management strategies
- **Follow-up imaging:** Repeat X-rays or other imaging modalities may be necessary to ensure that the fracture is healing correctly and has not displaced
- **Rehabilitation:** After the immobilization period, rehabilitation exercises or physical therapy may be needed to restore range of motion, strength, and function
- **Monitoring for complications:** The clinician should monitor for potential complications such as delayed union, nonunion, or posttraumatic arthritis
- **Patient education:** The patient should be educated on the signs of potential complications, such as increased pain, swelling, or changes in skin color, temperature, or sensation
- **Lifestyle modifications:** Advice on lifestyle modifications, like avoiding smoking and ensuring adequate nutrition, can be important for optimal bone healing

The specific treatment can vary depending on factors such as patient age, comorbidities, level of activity, and exact fracture characteristics. Orthopedic consultation may be warranted for further assessment and management, especially if there are concerns about the stability of the fracture or if the patient has other associated injuries. It is always important to treat the patient as a whole, considering all aspects of their health and well-being in the management plan. GPT: Generative pre-training transformer

valuable educational tool for medical students, doctors, nurses, and health-care professionals, offering treatment guidelines for certain medical conditions.

Our study underscores the complexity of orthopedic conditions from a patient's perspective, as they often have concerns related to their diagnosis, treatment options, and expected outcomes. Engaging ChatGPT with queries about the fractures investigated in the study allows the model to provide patients with reliable and comprehensible information, effectively addressing their queries and alleviating worries. This proactive approach enables patients to enhance their knowledge and

preparedness before consulting with a surgeon, potentially leading to heightened patient readiness. Ultimately, this may result in improved patient satisfaction, enhanced interaction, and increased adherence to treatment plans.

However, it is vital to acknowledge certain limitations and ethical considerations associated with ChatGPT's use in this context. First and foremost, it is imperative that patient confidentiality should be protected at all costs, and patient consent should be taken before data can be inputted into the AI database. Furthermore, despite its sophistication, it is important to acknowledge that the model lacks the capacity to provide comprehensive diagnoses from inputted imaging and cannot substitute for the basic human qualities inherent in medical practice.^[16,17] It is crucial to recognize that while ChatGPT might have potential applications in diagnosis, it can also impart false or inaccurate information, raising ethical concerns.^[20-22] As represented in this study, where ChatGPT struggled to accurately identify fractures, caution must be exercised to prevent its use in ways that could lead to mismanagement. Therefore, it is imperative to view ChatGPT as a valuable guide but not a replacement for medical clinicians in the realms of diagnosis and patient management or care. As the field of AI expands, potential future research should look into ways in how diagnostic findings and clinical evaluations could be incorporated into training programs more effectively.

CONCLUSION

In summary, our study underscores the utility of ChatGPT as a valuable tool for aiding in the management of common fractures by offering a comprehensive overview of diagnosis, management, and potential complications. While ChatGPT demonstrated proficiency in identifying correct X-rays of inputted limbs, it falls short in diagnosing fractures solely based on inputted images. Consequently, while junior doctors can leverage ChatGPT for guidance in the basic management of such conditions, it should be regarded as a supplementary resource rather than a clinical diagnostic tool. The study emphasizes the importance of utilizing AI tools judiciously within the health-care context, acknowledging their strengths and limitations.

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Case–control Comparative Study of Porous Metal Augments versus Bone Graft in Management of Segmental Acetabular Defect in Hip Arthroplasty Procedures

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Abstract

Introduction: Acetabular bone loss represents a great challenge during hip arthroplasty procedures. This study aims at evaluating the efficacy and functional outcome of cost-friendly alternatives (autograft or allograft) when compared to the porous metal augments during reconstruction of acetabular defects in either complex primary or revision total hip replacement. **Patients and Methods:** This is a retrospective matched control study for evaluation of short and midterm results of metal augments versus bone graft during hip arthroplasty procedures. Inclusion criteria included adult patients who suffered from segmental acetabular defect and underwent hip arthroplasty procedure. The study included 34 cases divided into 2 groups. Group 1 cases were reconstructed with augment reconstruction. Group 2 was the control group which was reconstructed using graft reconstruction. **Results:** The mean age for Group 1 was 52.29 years (range: 30–68) and for Group 2 was 52.1 years, (range from 32 to 71 years). The mean follow-up period was 74.8 months in Group 1 (range: 66–85 months) and 71.5 months in Group 2 (range: 60–102 months). Both the groups included 13 males and 4 females. Group 1 had a mean postoperative Harris Hip Score (HHS) of 90.5 (range from 85 to 94), and Group 2 had a mean postoperative HHS of 88.7 (range from 80 to 94) with $P = 0.236$. **Conclusion:** Acetabular reconstruction using cost-friendly alternatives shows similar short-to-midterm results when compared to trabecular metal augments in a budget-conscious health setting.

Keywords: Acetabular, allograft, augment, autograft, reconstruction

INTRODUCTION

Deficient acetabular bone stock poses a technical challenge during total hip arthroplasty because of reduced support from the anterior and posterior columns and varying degrees of medial wall and dome deficiency. This may be encountered in complex primary situations as well as revision situations.^[1]

The currently available treatment options for acetabular bone defects include large porous cups, trabecular metal (TM) augments, reinforcement rings, impaction bone graft, and structural bone grafting.^[2]

Although autogenous bone grafts remain the gold standard in various orthopedic scenarios due to superior integration potential, in complex acetabular reconstruction, autogenous bone supply is limited and causes donor-site morbidity. Thus, the allograft is often used in place of or in conjunction with autogenous graft. Allograft acts as a scaffold through which revascularization,

resorption, and finally new bone apposition occur. In other words, it is osteoconductive, but not osteogenic nor osteoinductive.^[3]

Bone grafts can be combined with acetabular rings to support the bone graft and compensate for part of the acetabular defect, decreasing the need for excessive grafting and at the same time providing structural stability. Many designs are available for these rings, e.g., Muller or Kerboul rings.^[4,5]

Recently, bone grafts have been widely replaced by porous TM augments that aim to reconstruct major acetabular bone

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defects. They are made of porous metal tantalum or titanium alloys and are supplied in various sizes and shapes to match the acetabular defects.^[6]

They are thought to overcome some of the problems encountered with conventional allografts such as graft resorption and graft infection. Yet their use is hindered by their availability and considerable costs, which remains a hurdle against their use in various health-care settings.^[4]

This study aims to evaluate the efficacy and functional outcome of autograft or allograft alone or in combination with reinforcement ring versus the porous metal augments during reconstruction of acetabular defects in either complex primary or revision total hip replacement (THR).

PATIENTS AND METHODS

The study was approved by our institutional review board. This is a retrospective matched control study for assessment of the early functional outcome of porous metal augments versus the use of bone graft in reconstruction of acetabular defects in either primary or revision THR to eliminate bias caused due to variations in age, sex, and type of the defect which may alter the outcome.

Cases of acetabular reconstruction performed in a tertiary referral center between January 2017 and December 2019 were reviewed. There were 83 cases of acetabular reconstruction. All cases of periprosthetic infection and pure cavitory defects were excluded. Inclusion criteria were patients older than 16 years old, who underwent either primary or revision THR, and who suffered from segmental or combined segmental and cavitory defects. Seventeen cases were performed using porous metal augments. The remainder of the cases were used as a control and reviewed for match in gender, age, and type of acetabular defect according to the Paprosky classification to decrease bias in the final results between both groups.

Thirty-four cases were included in the study, which were classified into two groups. Group 1 included 17 cases of acetabular reconstruction using porous metal augments. Group 2 included matched 17 cases with acetabular reconstruction using bone graft (either autograft, which was fixed with screws, or morselized allograft with reinforcement acetabular cup or acetabular ring) [Figure 1].

All cases underwent clinical and radiological assessment by one of the authors and were discussed in our departmental multiple disciplinary meeting. Radiographs included standard anteroposterior and lateral radiographs for the hip joint and whole femur, as well as obturator and iliac view radiographs for the acetabulum, and preoperative computed tomography to better evaluate acetabular defects and help planning of acetabular reconstruction. All patients underwent preoperative assessment in line with our hospital's policy.

