



A Prospective Observational Study on Short-Term Functional Outcome of Arthroscopic Anterior Cruciate Ligament Repair of Proximal Tears Using Knotless Single Suture Anchor Technique

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Abstract

Purpose To assess the clinical outcomes in patients with anterior cruciate ligament (ACL) proximal tears undergoing arthroscopic primary repair with knotless single suture anchor technique.

Methods The first twenty-two consecutive patients with proximal ACL tears (Sherman types I and II and high-grade partial tears) treated with arthroscopic primary repair with single suture anchor technique were evaluated until 6 months post-operatively. Patients were evaluated with validated functional outcome measures (IKDC and Lysholm scores) and clinical tests for ACL stability.

Results At 6-month follow-up, 91% of patients ($n = 20$) achieved excellent outcome measures for IKDC and Lysholm scores and had complete stability of the ACL to clinical testing. Two patients with poor outcomes at six weeks; one with subjective instability and the other underwent revision surgery represented a failure rate of 9%. The median Lysholm score was 96 (IQ range, 96–100) and median IKDC subjective score was 87.40 (IQ range, 78.20–88.50) at 6-month follow-up. The improvement in Lysholm and IKDC scores over a period of six months post-operatively was statistically significant when compared to preoperative scores ($p \ll 0.0001$). Maximum improvement in clinical outcomes is achieved in the first 6 weeks post-surgery with a slower increase thereafter, a time interval which may be considered as a figurative yield point for future work in this field.

Conclusion Arthroscopic ACL primary repair with knotless single suture anchor technique provides excellent short-term clinical outcomes in a carefully selected subset of patients with proximal ACL tears. More powered and longer duration studies are needed to understand longer term outcomes.

Level of Evidence Level IV, therapeutic case series.

Keywords Primary ACL repair · Knotless · Single suture anchor · Short-term outcome · Sherman · Partial ACL tear · Proximal tear · IKDC · Lysholm · Arthroscopic · Statistically significant

Introduction

Anterior cruciate ligament (ACL) injuries account for 25–50% of ligamentous knee injuries and causes significant morbidity [1]. Primary open repair of ACL was the standard of treatment for ACL tears in the 1980s and early 1990s;

however, it had a high failure rate due to improper patient selection and poor biological healing capacity of the ligament [2–4]. The advent of arthroscopic procedures during the same era led to a rapid transition away from open ACL repairs towards arthroscopic ACL reconstruction.

Arthroscopic ACL reconstruction has since become the gold standard for ACL ligament surgeries; however, issues related to graft morbidity and harvesting present certain disadvantages [5]. Commonly used graft choices include hamstring tendon, which can lead to hamstring weakness and reduced knee flexion strength, and bone patellar tendon, which can lead to anterior knee pain and kneeling pain [6]. Furthermore, recent biomechanical research has shown that ACL reconstruction does not restore normal joint kinematics

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and may not prevent the early development of secondary osteoarthritis after an ACL injury [7–10]. Also, revision surgery is often complicated after a prior reconstruction due to pre-existing tunnels, tunnel mal-positioning and/or tunnel widening, and the reduced availability of autograft tissue [11–13].

Arthroscopic ACL repair avoids graft related disadvantages and retains the most remnant which could theoretically improve proprioception, facilitate faster rehabilitation and a faster return to pre-injury levels. Experimental studies suggest that preservation of the native ligament, may more effectively restore normal joint kinematics and slow the progression of degenerative changes after an ACL injury [14–16]. Also, when the ACL is primarily repaired, there is minimal bone work and hence can be more easily converted to a reconstruction if the primary ACL repair happens to fail in the future. [17]

However, proper patient selection is paramount in ACL repairs. Selected patients should have proximal ACL tears (complete tears of Sherman type I and II or high-grade partial tears from the femoral side) with good tissue quality.

There is a recent renewed interest in ACL repair, due to the above reasons, in properly selected patients. The purpose of this study was to understand the short-term functional outcomes for ACL repair with single anchor surgical technique.

Methodology

A prospective observational study was conducted in a tertiary care hospital after receiving approval from the hospital institutional review board.

Patients

We included the first 22 consecutive patients who underwent arthroscopic primary ACL repair between 2019 and 2020 with a 6-month follow-up. All the surgeries were done by a single senior arthroscopic surgeon. All patients gave their written informed consent to participate in this study. In all the patients, primary ACL repair was indicated based on careful preoperative and intraoperative assessment. Patients were informed about conventional ACL reconstruction and consented to undergo this procedure if intraoperative evaluation ACL tear pattern or the tissue quality did not fulfil the inclusion criteria.

Inclusion Criteria

1. Clinically incompetent ACL (positive anterior drawer test, Lachman's test, pivot shift tests)
2. Acute ACL tears (<4 months since injury onset)

3. Acute femoral avulsion type ACL injury (type I Sherman)
4. Proximal ACL tear (type II Sherman)
5. Sub-synovial ACL tear/stretch injury
6. High-grade partial ACL tear from the femoral side
7. Good tissue quality
8. Full extension and at least 90 degrees of knee flexion prior to surgery
9. MRI imaging consistent with above inclusion criteria (Sherman Type I and II complete tears, and high-grade partial ACL tears from femoral side)

Exclusion Criteria

1. Delayed ACL tears (>4 months)
2. Complete ACL tear (Sherman type III, IV and V)
3. Poor tissue quality
4. Multi-ligamentous injury
5. Chondral injuries more than 4 cm
6. Associated peri-articular fracture
7. Low-grade partial ACL tears
8. Partial ACL tears involving the tibial insertion site or mid substance
9. Lack of full knee extension or knee flexion less than 90 degrees
10. Significant quadriceps wasting
11. Prior knee surgeries
12. Lack of written informed consent

All patients were recruited into the study after Institutional Ethical Clearance. Patients gave written valid informed consent prior to study participation. All inclusions were based on clinical and MRI findings of repairable ACL tears. Pre-operative baseline data were obtained for all patients including demographic factors (age, gender etc.), injury related factors (duration and aetiology of injury, associated knee pathologies), clinical data (knee examination) and functional outcome measures. Functional outcome was assessed prior to surgery using two validated instruments IKDC and Lysholm score [18]. Post-operatively patients were followed up at regular intervals of 6 weeks, 3 and 6 months and clinical assessment and outcome measure scoring was performed at each visit in addition to brief history for any potential complications (such as pain, stiffness, infection, graft re-tear, instability etc.). All data collection was carried out by the first author and the surgeon was blinded to outcome scoring throughout the study. Clinical assessment was performed by both the authors. Two patients dropped out of the study at 6 weeks post-surgery and despite repeated methods to contact them they were unreachable to participate further and hence considered as lost to follow-up.

Surgical Technique

All surgeries were performed under spinal anaesthesia with administration of an intravenous antibiotic prophylaxis. An examination under anaesthesia of the knee is performed prior to surgery to confirm the antero-posterior instability. A mid-thigh tourniquet is applied with side support with leg hanging by the end of the table. After preparation, tourniquet is inflated and a routine diagnostic arthroscopy was performed through a standard anterolateral portal. Under visual control, an antero-medial portal was created. A probe is used to assess the quality of the torn ACL tissue, the tear site and concomitant knee joint injuries (Fig. 1). Eligibility for ACL repair confirmed according to the abovementioned inclusion criteria intra-operatively. Concomitant meniscal injuries were managed either with direct repair or with cautious partial resection when repair was deemed not feasible due to configuration of the tear or pre-existing degenerative meniscopathy. Concomitant chondral injuries were managed according to staging.

Femoral notchplasty was performed if deemed necessary. The anteromedial portal is used to perform microfracture holes around the femoral footprint to enhance biological healing of the ACL stump. A malleable Passport cannula (Arthrex[®], USA) was placed in the anteromedial portal to facilitate suture passage, management, and ligament repair. The stump is then sutured from distal to proximal in a non-locking Krackow technique with no. 2 Fiberwire suture (Arthrex[®], USA) using a Firstpass Mini (Smith and Nephew[®], USA) suture passer (Fig. 2). A minimum of 2–3 passes are taken through the ACL stump with each limb of the suture, to hold the tissue firmly and traction is checked on the suture. The two ends of the suture are then retrieved out through the AM portal.