The technique of reconstruction was decided according to available instruments that can be used. Augment reconstruction

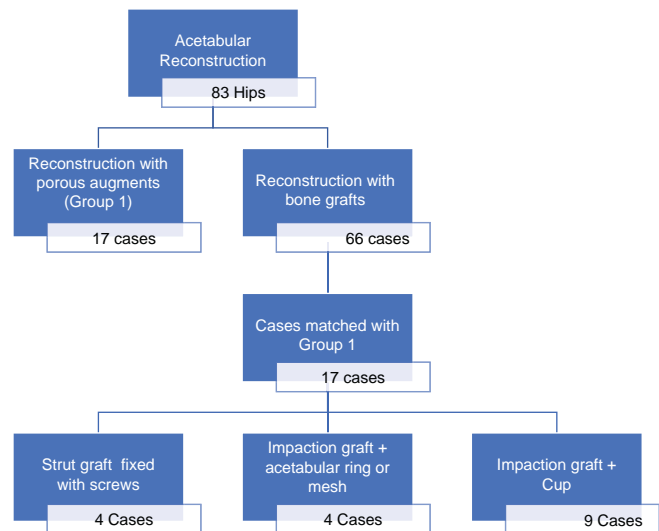


Figure 1: Flowchart diagram for acetabular reconstruction cases received during the study period in our institution and its method of management

was used whenever possible if there was a segmental defect that needed reconstruction. Augment reconstruction was used whenever possible if there was a segmental defect that needed reconstruction. Through a standard posterior approach, with patients in the lateral position; the true acetabulum was identified, this was followed by sequential acetabular reaming while preserving the integrity of the remaining bone stock. The acetabular defect was assessed, and the appropriate augment was trailed together with appropriate size shell. Finally, the augment was used to fill the defect and secured with screws. Then, a thin layer of cement was inserted between the augment and the metal shell in case of cementless reconstruction, or the cemented cup was put in place taking into consideration the proper version and abduction of the cup. In case of lack of augment availability, the graft was used either alone with cup placement or augmented with mesh or reconstruction ring to ensure structural stability whenever needed. In the case reconstruction using bulk autografts, the allograft was prepared by removing the cartilage layer and then initially secured along the defect with K-wires. This was followed by sequential reaming till the appropriate size, then use a trial to ensure the press fit fixation of the cup. The acetabular cup was applied and followed by screw fixation of the autograft and implantation of the definite shell.

In the case of allograft use, the graft was morselized into small chips and impacted to fill the defect, and a titanium mesh was added and secured by screws if indicated. A ring was added in cases of segmental or medial defects. The ring was secured in the best-fit position regardless of the abduction and version. This was followed by cementing the cup while taking into consideration the appropriate version and abduction angle and restoring the center of rotation.

All surgeries were conducted through the standard posterior approach, with the patient in lateral decubitus by one of the authors. The acetabulum was properly exposed with a

proper assessment of the extent of the acetabular defect. In Group 1, the acetabulum was reconstructed using porous metal augments (manufacturer's name/Zimmer Biomet) [Figure 2].

In Group 2, a femoral head autograft was used in four patients to reconstruct the defect and fixed with K-wires preliminary, while proper reaming was performed. A mesh or re-enforcement ring were used according to surgeon evaluation of the acetabular defect together with the morselized graft to secure the graft. Then, a socket cemented into the ring [Figure 3], or in case of mesh use, the socket was cemented directly to the acetabulum.

The trial for the acetabular socket was used first to assess the possibility of cementless cup by achieving a press fit fixation of the trial, if failed a cemented socket will be implanted instead. Either a porous socket was used and fixed by screws into the acetabulum, or a cemented socket was used. In case of bulk autograft use, it was fixed and secured with screws after application of the cup [Figure 4 and Table 1].

All patients received low-molecular-weight heparin postoperatively for 28 days after the operation. Antibiotics were given at induction of anesthesia and continued for 24 h

postoperatively as per our hospital's guidelines. Patients were asked to start only toe-touch weight-bearing postoperatively for 6 weeks, followed by gradual progression to full weight-bearing over a further 6 weeks.

A wound check was performed at 2 weeks, followed by clinical and radiological follow-up at 6, 12 weeks and then annually thereafter. Radiological assessment included standard anteroposterior radiographs of the hip. Functional assessment was conducted using the Harris Hip Score (HHS). Failure was defined as radiological signs of acetabular loosening, e.g., radiolucent areas development, migration of implants, or need for revision surgery.

Both the groups were matched for their acetabular defects according to the Paprosky classification. Each group had 2 cases of IIA acetabular defect, 10 cases of IIB acetabular defect, 4 cases of IIC acetabular defect, and 1 case of IIIA acetabular defect according to the Paprosky classification. Medical morbidities in each group are illustrated in Table 2.

Group 1 was performed using augment and cementless cup in 4 cases and augment and cemented cup in 10 cases. Group 2



Figure 2: A case of acetabular defect (Paprosky type IIB type) reconstructed using acetabular augment, showing (a) pre-operative pelvis AP radiograph, (b) preoperative hip AP radiograph, (c) Immediate postoperative pelvis AP radiograph after reconstruction using acetabular augment, (d) Immediate postoperative hip AP radiograph, (e) 6-months follow-up AP radiograph of the hip, (f) 6-months follow-up radiograph pelvis AP radiograph, (g) 36-months follow-up AP radiograph of the hip

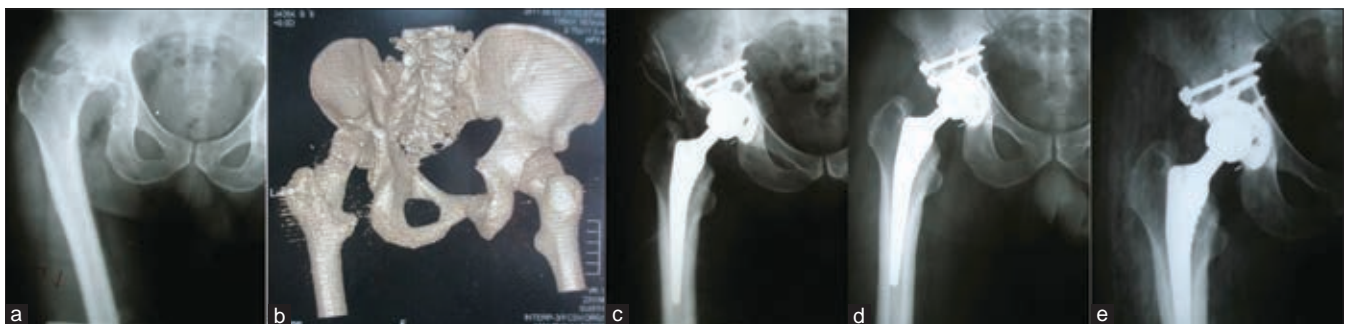


Figure 3: A case of acetabular defect (Paprosky 2B type) reconstructed using bulk autograft and a cementless socket showing (a) pre-operative pelvis AP radiograph, (b) pre-operative 3-D reconstruction CT, (c) Immediate post-operative AP radiograph of the hip, (d) 12-months follow-up AP radiograph of the hip, (e) 66-months follow-up AP radiograph of the hip



Figure 4: A case of acetabular defect reconstructed using allograft impaction and mesh and acetabular socket showing (a) pre-operative AP radiograph of the pelvis, (b) pre-operative lateral radiograph of the hip, (c) Immediate post-operative AP radiograph of the pelvis with cerclage application around the femoral shaft, (d) 3-months follow-up AP radiograph of the pelvis, (e) 6-months follow-up AP radiograph of the hip, (f) 12 months follow-up AP radiograph of the hip, (g) 24-months follow-up AP radiograph of the pelvis, (h) 36-months follow-up AP radiograph of the pelvis, (i) 38-months follow-up AP radiograph of the pelvis

Table 1: Types of acetabular reconstruction in each group

Acetabular reconstruction in Group 1		Acetabular reconstruction in Group 2	
Cemented socket + augment	13 cases (76.5%)	Contemporary flanged socket + allograft	7 cases (41.2%)
		Cementless socket + bulk autograft	4 cases (23.5%)
Cementless socket + augment	4 cases (23.5%)	Cemented socket + reinforcement ring + allograft	2 cases (11.8%)
		Cemented socket + mesh + allograft	3 cases (17.6%)
		Cementless socket + allograft	1 case (5.9%)