The femoral insertion point is marked and entry made with a SwiveLock awl (Arthrex[®], USA) to the necessitated depth (usually 20–23 mm). The two ends of Fiberwire are

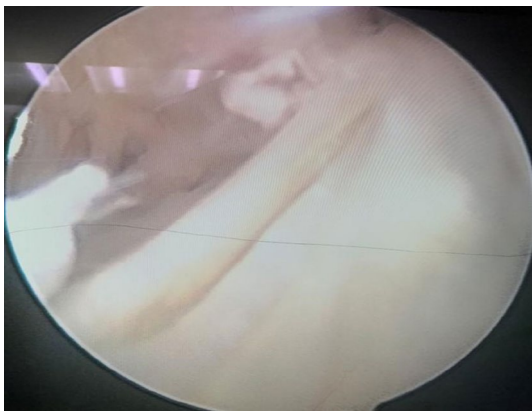


Fig. 1 Single bundle proximal ACL tear (Sherman type II)



Fig. 2 Non-locking Krackow technique of the torn ACL bundle with fiberwire suture using a Firstpass Mini suture passer

loaded into the eyelet of a 4.75 mm PEEK (polyether ether ketone) SwiveLock (Arthrex[®], USA) self-punching anchor. The driver is introduced through the accessory medial portal and inserted into the socket by tapping and then screwing it home while maintaining adequate tension on the suture limbs, Figs. 3 and 4. Standard closure is done and knee immobilizer is applied.

Post-Operative Protocol

The patients were kept in the hospital overnight and were discharged on the first post-operative day. All the patients followed same post-operative rehabilitation protocol. The patients were trained for static quadriceps strengthening exercises, passive knee ROM till 60 degree and non-weight bearing crutch walking with a long knee brace on till first 2 weeks. From the third week, active isometric quadriceps exercises were started

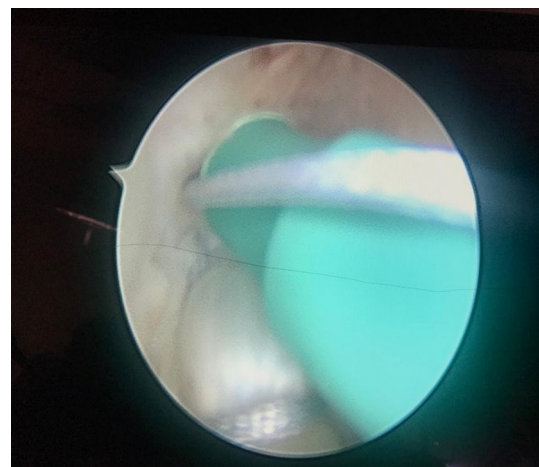


Fig. 3 SwiveLock anchor with loaded ends of the fiberwire is inserted into the socket



Fig. 4 Completed repair of the torn ACL bundle with SwiveLock anchor in situ

and active and passive knee ROM started to tolerable levels; partial weight bearing initially which progressed to full weight bearing with the support of walker with long knee brace on by the end of 3rd week. From the 4th week onwards, the long knee brace was removed and functional ACL knee brace was given for assistance. At this juncture, they were allowed to ride a bicycle or drive a car. By the end of 6th week patients were trained to walk without any brace, wall assisted squatting till 90 degree of flexion and stair ascending and descending. From the 12th week onwards ACL functional brace was removed and normal activities including slow jogging was started. At 24 weeks patients were evaluated by checking the ability to hop on the operated limb in straight line and in zig-zag manner and if successful, they were allow to participate in running and their pre-injury sports activities.

In cases, where meniscal repair had been performed, patients were restricted to partial weight bearing and flexion to a maximum of 90° in the first 4 weeks post-operatively.

Statistical Analysis

Statistical analysis was done using Graph pad prism 9.0.0 (California, USA). Continuous data were summarised as median and interquartile range (IQR) and categorical data, as percentages. Shapiro–Wilk test was used to test for normality of continuous data. Median values for baseline and post-operative data were compared using the Wilcoxon-matched pairs signs rank test. Improvement in scores were compared between groups using Wilcoxon rank sum test.

Results

Patient Demographics

Twenty-two patients were included in the study. Median age at surgery was 31.50 years (range 17–56), out of which

majority ($n = 14$) were under 35 years of age. Most of the study patients were males (63.6%) and left knee (59.1%) was more commonly injured than the right (40.9%).