Table 2: Patient demographics

	Group 1	Group 2		
<i>n</i>		17 cases		
Mean age (years) (range)	52.3 (30–68)	52.1 (32–71)		
Males: females, <i>n</i> (%)	13 (76.5) and 4 (23.5)	13 (76.5) and 4 (23.5)		
Side (%)				
Right	11 cases (64.7)	10 cases (58.8)		
Left	6 cases (35.3)	7 cases (41.2)		
Comorbidities (%)	HTN: 2 cases (11.8) Combined DM and HTN: 1 case (5.9) IHD: 1 case (5.9) RA: 3 cases (17.6) SLE: 3 cases (17.6) Seronegative arthropathy: 1 case (5.9)	HTN: 1 case (5.9) DM: 3 cases (17.6) Combined HTN and DM: 1 case (5.9) IHD: 1 case (5.9) RA: 3 cases (17.6) SLE: 1 case (5.9)		
Primary diagnosis (%)	OA: 3 cases (17.6) AVN: 2 cases (11.8) Posttraumatic arthritis: 1 case (5.9) Aseptic loosening: 11 cases (64.7)	OA: 1 case (5.9) Hip dysplasia: 3 cases (17.6) Posttraumatic arthritis: 3 cases (17.6) AVN: 1 case (5.9) Aseptic loosening: 9 cases (52.9)		
Acetabular defects	IIA: 2 cases in each group IIB: 10 cases in each group IIC: 4 cases in each group IIIA: 1 case in each group			
procedures performed	Primary THR (6 cases)	Revision THR (11 cases)	Primary THR (8 cases)	Revision THR (9 cases)
	Uncemented socket + augment: <i>n</i> =1 case	Uncemented socket + augment: <i>n</i> =3 cases	Strut graft <i>n</i> =3 cases	Strut graft <i>n</i> =1 case
	Cemented socket + augment: <i>n</i> =5 cases	Cemented socket + augment: <i>n</i> =8 cases	Impaction graft <i>n</i> =5 cases	Impaction graft <i>n</i> =8 cases
			Cemented <i>n</i> =4 cases	Cemented <i>n</i> =5 cases
			Uncemented <i>n</i> =4 cases	Uncemented <i>n</i> =4 cases

HT: Hypertension, DM: Diabetes mellitus, IHD: Ischemic heart disease, RA: Rheumatoid arthritis, THR: Total hip replacement, SLE: Systemic lupus erythematosus, OA: Osteoarthritis, AVN: Avascular necrosis

was performed using strut autograft and a cementless cup in four cases; impaction allograft and a cementless cup in one case; impaction allograft and a cemented cup in seven cases; impaction allograft, Muller ring, and a cemented cup in two cases; and impaction allograft, peripheral mesh, and cemented cups in three cases [Table 1].

Data were coded and entered using the Statistical Package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data were summarized using mean and standard deviation for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between the groups were done using an unpaired *t*-test in normally distributed quantitative variables while the nonparametric Mann–Whitney test was used for nonnormally distributed quantitative variables. For comparing categorical data, a Chi-square test was performed. The exact test was used instead

when the expected frequency is <5. *P* < 0.05 was considered statistically significant.

RESULTS

The mean follow-up period was 74.8 months in Group 1 (range from 66 to 85 months) and 71.5 months in Group 2 (range from 60 to 102 months). There was no statistically significant difference between both the groups (*P* = 0.236).

The mean patients' age for both the groups was 52.3 years (range from 30 to 68 years). The mean age for Group 1 was 52.29 years (range: 30–68), while the mean age for Group 2 was 52.1 years (range from 32 to 71 years). Both the groups included 13 males and 4 females. There was no statistically significant difference between both the groups (*P* = 0.933).

The mean operative time was 98.8 min (range from 75 to 180 min) in Group 1 and 122.2 min (range 75–180 min) ($P = 0.111$). The operative time was shorter in Group 1 as the application of the augment and its fixation is faster and easier than graft application and its proper reaming. The mean blood loss in Group 1 was 444.1 mL (range from 250 to 1000 mL), while it was 531.2 mL in Group 2 (range from 250 to 800 mL) ($P = 0.557$). Less blood loss was encountered in Group 1 as it had a shorter operative time.

Group 1 included six cases of primary THR (three cases of OA, two cases of Avascular necrosis (AVN) of the femoral head, and one case of fracture acetabulum). The other 11 cases were revision THR cases following aseptic lessening. Group 2 included eight cases of primary THR (three cases of dysplasia, three cases of fracture acetabulum, one case of AVN, and one case of OA). The other nine cases were revision THR for aseptic loosening. Acetabular defects were evaluated using the Paprosky classification [Table 2].

At the time of the study, a trabecular augment's cost was 27000 Egyptian pounds (EGP) (about 900 \$) while the cost of an allograft femoral head was 1500 EGP (about 50 \$) and routinely three femoral head allografts were used in each case when allograft reconstruction was done with a total cost of 4500 EGP (about 150 \$). The reconstruction Muller ring used in our study was about 17,000 EGP in its cost (about 566.66 \$). The average cost for augment use in Group 1 was 28,885 EGP (about 963 \$). The average cost for acetabular reconstruction using graft with or without reconstruction ring was 21,441 EGP (about 714.7\$). The hospital stay period and follow-up protocol was the same between both groups implementing the same cost. on the other hand the cost for reconstruction method was less in Group 2.

Group 1 had one case of heterotopic ossification postoperatively which did not affect the patient's function. Group 2 had one case of sciatic nerve palsy postoperatively, which improved after 9 months. Loosening of the acetabular component was defined by the presence of progressive radiological signs of loosening, such as loosening lines or change of the acetabular socket position whether the patient has any clinical signs of loosening or not. No cases of radiological loosening were encountered during the follow-up. Group 1 had a mean postoperative HHS of 90.5 (range from 85 to 94). Group 2 had a mean postoperative HHS of 88.7 (range from 80 to 94) ($P = 0.236$) and no statistically significant difference between both the groups regarding the final functional outcome.

DISCUSSION

Recent literature has favored the use of porous coated augments over traditional nonporous reconstruction options and bone graft in acetabular defect reconstruction. Many studies however have failed to address the issue of added cost the porous augments add to the procedure. Such costs might not be feasible in all health settings, and might not be suitable for all patients, particularly low-demand ones and elderly patients.

This study aimed to question the recent trend in the market and investigate whether the use of porous coated augments has an advantage over other budget-friendly alternatives in the medium term (5–6 years) in a budget-oriented health setting and assessment of functional outcomes following the use of either method in acetabular reconstruction and the incidence of complications in both the groups.

Our study included two groups which were matched in terms of defect characteristics and patients' demographics. The study included segmental defects or combined segmental and cavitory defects (types IIa to IIIA) but did not include pure cavitory defects or pelvic discontinuity-type defects.

Our results failed to show a significant difference in the short to medium term between both the groups in terms of survivorship and complications rate, failure, and short-to-medium survivorship.

During acetabular reconstruction surgery, the surgeon strives to create a stable and durable construct and restore the hip's center of rotation to its anatomical location.

Fixation methods for acetabular component reconstruction may be either biological or nonbiological. Nonbiological fixation attempts to achieve mechanical stability without osseointegration of the acetabular component to the host bone.^[7] Examples of nonbiological techniques include acetabular cages, roof rings, or floor mesh.

In most hips, the location of the segmental bone loss is superoanterior or superoposterior and the remaining bone allows for sufficient component-bone contact (Paprosky type II). In this setting, the structural allograft, termed a shelf graft or minor column graft,^[8] serves to provide support that allows for full stability with the use of a hemispherical component. For hips with massive segmental bone loss with or without pelvic discontinuity (Paprosky type III), structural allograft may be used in conjunction with other devices that achieve mechanical stability. If a nonbiological device is used, such as a nonporous coated ring or mesh, the initial fixation must be strong enough to withstand the forces until graft incorporation occurs.

On the other hand, porous metal augments provide structural support for the acetabular component until bone ingrowth occurs, they aim to achieve biological fixation, and several studies have favored them over nonbiological fixation methods such as nonporous rings; however, osseointegration becomes difficult with larger acetabular bone defects.^[9,10] It has been historically stated that 50% surface area contact between viable host bone and the acetabular component is required for successful osseointegration.^[11] However, many surgeons have argued that factors such as component size and quality of host bone likely affect the percentage of contact required for osseointegration and therefore the 50% surface area contact is rather arbitrary.^[12]

Whitehouse *et al.*^[13] reported a 92% survival rate at 10 years in 53 revision THAs with TM cup and augments used for the treatment of IIA–IIIB Paprosky defects. Grapiollo *et al.*^[14] also

demonstrated a 92.8% survival rate at 5 years for 55 revision hip arthroplasties, 42 IIIA and 13 IIIB. Paprosky defects are managed with TM shells and augments. Midterm results have been quite promising, with a low rate of aseptic loosening, improvement in the clinical scores, and restoration of the center of rotation of the hip.

Similarly, Löchel *et al.* reported a 10-year survivorship of 92.5% in a series of 62 hips using a combination of TM shell and augment. Defects included IIA to IIIB, and there were five cases of pelvic discontinuity.^[15]

Schlegel *et al.*^[16] reported a series of 164 revision THAs reconstructed with fresh frozen femoral head allograft and the Müller ring. Among them, 56% had AAOS type III acetabular defects and 5% had AAOS type IV acetabular defects (pelvic discontinuity). The survival rate was 98% at 5 years, but no difference was observed regarding the severity of the acetabular defects.

Hourscht *et al.*^[17] investigated the outcomes of the Ganz ring with structural allograft in revision THAs with AAOS type III and IV acetabular defects. Additionally, the type IV was reinforced with a plate. The authors showed that the AAOS type of acetabular defect was the only independent risk factor of failure, the type IV being at a significantly higher risk for failure. The 5-year survival rate using revision for any reason was 86% and 57% in types III and IV, respectively. Therefore, the authors concluded that the Ganz ring should not be used when there is a pelvic discontinuity. The data^[17,18] show that the Ganz ring should not be used for major acetabular defects or segmental defects affecting the medial wall.

Hsu *et al.*^[12] reported on a series of Paprosky type III acetabular defects and PD reconstructed with the Burch–Schneider (BS) ring and structural allograft. The authors showed survival rates of 76% and 57% at 5 and 10 years, respectively.

Likewise, Jones *et al.*^[19] used allograft and autograft along with the BS ring to revise 30 hips rated Paprosky III. Their results showed a survival rate of 91% at 9 years.

It has been determined that the BS ring is a viable option reconstructing severely damaged acetabula.^[19,20]

Gibon *et al.*^[21] reported a study regarding 37 patients with Paprosky III defect, reconstructed using the Kerboul ring showing 95.3% survival at a mean follow-up of 8.2 years. Makita *et al.*'s^[22] study showed a 90.7% survival at a mean

follow-up of 11.2 years on 65 patients with Paprosky III defect, reconstructed using Kerboul ring with bulk allograft.

Overall, the Kerboul device is a reliable option for revision THA with severe acetabular bone loss. However, its main disadvantage in the mid and long term is a 21.6% rate of migration when the teardrop is obliterated.^[21,23]

Comparative data on survival rates between the different rings for the reconstruction of the severely damaged acetabulum are shown in Table 3.

Some research papers had questioned the long-term outcome of morselized allograft usage and its possible complications. Shon WY *et al.*^[24] stated that a cage must be used to protect structural grafts that replace more than 50% of the acetabulum. The primary benefits of the rings and cages include the ability to restore the hip center, the ability to cement a liner in any position without regard to the ring position, the ability to provide a uniform load to the allograft that stimulates bone remodeling and incorporation into host bone,^[25] and the ability to elute local antibiotics from the cement. When the cage fails, cementless revision can be performed. The cage safeguards the structural or morselized allograft during its remodeling process.^[26] The main drawback is the possibility of cage fracturing or loosening because of inadequate biologic attachment. However, if the graft remodels before the ring fractures, it can be viable to have a standard cementless acetabular revision afterward.

Additionally, due to the high failure rate, it is best to avoid using impaction morselized graft in conjunction with peripheral mesh when there is a significant segmental defect and a significant medial deficiency. Failures are attributed to graft integration failure, mesh migration, and fracture.^[27] At a mean follow-up of 5.2 years, Baauw *et al.*^[28] reported an overall reoperation rate of 7.4% (15 of 204 hips), an acetabular revision rate of 6.4% (14 of 204 hips), and an 8.8% radiographic loosening rate (18 of 204 hips).

The long-term outcome of porous metal augment in acetabular reconstruction was promising with good results obtained. Lochel *et al.*^[15] reported that the overall survival of the acetabular component at a mean of 10 years postoperatively was 92.5% using metal augment and TM shell. The type of acetabular defect encountered in this study was Paprosky IIA in 5 cases (5.2%), type IIIB in 13 cases (24.5%), type IIC in 6 cases (11.3%), type IIIA in 23 cases (41.5%), type IIIB in 9 cases (17%), and pelvic discontinuity in 5 cases (9.4%).^[15]

Table 3: Comparison of both groups regarding their results

	Group 1 (range)	Group 2 (range)	P
Follow-up (months)	74.7 (66–85)	71.5 (60–102)	0.236
Operative time (min)	98.8 (75–180)	122.2 (75–180)	0.111
Blood loss (mL)	444.1 (50–1000)	531.2 (250–800)	0.557
Complications	1 case of heterotopic ossification	1 case of temporary sciatic nerve palsy	
Functional scores	HHS 90.5 (from 85 to 94)	HSS 88.7 (from 80 to 94)	0.169

HHS: Harris Hip Score

The strength of this study lies in the fact that there are no studies in the literature that compare metal augments to other methods of acetabular reconstruction with matching of the cases regarding the type of the defect and patients' demographics to decrease bias in end results. Furthermore, it addresses one of the main issues that is usually overlooked, which is the increasing cost burden of hip replacement with acetabular reconstruction procedures, with manufacturers constantly providing more and more options, while ignoring the added cost these options add to the patient and health system. This is of particular importance in the current global economic crisis which has hit developing countries much more than developed countries. Despite being a retrospective study, two groups were matched in terms of demographics and defect characteristics adding to the validity of the results. The weakness of the study is the retrospective nature and small sample size owing to the increased cost of the biological fixation methods in our health setting. Furthermore, the variability of reconstruction methods used in group 2 may cause bias in end results. However, the type of such procedure offers usually different scenarios that necessitate change in treatment protocol. Difficult primary cases may be operated with autograft femoral head as a solo tool for reconstruction. However, revision cases, lacks the availability of femoral head, which necessitated the use of allograft with or without different reconstruction options, as the Muller ring according to the size and severity of the acetabular defect.

Although the study failed to address any difference in early and midterm results between biological fixation methods and cost-friendly alternatives, yet literature does suggest that long-term survivorship might be better with biological fixation, therefore the authors would still recommend the use of TM augments and biological fixation methods when economically feasible and particularly in the younger patients.

CONCLUSION

Old traditional methods of acetabular reconstruction in the form of graft aided with reinforcement ring can provide comparable results regarding survival and functional outcome to the porous metal augments providing less economic burden for the patient or the health system.

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Conflicts of interest

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A Rare Aberrant Division of Radial Nerve Encountered During Fixation of Distal 1/3rd Shaft Humerus Fracture

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Abstract

The radial nerve is a continuation of the posterior cord, which is composed of axons from C5 to C8. Rarely are abnormalities in the posterior cord's branching pattern mentioned in the literature. An unusual change encountered in the radial nerve is described in this case report, during fixation of distal 1/3rd shaft humerus fracture left side in a 22-year-old male, where the radial nerve is seen as two distinct bundles, anterior and posterior. The posterior division provided aberrant branches to the long head of the triceps muscle, medially, while the anterior division persisted as the main radial nerve. To expose the humerus shaft for fixations, an orthopedic surgeon must be aware of the radial nerve divisions.

Keywords: Aberrant nerve division, humerus fracture, radial nerve

INTRODUCTION

The brachial plexus comprises the axonal network originating from the C5 to C8 and T1 spinal nerves. Notably, the radial nerve, an extension of the posterior cord, emanates from the C5–C8 spinal nerves.

Various studies (Hasan and Narayan, 1964; Hollinshead, 1958; Kerr, 1918) have demonstrated the prevalence of anomalies within the brachial plexus and its terminal branches.^[1] These anomalies may arise during the developmental stages or branching processes of the plexus.^[1,2] Anomalies occurring during formation can manifest either as pre- or post-fixed abnormalities, impacting trunks, divisions, and cords. Notably, anomalies within the cord branches occur more frequently than those in the formation phase. It is pertinent to note that terminal branch positioning exhibits minimal variability.^[1]

The posterior cord in the axilla extends to give rise to the radial nerve, with root values originating from C5, C6, C7, and C8. Subsequently, it traverses the spiral groove, innervating both the long and medial heads of the triceps muscle. The lateral head of the triceps muscle receives branches from the nerve within the groove. Following its passage through the lateral intermuscular septum into the ventral compartment, the radial nerve bifurcates into superficial and deep branches.^[1]

This case report delineates an uncommon alteration in the branching pattern of the radial nerve after the management of a distal 1/3rd shaft humerus fracture.

CASE REPORT

A 22-year-old male presented to the emergency department at MMIMSR with an alleged history of a fall from height, resulting in complaints of pain and deformity in the left distal arm and elbow region. Upon evaluation, his neurovascular status was found to be intact. Radiological investigations revealed a fracture in the distal 1/3rd of the left humerus shaft [Figure 1].

Subsequently, the patient underwent plate fixation for the fracture using a posterior approach [Figure 2]. The surgical procedure involved a straight incision extending from the acromion to the olecranon fossa. The triceps muscles, specifically the long and lateral heads, were identified.