Eleven patients (50%) had meniscal injuries out of which one had both menisci tear for which lateral meniscus partial resection was done and medial meniscus was repaired; of the remaining ten patients three had lateral meniscal tears (all of whom underwent partial resection) and seven had medial meniscal tears out of whom two underwent repair and five had partial meniscectomy. Five patients had chondral injuries, out of which one had patella grade IV (microfracture done), one had medial femoral condyle grade III defect (underwent screw fixation), three had medial femoral condyle grade IV defect (underwent microfracture). There was one case of associated ligamentous injury of complete MCL tear who underwent simultaneous MCL reconstruction with gracilis autograft.

The aetiology of injury in the majority of our patients was domestic fall ($n = 18$) and three were sports related injuries. The median delay from injury to surgery was 8 weeks (range, 4 days to 4 months).

Two patients were lost to follow-up after visit at 6 weeks, both of them had poor functional scores at 6 weeks. Hence, both the patients were contacted through telephone calls subsequently. One patient reported subjective clinical instability and the other had persistent pain from 8 weeks post-operatively and had undergone a revision surgery done elsewhere at 3 months post-operatively. We considered these two as clinical failures.

Overall Assessment

We found that overall 90.9% of patients had excellent outcomes. This excluded the two patients lost to follow-up after 6 weeks and represented an effective failure rate of 9%.

Objective Outcomes

Among the patients that completed the study, all had completely stable knees at 6 weeks, 3 months and 6 months follow-up to Lachman, anterior drawer and pivot shift tests.

There was statistically significant improvement in Lysholm and IKDC scores both at 6 weeks ($n = 22$, $p < 0.0001$) and at 6 months ($n = 20$, $p < 0.0001$) follow-up when compared to pre-operative scores.

The median difference between pre-operative and 6 months post-operative Lysholm scores was 58.50 (95 CI 52.00–70.00). The median difference between pre-operative and 6 months post—operative IKDC scores was 59.93 (95 CI 54.10–64.40) (Table 1). The most significant increase in both outcome measures was obtained between baseline and six weeks, with a slower increase reported between 6 weeks and 6 months (Fig. 5).

Table 1 Functional outcome measures as assessed by validated outcomes of IKDC and Lysholm at baseline, 6 weeks, 3 months and 6 months post-surgery

	Baseline	6 weeks	3 months ^a	6 months ^a
Lysholm scores median (IQR)	38.00 (26–46.25)	78.00 (78.00–86.50)	92.50 (91.00–94.00)	96.00 (96.00–100.00)
Grading	22-poor	2 poor 9 fair 11- good	2 lost to follow-up 4 good 16 excellent	2 lost to follow-up 20 excellent
IKDC scores median (IQR)	24.70 (21.28–26.40)	55.20 (44.80–57.78)	65.50 (62.38–73.60)	87.40 (78.20–88.50)

n number of patients, *IKDC* International Knee Documentation Committee

^a*n* = 20. 2 patients with poor scores at 6 weeks were not followed up at 3 or 6 months

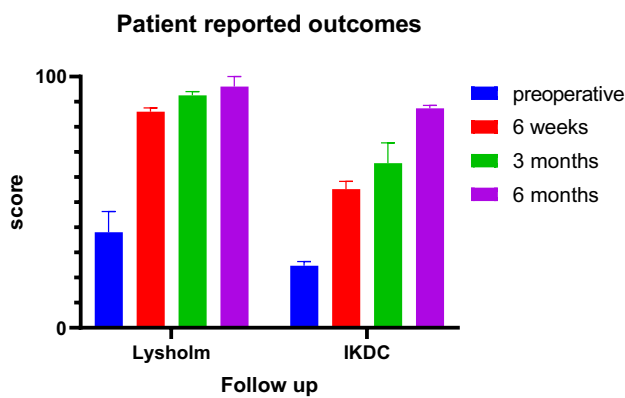


Fig. 5 Bar-chart representing pre-operative and post-operative functional scores

The improvement in both Lysholm and IKDC scores was not found to be affected by gender, age (< 35 vs > 35 years) or the presence or absence of meniscal injuries (Table 2).

Discussion

The goal of primary ACL repair is to reattach the proximally torn ACL to its original insertion point on the lateral femoral condyle. This point of insertion should have maximal biological capacity for healing without changing the isometry of the inserted ligament.