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Subsequently, a deep dissection was performed to locate the radial nerve, which was found not to be near the fracture fragments. Following nerve identification, additional dissection was conducted proximally and distally to delineate the nerve's branching pattern within the planned skin incision for humerus plating. As the nerve traversed the lateral intermuscular septum and proceeded distally, the anterior division of the radial nerve exhibited typical characteristics, while the posterior division was observed to emit aberrant branches into the long head of the triceps muscle medially [Figure 3].

To preserve this aberrant branching pattern, the long head of the triceps muscle was utilized as a muscle flap, raised along with the nerve to safeguard its function. Subsequent plating of the distal 1/3rd humerus was carried out using an extra-articular distal humerus locking plate, with meticulous attention to preventing iatrogenic damage to the radial nerve.

Postoperatively, the patient exhibited no signs of neurovascular compromise, with complete preservation of radial nerve function.

DISCUSSION

The literature sparingly addresses variations in the architectural configuration of the radial nerve, with a notable prevalence of documented variations in the medial and lateral cords compared to those in the posterior cord.^[1,3] Noteworthy instances include the posterior cord's self-division into two roots, subsequently encapsulating the subscapular artery, which then fuses to form the radial nerve.^[4] Furthermore, Kuwar elucidated a scenario wherein the origins of the radial nerve were observed to embrace the subscapular artery.^[5] In a distinct scenario, documentation has highlighted the emergence of the radial nerve from the junction between the posterior section of the middle and inferior trunks, devoid of any involvement from the superior trunk.^[6] Moreover, Honma *et al.* observed an anomalous artery in the axilla traversing the radial nerve during its course from deep to superficial layers.^[7]

Muthoka *et al.* conducted a detailed examination of the posterior cord's architecture within the Kenyan population, revealing that 10% of posterior cords exhibited a stereotypical branching pattern. Interestingly, variations in the emergence of the radial nerve from the posterior cord or the radial nerve itself were absent, maintaining their intrinsic nature.^[8] However, these distinctions do not align with the current case report, wherein the radial nerve demonstrated a typical formation, dividing into its ventral and dorsal divisions. According to Jamuna, the radial nerve, originating from the posterior cord, typically exhibits anterior and posterior branches. The radial groove was noted to be traversed by both divisions, with the posterior division giving rise to branches originating from the radial nerve.^[9] The principal radial nerve, accompanied by its anterior division, continued its course along the upper limb as expected.^[9] Ramasamy *et al.* demonstrated that the posterior division of the nerve regularly



Figure 1: Pre – OP Xray



Figure 2: Post – OP Xray

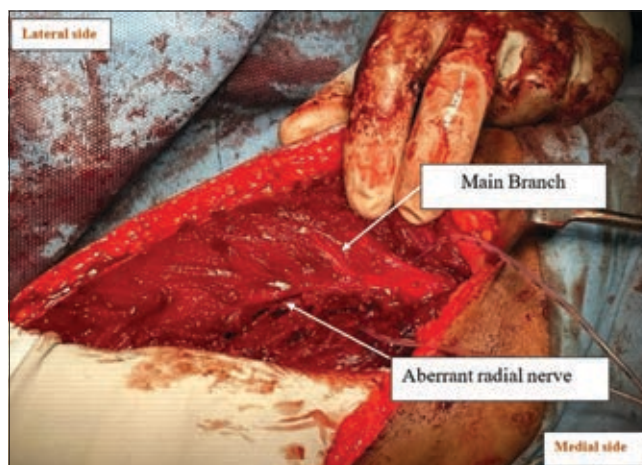


Figure 3: Aberrant branching of nerve

provides branches to the triceps muscle and penetrates the muscle distally.^[10]

It is paramount to acknowledge that cadaveric dissections have meticulously observed all documented variants reported

in the literature. Notably, the reports by Ramasamy *et al.*^[10] and the current case represent the sole instances of aberrant radial nerve division encountered during routine orthopedic surgical procedures.

CONCLUSION

This case underscores the critical importance of recognizing and understanding rare anatomical variations, particularly in the context of orthopedic surgical interventions. Surgeons must remain vigilant during procedures involving the humerus shaft, ensuring meticulous attention to radial nerve divisions to prevent inadvertent nerve injury. At this level, the radial nerve is less mobile and thus dissection becomes difficult to carry out, meticulous dissection should be carried out while exploring the nerve and during fixation of the bone. The insights gleaned from this case shed light on the complexities of aberrant anatomy encountered in routine orthopedic practice, emphasizing the necessity for comprehensive anatomical knowledge and surgical expertise in managing such cases effectively.

Declaration of patient consent

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

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Conflicts of interest

There are no conflicts of interest.

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Bicondylar Hoffa's Fracture with Transverse Patella Fracture in an Adolescent Boy

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Abstract

An early adolescent boy presented with an alleged history of road traffic accident sustaining a closed injury to the left knee. On X-ray and computed tomography imaging, he was diagnosed with left femur bicondylar Hoffa's fracture with transverse patellar fracture. Hoffa's fracture is described in adults and rarely occurs in the skeletally immature population and hence poses a dearth of knowledge about the treatment for the same. Our patient underwent open reduction and internal fixation. The patient was followed up regularly and achieved radiological union and good knee function.

Keywords: Adolescent, double Hoffa, Hoffa's fracture, patella fracture

INTRODUCTION

Physal fractures of the distal femur are relatively uncommon. Approximately 7% of all fractures of lower extremities and about 6% of all physal fractures are related to distal femur physal fracture.^[1] The majority present as Salter and Harris type 2 fractures. Cases showing the coronal split of the distal femur also referred to as Hoffa fractures are routinely seen in adults, however, they are rare in children. We present a case of conjoint bicondylar Hoffa fracture with an associated patellar transverse fracture in an adolescent boy. These fractures in children often tend to have higher complication rates such as disturbances in growth, neurovascular injuries, and early arthritis of the knee.^[1,2] Our case was managed by open reduction and internal fixation of the medial Hoffa fracture and patella fracture, lateral Hoffa fracture was left undisturbed as it was an undisplaced fracture. The patient had a good union of the fracture and no long-term complications.

CASE REPORT

An early adolescent boy presented with left knee pain, swelling, and deformity following a road traffic accident (RTA). On examination, the knee appeared swollen with no external injury, there was diffuse tenderness with bony crepitation felt along the distal end of the femur and patella. The motion of

the injured knee was painfully restricted. There were no other injuries noted. Neurovascular status was intact.



Figure 1: X-rays (lateral and anteroposterior view) showing left knee medial Hoffa's fracture (yellow pointer) and a transverse patella fracture (blue pointer). Please note there is no obvious evidence of lateral Hoffa fracture

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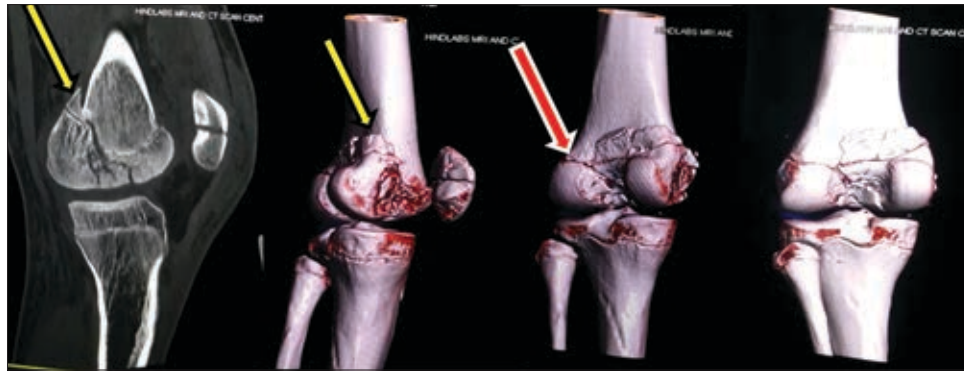


Figure 2: Computed tomography scan (plain and three-dimensional reconstruction) showing a comminuted medial Hoffa fracture (yellow pointer) of the left knee with undisplaced Hoffa fracture of the lateral condyle of the left knee (red pointer)

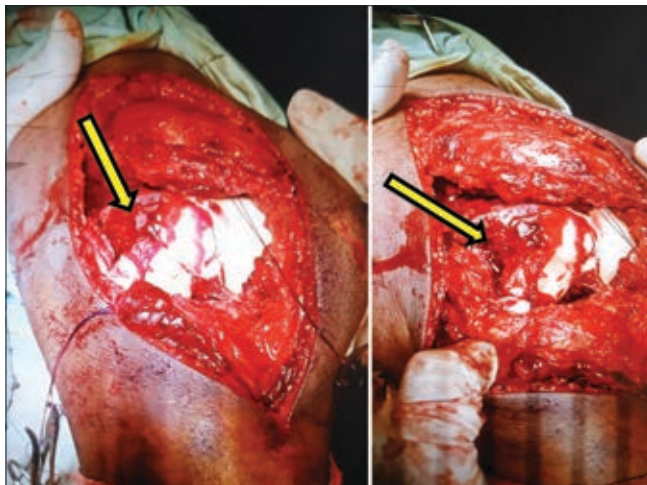


Figure 3: Intraoperative picture showing left knee medial Hoffa fracture with comminution (yellow pointer)

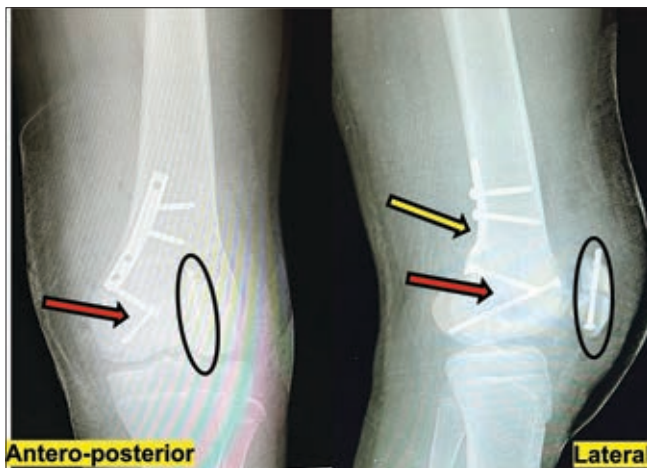


Figure 4: Postoperative X-rays (anteroposterior and lateral view) showing left knee fracture fixation of the medial Hoffa with a buttress plate (yellow pointer) and 4 mm cannulated cancellous screw (red pointer). The patella fracture was fixed with a 4 mm cannulated cancellous screw (black circle). Note that the lateral condyle Hoffa's fracture was not fixed as it was undisplaced

X-ray of the knee (anteroposterior and lateral views) showed a medial Hoffa fracture with a transverse patella

fracture [Figure 1]. Computed tomography (CT) scan of the left distal femur with three-dimensional (3D) reconstruction was done for better clarity of the fracture pattern and for planning the surgery. CT scan showed a displaced medial Hoffa's fracture, undisplaced lateral Hoffa's fracture, and transverse patella fracture with comminution in the articular surface [Figure 2].

He underwent open reduction and internal fixation with a one-third tubular plate as a buttress plate along with a 4-mm cannulated cancellous (CC) screw for the medial Hoffa fracture. It was a medial subvastus with medial parapatellar extension, the length of incision was about 10 cm. The transverse patella fracture was fixed with a 4-mm CC screw fixation under spinal anesthesia [Figures 3 and 4]. A standard medial subvastus approach was done to access the displaced medial Hoffa fracture. The patellar extensor mechanism was noted to be uninjured. The lateral Hoffa's fracture was undisplaced and hence was decided intraoperatively for conservative management. Postsurgery, the limb was immobilized in an above-knee plaster cast for 4 weeks and was kept nonweight-bearing. At the end of 4 weeks, the cast was removed and physiotherapy for the knee joint was initiated.

The patient was followed up regularly for 18 months. At the latest follow-up, radiographs showed a good union of the fracture with a good functional knee joint range of motion [Figures 5 and 6]. He was back to his routine activities and had no issues.

DISCUSSION

Bicondylar Hoffa fracture along with transverse patellar fracture in an adolescent boy is a rare case and this combination of injuries has not been reported in the literature.^[1]

Hoffa fracture is a distal femoral intraarticular fracture in the coronal plane either isolated (medial or lateral) or both the condyles are involved.^[2] The chances of lateral femoral condyle getting fractured are three times more common than medial.^[3,4]

These injuries are caused by very high-velocity impacts on the knee joint such as RTAs, as in our case, but pediatric



Figure 5: Clinical picture showing left knee functional range of movement at the knee joint



Figure 6: Follow-up left knee X-rays (anteroposterior and lateral view) showing good union and no evidence of physeal arrest or scarring (red and yellow pointer)

Hoffa's fracture can occur in a sports injury or trivial injury as well.^[5] The exact mechanism of injury is still unknown but it is proposed as direct impact and indirect shearing force with axial loading in a flexed or hyperflexed knee can result in such fractures.^[6] In our case, the cause is an RTA, so we presume it was a direct impact injury because, in addition to bicondylar Hoffa's fracture, there was a transverse patellar fracture as well.

These fractures can be easily missed on radiographs in both anteroposterior view and lateral view because of being coronal with the intact anterior part of condyles.^[7] As per our literature review, previous authors have also considered CT scans with 3D reconstruction as the investigation of choice to delineate the exact pattern of injury and for a better surgical approach.^[8] In our case, the medial Hoffa's fracture was displaced and comminuted whereas the lateral Hoffa fracture was undisplaced. There was a transverse patella fracture as well.

The treatment of choice is surgical because the conservative method of close reduction results in long-term complications

and is associated with avascular necrosis resulting in a poor prognosis. Malunion and early osteoarthritis are common long-term issues with conservatively managed Hoffa's fractures.^[9] Open reduction and internal fixation were performed in most of the previous literature and we preferred it as well.^[10,11] We did open reduction and internal fixation using a one-third tubular plate acting as a buttress plate along with 4-mm CC screws for medial Hoffa's fracture, lateral Hoffa's fracture was managed conservatively. Patella fracture was managed with a 4-mm CC screw fixation. Early diagnosis, proper planning, and surgical execution are very essential to prevent any avoidable complications in the long run. Our patient had a good clinic-radiological outcome at the end of 18 months following the procedure.

CONCLUSION

1. Hoffa's fractures are commonly seen in adults, however, they can be seen in skeletally immature patients as well
2. A high index of suspicion is necessary for evaluating these injuries, hence advanced imaging in the form of a CT scan is mandatory to understand the fracture pattern
3. Early diagnosis and prompt treatment are essential for a better radiological and functional outcome
4. As per our literature review, we have not come across any case reports with a similar pattern of injury in skeletally immature patients.

Declaration of patient consent

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

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Conflicts of interest

There are no conflicts of interest.

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Knee Arthroplasty for Ankylosis in a Patient with Severe Hemophilia A

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Abstract

Hemophilic arthropathy is a common complication of hemophilia A and can lead to chronic synovitis, joint damage, and eventually ankylosis. We present a case report of a 39-year-old male patient with a history of recurrent hemorrhages into the joints. He had a history of traumatic injury to both upper limbs and lower limbs. The patient was on bed rest for 6 months. Subsequently, he developed ankylosis of both elbows in 30° of flexion and ankylosis of the right (Right) knee in 40° of flexion with tricompartmental arthritis of the left knee joint. Radiologically, the left knee joint showed reduced joint space with tricompartmental arthritis. The patient was managed by the tumor prosthesis for the Rt knee. He was advised for management of the elbow joints for which he was not willing. Postoperatively, he was allowed knee range of motion exercises and walking with a walker for 4 weeks followed by a stick for 1 month. At 6-month follow-up, he was able to walk effortlessly without support. The Knee Society Score improved from 47 preoperatively to 75 at 6-month follow-up.

Keywords: Ankylosis, arthropathy, arthroplasty, hemophilia

INTRODUCTION

Hemophilic arthropathy, a significant complication in individuals with hemophilia, an inherited bleeding disorder characterized by deficient clotting factor VIII or IX, arises from recurrent hemorrhagic episodes within the joints. This results in chronic synovitis, joint deterioration, and ultimately, ankylosis. Hemophilia, affecting approximately 1 in 5,000 male births, is a spectrum of severity based on the degree of clotting factor deficiency. Hemorrhagic episodes within synovial joints, a hallmark feature of hemophilic arthropathy, perpetuate progressive joint damage. Synovial proliferation, inflammation, and fibrosis ensue after blood enters the joint space, causing articular cartilage erosion, subchondral bone exposure, and joint instability. The consequences of hemophilic arthropathy extend beyond localized joint pathology, significantly impacting patient mobility, functionality, and quality of life. The encroachment of ankylosis further exacerbates ambulatory challenges, leading to musculoskeletal limitations and functional impairments. In this case report, we detailed the clinical course of a 39-year-old male patient with hemophilic arthropathy affecting the right knee, marked by bony ankylosis in 40° flexion for 6 years, causing considerable

ambulatory impairment. Concurrently, immobilization has led to ambulatory challenges, highlighting the severe functional consequences of this debilitating condition. By conducting a comprehensive examination of the patient's history, clinical findings, and diagnostic imaging, this report elucidates the multifaceted clinical landscape of hemophilic arthropathy, thus contributing to the evolving understanding and management of this complex pathology.