The principal findings in our study were that 91% of the patients with proximal ACL tears (Sherman I and II) who underwent arthroscopic primary repair with single-bundle single-anchor technique achieved a clinically stable knee at 6 months follow-up with significant improvements in both IKDC and Lysholm scores. The Lysholm scores indicates that there was significant pain relief at the end of 6 weeks post-operatively and then a much slower improvement in scores in the following assessments. The IKDC scores also showed the most significant improvement at 6 weeks follow-up, but continued to show a gradual and steady improvement over the study duration. These outcomes are concurrent with the previous studies with suture anchor techniques for proximal ACL tears [19–21]. The above data also signify that the best patient recovery for pain and stability measures is obtained in the first 6 weeks of surgery and that the pain levels will only show a slight decrease thereafter whereas

Table 2 Effect of age, gender and meniscal injuries on improvement in scores

	<i>n</i> (%)	Difference between scores pre-operatively and at 6 months follow-up ^a		<i>p</i> value
		Lysholm	IKDC	
Age < 35 years	14 (70%)	59 (IQR 46–70.5)	59.93 (IQR 53.8–70.1)	Lysholm–0.6204
> 35 years	6 (30%)	58 (IQR 52–79.5)	60.95 (IQR 51.7–69.0)	IKDC–0.6453
Male	14 (70%)	54.50 (IQR 46–70.5)	62.10 (IQR 54.9–68.4)	Lysholm–0.2306
Female	6 (30%)	63.5 (IQR 53.75–79.75)	55.8 (IQR 51.78–68.45)	IKDC–0.5058
With meniscal injuries	11 (55%)	55 (IQR 52–74)	64.4 (IQR 58.8–70.1)	Lysholm–0.67
Without meniscal injuries	9 (45%)	62 (IQR 45–68.4)	54.1 (IQR 49.5–61)	IKDC–0.06

^aMedian (IQR)

^bWilcoxon rank sum test

stability will continue to improve as the patient progresses. Interestingly, we had two patients dropped out of our study at this yield point due to severe pain and postulate that their pain levels would have stayed the same or increased thereafter leading to loss of follow-up. Based on this small data set, one can then establish a yield point of recovery at 6 weeks which tells the treating surgeon as to possible future course of the knee function. More studies are needed to validate this possible yield point.

Achtnich et al. studied twenty ACL repairs with 28 month follow-up, using single knotless suture anchor similar to our technique. In contrast to our method of relatively easy suture passage and knots through the ACL stump, they used a more traumatic method of curved wire passer for the ACL sutures in a modified Mason Allen stitch configuration and smaller 2.9 mm PushLock anchor for the refixation. The damage to residual stump tissue may explain their higher failure rate of 15% with one early re-tear at 3 months post-operatively and two cases of recurrent instability at the end of 28 months [20].

In contrast to our study, in which we performed single-bundle refixation, the studies of DiFelice et al., Hoffman et al. and Weninger et al. used a double-bundle refixation technique [19, 21, 22]. In their case series of eleven patients with proximal avulsion tears, Di Felice used an interlocking Bunnell stitch with a Scorpion passer with number 2 Fiber Wire for each of the bundles and reattached ACL to femur using separated 4.75-mm BioComposite SwiveLock suture anchors. At mean follow-up of 41 months in their study period, the mean IKDC was 86 and the mean Lysholm score was 93. The author reported one clinical failure with early re-tear after three months with a failure rate of 9%. In our study, we achieved similar functional scores at 6 months itself with a more cost effective single anchor single-bundle technique instead of double anchors and double-bundle technique and had a similar failure rate of 9%. Hoffmann et al. also used a technique using Scorpion suture passer passed individually through both the bundles and fixed with single 2.9-mm push lock anchor in 12 patients. Their study showed excellent subjective outcomes only in seven patients (58%) compared to 91% in our study. They noted a mean Lysholm score of 85.3 points and mean subjective IKDC score of 87.3 points. At mean follow-up of 79 months, 25% of their patients had significant early residual laxity; one patient had atraumatic re-tear at 8 weeks post-operatively and two patients had impairing knee instability [21]. Compared to the prior mentioned studies, our results are similar if not better to the available literature on the topic using a single anchor construct, even after extending our inclusion criteria to Sherman type II unlike all the other studies using similar anchor technique in which they included only proximal avulsion type ACL tears only [19–21]. The use of the single anchor construct is important especially for low cost settings where

cost and availability of anchors becomes consequential to the treating surgeon. Our suggestion is that a single anchor technique in a low cost setting may offer comparable results to a double anchor technique.

The surgical technique of ACL repair is still a subject of controversial discussion and there is no consensus yet on which is the preferred method of fixation. Both the internal brace augmentation techniques and double anchor techniques like in Di Felice et al. study make the surgery expensive. In addition, single-bundle technique like in the current study and Achtnich et al. study has the advantage of reduced amount of suture material placed in the ACL which can minimize the risk of strangulation of the ACL bundle. This reduces the potential to cut the ACL bundle apart as well as reduce the foreign material content in the femur, unlike the technique in Hoffman et al. study which might explain their high failure rate including one early atraumatic re-tear. Further, femoral footprint visualisation is better with the preserved intact ACL, so double-bundle re-fixation and its placement in anatomic landmark could be challenging [20]. Nevertheless, the ACL re-fixation technique should be considered for only partial or single-bundle ACL tears in patients with symptomatic instability.

Furthermore, suture passage using a Scorpion suture passer is less traumatic than passing a curved suture passer through the ACL as in the study by Achtnich et al [23]. The latter method might relatively weaken the ACL bundles which possibly could be one of the causes of higher failure rate in their study.

Our proposal for a possible yield point of ACL repair surgery at 6 weeks post-operatively needs further validation. In our small sample size cohort, we observed maximal reduction in pain and functional recovery at 6 weeks post-operatively with a slower increase thereafter. Further, the two patients who dropped out of our study at 6 weeks had severe pain at this interval and affected their ability to continue in the study. It can be postulated that the 6 weeks guide can be used by the treating surgeon as a figurative yield point to calculate patient success.

Interestingly, in our subgroup analyses, we found that the concomitant meniscal injuries with appropriate treatment did not affect the clinical outcomes as there was no statistical significance in the improvement in functional scores. Also, there was no statistically significant difference between age groups (< 35 and > 35 years) or genders. These findings are concurrent with the previous studies and signify that demographic and associated factors are not so important to outcomes once proper patient selection has taken place [19, 20]. A systematic meta-analysis on the role of various factors (demographic and associated injuries) on the outcomes of ACL repair surgery will improve our understanding further.

In the current study, the median delay from injury to surgery was 8 weeks (range, 4 days to 4 months). While

Achtnich et al. included patients operate within 6 weeks from injury, Hoffman et al. study had a mean delay from injury to surgery of only 5.8 (range 1–20) days and for Di Felice et al. study it was 28 days with longest delay of 93 days. The fact that both Di Felice et al. study and our study had the least failure rates might indicate that the inclusion criteria for ACL repair could be stretched to 4 months from the date of the injury [19–21].

One of the major limitation of our study is the small sample size ($n = 22$). This affects both our calculation parameters and sub-group analyses. However, this is one of the larger sample sizes as compared to previous literature on this topic [19, 21]. Another limitation is the short duration follow-up of 6 months only as compared to longer follow-ups in other studies on this topic [20]. We have showed that maximal recovery happens at 6 weeks post-operatively and postulate that the results achieved at 6 months will plateau thereafter, as reported in previous studies [19–21]. Longer duration and larger sample size studies are needed to validate the results above. In addition, heterogeneity in associated injuries including type of meniscal tears and different grades of chondral lesions were also a limiting factor.

Further, relook arthroscopies and MRIs of the knees in the long term will help us to better understand the healing process after ACL repair. One of the bigger losses in our study was the two patients who lost to follow-up as it would have been interesting to see their progression beyond the yield point and if any further intervention was required.

Conclusion

Arthroscopic ACL primary repair with knotless single suture anchor technique gives excellent short-term clinical success in a carefully selected subset of patients with Sherman type I and type II ACL tears with good tissue quality. We believe that primary ACL repair in properly selected patients has a big role to play in the management of ACL injuries. Further, we suggest a figurative yield point at 6 weeks post-surgery which should help the clinician understand the expected future outcome of the operated knee.

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Declarations

Conflict of interest JJ and MA declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human or animal subjects performed by the any of the authors.

Informed consent For this type of study informed consent is not required.

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