CASE REPORT

The patient is a 39-year-old Asian male who has a history of hemophilia A and a positive family history. The patient had experienced pain in the right knee for 6 years and had been facing difficulties in ambulation for 4 years. Two of his brothers have been diagnosed with the same condition. In the past, the

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patient was treated conservatively for a traumatic injury to his both upper limb and lower limb, which subsequently led

to ankylosis of both elbows and right knee joint and tricompartmental arthritis of the left knee [Figure 1].



Figure 1: (a) Right knee fixed in 30° of flexion, and foot in compensatory equinus. (b) Preoperative X-ray bilateral knee (AP standing and lateral view). (c) Bilateral elbow fixed in flexion. (d) X-ray right elbow (AP and lateral view). AP: Anterior-Posterior

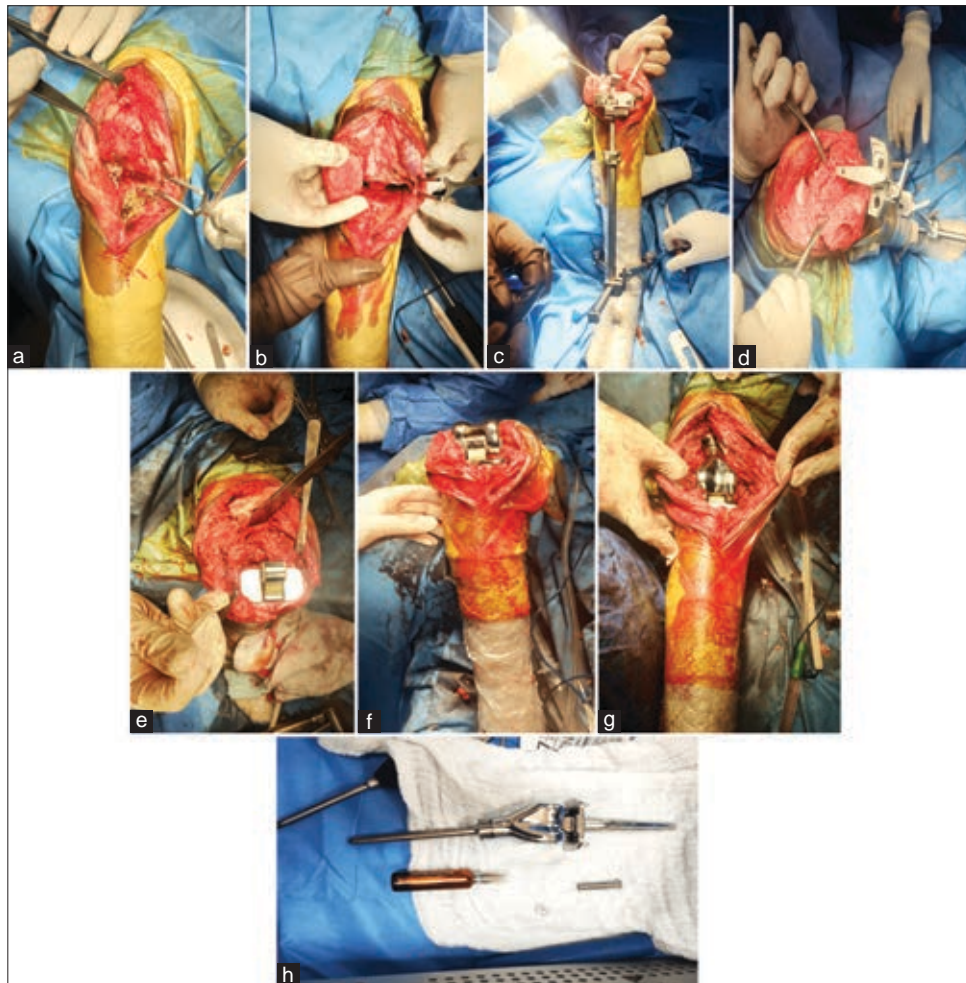


Figure 2: (a) Patellofemoral osteotomy is done; patella retracted laterally. (b) A piece of bone was removed from the femoral side using an osteotome to create the joint space. (c and d) Tibial zig was inserted and alignment was checked in coronal and sagittal planes. (e-g) Tibial and femoral components were placed. (h) Tumor prosthesis (Restor™ Femur and Tibia)

Clinical findings

The patient had bony ankylosis in the flexion of the right knee joint, confirmed on examination. The right knee was fixed in flexion at 40°, and bilateral elbow joints were fixed 30° short of extension. There were 10° of valgus deformity (Grade I) of the Right knee joint and 40° of fixed flexion deformity at the knee joint. There was a wasting of the quadriceps and calf muscles and a compensatory equinus of (Right) foot. Radiologically, the right knee joint showed bony ankylosis in flexion >40° (Type 3a), while the left knee joint showed reduced joint space with tricompartmental arthritis. Both elbow joints had bony ankylosis 30° short of extension.

Therapeutic intervention

Spinal anesthesia was given. A tourniquet was used and part was prepared and draped. Factor VIII 100% correction was done preoperatively (1 h before taking to O.T.). A midline skin incision was given over (Right) knee. A medial parapatellar approach was used. A patellofemoral osteotomy was done, and the patella retracted laterally. A minimum dissection of the soft-tissue sleeve was done on the medial side as it was a valgus knee. Under the image intensifier, the knee joint line was noticed and with the help of osteotome, a biscuit of bone from the femoral side was removed to create the joint space. An additional femoral cut was taken to achieve a proper extension gap. A 7-mm tibial cut was made with the help of a tibial zig. Flexion and extension gap were checked and all the cuts were taken and the trial was done. We performed replacement using a tumor prosthesis. Restor femur FR COCR and restor tibia FR SS were put in [Figure 2]. Intraoperatively, we got the full range of extension and flexion of 120°. The wound was closed in layers and the drain was put. The patient received 2250 units of factor VIII postoperatively after 12 h of surgery. Postoperatively, the patient was transfused 2 units of PRBC. The operated limb was splinted in a knee brace for 48 h. Static quadriceps exercises were started on postop Day 1. Knee range of motion (ROM) exercises were started on postoperative day 3 [Figure 3]. The patient was allowed to walk with a walker on Day 3. Postoperative Day 10, the patient complained of pain and swelling over the (Right) knee. On examination, hemarthrosis developed over (Right) knee. For this, the patient was advised for 100% factor VIII correction, and screening for factor VIII inhibitors was done. The patient was allowed to walk with a walker and knee range of motion exercises were stopped for 5 days as recommended by the hematologist. The patient was reported positive for screening for factor VIII inhibitor on Day 12. The patient was further managed with factor VII inhibitor bypassing activity (FEIBA) infusion. For Days 12–15, 75 I.U./Kg/BW dose of FEIBA, i.e. 3500 I.U. was given every 12 h. For Day 16– Day 25-factor FEIBA is given in doses of 50 I.U./Kg/BW, i.e., 2500 I.U every 12 h [Figure 4].

On Day 15, alternate stitches were removed and postoperative physiotherapy and rehabilitation program was initiated again. The patient was discharged on Day 18 with proper precaution and medical advice. The patient's follow-up was done on an outpatient department (OPD) basis, and stitches were removed



Figure 3: Postoperative Day3 (a) X-ray. (b and c) Knee range of motion exercises

on Day 21. The patient was in regular follow-up in orthopedics OPD as well as Hemophilia Comprehensive Care Center.

Postoperative protocol for factor correction

The correction was continued as follows:

70% on a postoperative Day 1–3 (1500 I.U. every 12 h), 50% on Days 4–7 (1000 I.U. every 12 h), and 30% on Days 8–11 (500 I.U. every 12 h).

Factor recovery level

One hour postfactor infusion on Day 2 and Day 7.

Factor trough level

Before factor infusion Day 2 and Day 7.

RESULTS

At the time of discharge, the patient attained an extension lag of 15° and flexion up to 80°. The patient was followed at 6 weeks, 3 months, and 6 months. During the clinical examination after 6 months, the patient was able to walk effortlessly without support. Knee ROM at 6-month follow-up was 0° extension to 90° flexion [Figure 5]. The Knee Society Score also improved from 47 preoperatively to 75 postoperatively.

DISCUSSION

Hemophilia is a genetically inherited disease that mainly affects males due to a deficiency in a coagulation factor. As

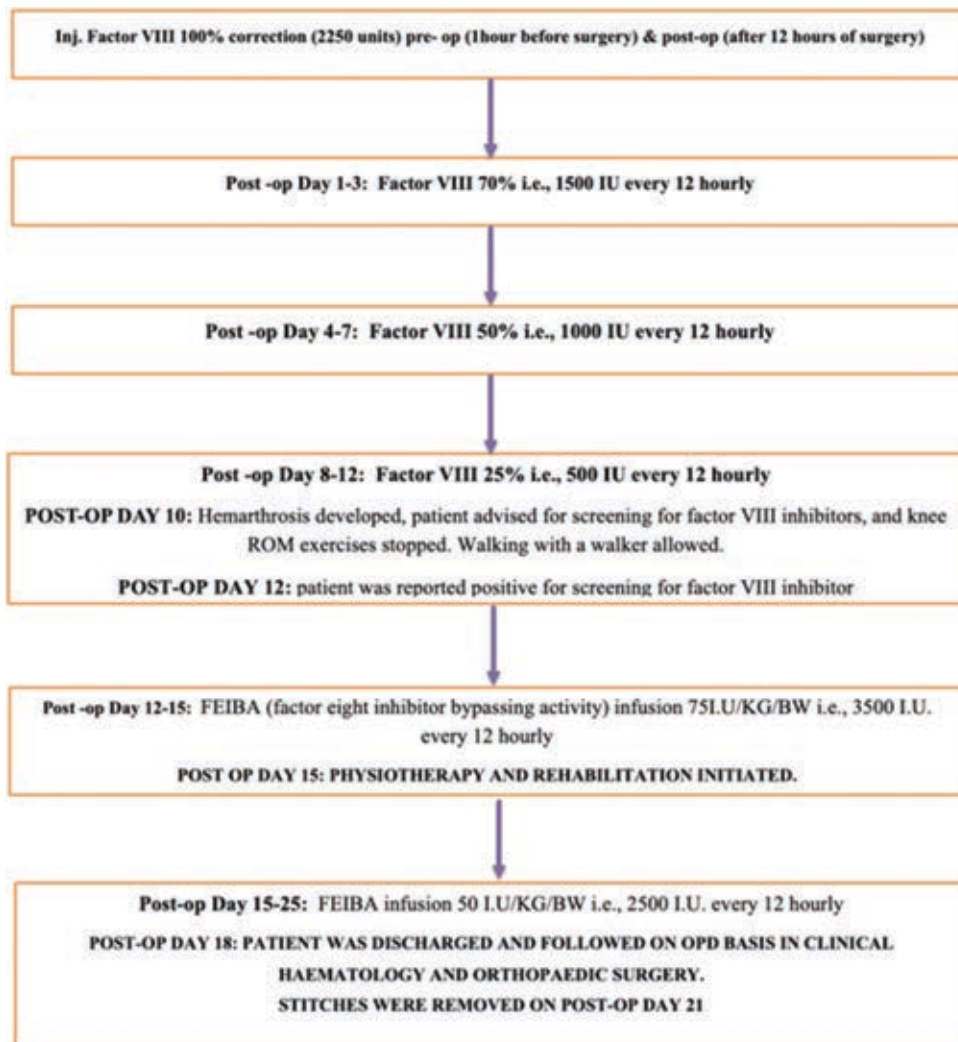


Figure 4: Treatment plan for patient planned for TKR with hemophilia A. ROM: Range of motion. TKR: Total Knee Replacement

a result, patients experience bleeding, which often occurs in the joints, including the ankle, knee, and elbow but can also affect muscles, the central nervous system, and internal organs. These recurrent bleeding episodes can lead to the development of degenerative joint disease, which has been observed in young adults as well.

Hemophilic arthropathy is a common complication of hemophilia A and can lead to chronic synovitis, joint damage, and ankylosis. The management of hemophilic arthropathy involves both conservative and surgical interventions. Conservative management includes physiotherapy, pain management, and joint injections. Surgical interventions include synovectomy, osteotomy, and arthroplasty. The choice of intervention depends on the severity and location of the joint involvement, the patient’s age, and overall health status.^[1-3]

Jaworski *et al.*^[4] gave 48 IU/kg and 12 IU/kg of plasma-derived factor VIII concentrate pre- and postoperatively, respectively. Due to poor bone quality, femoral and tibial components of the S-ROM dePuy prosthesis were toughened by intramedullary nails. Using bone cement and gentamycin, the prosthesis was



Figure 5: 6-month follow-up. (a) Standing. (b) Knee range of motion 90° flexion. (c) 0° extension

fixed. They also reported that the patient’s lack of pain was the primary difficulty in the case. The patient was having

movement issues as a result of limb axis deviation in an ankylosed knee. The positive results of past arthroplasty procedures on this patient led him to seek an improvement in his quality of life by enhancing the functionality of the limb and mobility. Based on the patient's medical history and current clinical condition, it was determined that a mobile hinge prosthesis would be the most suitable option.

According to Comanho,^[5] a study was conducted on 9 patients with ankylosed knees who underwent TKA, and all of them showed improvement in both pain and ROM. Based on this observation, investigators hypothesized that TKA is a preferred treatment option for ankylosed knees. Strauss *et al.*^[6] divided their patients with hemophilia into two groups: Group 1 had stiff knees with a range of motion of 50° or less, while Group 2 had no stiffness and a range of motion greater than 50°. The results showed that after TKA, the mean improvement in range of motion for Group 1 was 46°, while it was less than 9° for Group 2. The investigators concluded that TKA is an effective procedure for hemophilia patients with a progressive range of motion loss. Cohen *et al.*^[7] also found that despite the potential complications that can arise after TKA in patients with hemophilia, the procedure can ultimately improve the quality of life in the long term.

Studies by Felli *et al.*^[8] and Petrou *et al.*^[9] have shown promising results for mobile-hinged prostheses in primary and revision arthroplasty procedures for patients with RA. In one report, the use of the S-ROM DePuy prosthesis was described in 16 cases of primary and revision arthroplasties in patients with significant instability in the knee joint. During a 2-year follow-up, no cases of prosthesis loosening were observed. Sunnassee *et al.*^[10] detail the application of mega-prosthesis to address musculoskeletal issues in five patients with hemophilia. Two of these patients had pseudotumors, while another two experienced periprosthetic fractures. The final patient had a mix of contracture ROM varying from -18° to 56°. One of the pseudotumor patients required limb amputation due to persistent bleeding, but the other four showed reduced symptoms and improved ROM. In particular, one patient with a stiff knee had their ROM increase from 0° to 110°. The authors found that mega-prosthesis is a suitable alternative for managing complicated total knee arthroplasty alopecia.

CONCLUSION

Hemophilic arthropathy is a serious complication of hemophilia A that can lead to joint damage and ankylosis. Early diagnosis and appropriate management are essential to prevent joint damage and improve functional outcomes. Surgical interventions such as arthroplasty can effectively

correct fixed flexion deformities and improve joint function. However, these interventions carry a risk of complications, and careful preoperative evaluation and postoperative care are necessary to minimize the risk of complications.

Use of Artificial Intelligence tools

Paperpal was used to correct the grammatical errors and refine the language of the case report.

Declaration of patient consent

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

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Conflicts of interest

There are no conflicts of interest.

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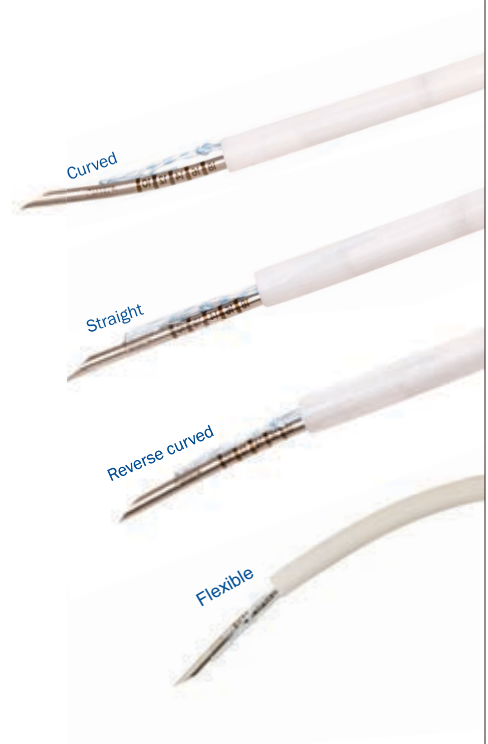
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