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Anterolateral ligament reconstruction improves the clinical and functional outcomes of anterior cruciate ligament reconstruction in athletes

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Abstract

Purpose To compare the outcomes of anterior cruciate ligament (ACL) reconstruction with those of combined ACL and anterolateral ligament (ALL) reconstruction in ACL-deficient knees. The objective of this study was to improve knowledge regarding the treatment of ACL-deficient knees with combined ACL and ALL reconstruction. Combined ACL and ALL reconstruction has been hypothesized to result in better clinical and functional outcomes than isolated ACL reconstruction (ACLR).

Methods One-hundred and seven adult male athletes with ACL tears and high-grade pivot shifts were randomized into two groups. Those in group A ($n=54$) underwent ACLR, while those in group B ($n=53$) underwent combined ACL and ALL reconstruction. The median age was 26 (18–40) and 24 (18–33) years in groups A and B, respectively, and the median follow-up was 60 (55–65) months. Physical examination findings, instrumented knee laxity tested using a KT-1000 arthrometer, and International Knee Documentation Committee Scale (IKDC) scores were used to evaluate the outcomes.

Results One-hundred and two patients were available for follow-up: 52 in group A and 50 in group B. Postoperatively, the pivot shift was normal in 43 (82.7%) and 48 (96%) patients in groups A and B, respectively ($p<0.001$). The median instrumented knee laxity was 2.5 ± 0.7 (1.2–6.1) mm in patients in group A and 1.2 ± 0.7 (1.2–3.2) mm in patients in group B ($p<0.001$). Additionally, 44 (84.6%) patients in group A had normal IKDC scores and 3 (5.8%) had nearly normal scores, while 48 (96.0%) patients in group B had normal IKDC scores and 2 (4%) had nearly normal scores ($p<0.001$).

Conclusion Combined ACL and ALL reconstruction, compared with isolated ACLR resulted in favourable clinical and functional outcomes, as demonstrated by decreased rotational instability and instrumented knee laxity, a lower graft rupture rate and better postoperative IKDC scores.

Level of evidence 1.

Keywords ACL repair · ACL + ALL reconstruction · Knee rotational stability

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Introduction

Anterior cruciate ligament reconstruction (ACLR) is currently one of the most common procedures in sports medicine [31, 43]. Despite advancing knowledge of ACL injury and techniques for ACLR, persistent rotational instability and graft rupture remain concerns following this surgery [1, 3, 15, 33, 34, 37, 43]. These undesirable outcomes have directed sports orthopaedic surgeons to seek alternative procedures. During the past few years, the anatomy and function of the anterolateral ligament (ALL) have been described in detail [4, 13, 21, 41, 42]. The ACL is the primary restraint during the anterior drawer test (ADT) at all flexion angles and during internal rotation at flexion angles less than 35°. The ALL is a secondary stabilizer for the ACL, preventing anterior tibial translation and internal rotation, especially at 30°–90° of knee flexion [23, 25]. Since the ALL has also been found to prevent the knee pivot shift phenomenon, injury to this ligament is thought to be responsible for inadequate restoration of rotational knee stability following ACLR [4, 5, 23, 25, 26, 29, 30, 39]. Additionally, in the ACL-deficient knee, the ALL and Kaplan fibres contribute to restraint during the pivot shift and anterior tibial translation [12]. Internal rotation significantly increases with further sectioning of the ALL and Kaplan fibres at flexion angles of 30°–90° and 60°–90°, respectively [12]. Although some authors stated that the ALL is not strong enough to cause a Segond fracture and that other structures such as the iliotibial band (ITB), Kaplan fibres and anterior oblique band (AOB) of the fibular collateral ligament (FCL) are involved, [12, 24] with the understanding of the anatomy of the ALL, biomechanical and radiological tools have been used to determine that a Segond fracture could be bony avulsion of the ALL [4, 5, 10, 12, 23, 25]. The precise pathogenesis of Segond's fracture has been the subject of debate because of the complexity of the anterolateral ligamentous anatomy. Recently, Claes et al. have reported that Segond's fracture is actually a bony avulsion of the ALL [4, 5, 12]. ALL injuries have been found in up to 79% of cases of acute ACL injury [6, 30, 42]. Nevertheless, the indications for and outcomes of performing combined ACL and ALL reconstruction surgery to restore normal knee kinematics in ACL- deficient knees are still being explored [36, 38, 46]. Few clinical studies of combined ACL and ALL reconstruction surgery have been performed [17, 29, 37, 38, 46]. Those studies reported better clinical and functional outcomes and a lower graft rupture rate with combined ACL and ALL reconstruction than with isolated ACLR and as well as no specific complications [37]. In this study, the outcomes of ACLR were compared with those of combined ACL and ALL reconstruction in ACL-deficient knees using a comparative, prospective randomized methodology. Combined ACL and ALL reconstruction in comparison with isolated ACLR was hypothesized to result in better clinical and functional outcomes.

Material and methods

This study was ethically approved by the institutional review board of the Al Razi Orthopaedic Hospital, Ministry of Health, Kuwait and was, therefore, performed in accordance with the ethical standards laid down in the Declaration of Helsinki and amended by the 64th WMA General Assembly, Brazil, 2013. (ID number: RAZI-IRB-2014-08-0001). Oral assent and written consent were obtained from the participants before enrolment in the study. A prospective randomized trial including 107 male athletes with combined ACL and ALL tears was carried out between April 2014 and March 2015. The median follow-up was 60 months, ranging from 55 to 65 months; the median age was 26 (18–40) years and 24 (18–33) years in groups A and B, respectively. The median duration between injury and surgery was 3 months (2.5–3.7) in group A and (2.5–3.8) in group B. Five patients (4.6%) did not complete their follow-up. Out of 102 patients, 42 patients played soccer, 26 played handball, 5 participated in Crossfit, 15 played basketball, 7 played volleyball, 5 played tennis, 1 practised kung-fu, and 1 fenced. In addition to ACL injuries, meniscal injuries were reported in 28 patients (28.4%), 15 (28.8%) in group A and 13 patients (26.0%) in group B, with a total number of 29 injured meniscus 18 medial, and 11 lateral as 1 patient had injured both menisci (Table 1). A preoperative pivot-shift test was carried out under anaesthesia by one surgeon for three positions of rotation: medial, neutral and lateral rotation of the tibia [16, 19, 35]. Nevertheless, the diagnosis of combined ACLs and ALLs tears was based on the findings of three-dimensional magnetic resonance imaging (MRI). Patients with a high-grade pivot shift (III), Segond fracture, a high level of sports activity and those participating in sports involving frequent pivoting were considered to have met the inclusion criteria [5, 17, 25, 37, 38, 46]. Patients with a history of knee surgery, i.e., high tibial osteotomy (HTO), knee dislocation, or preoperative signs of osteoarthritis and those presenting for ACL revision surgery or multiligamentous knee injury, were excluded [26]. Patients were randomized into two treatment groups via simple randomization (flipping a coin) behind closed doors prior to the surgical appointments. Those in group A ($n=54$) underwent ACLR, while those in group B ($n=53$) underwent combined reconstruction of the ACL and ALL. However, 102 patients were presented for the final analysis (Fig. 1). All surgeries were performed by the same fellowship-trained orthopaedic sports surgeon with the assistance of another orthopaedic surgeon. The postoperative

Table 1 Background characteristics of the patients

	Group A			Group B	
Characteristic	52 (100%)			50 (100%)	
Median age (range) years	(26) 18–40			(24) 18–33	
Sex male/female No	52/0			50/0	
Median duration between injury and operation (range) months	(3) 2.5–3.7			(3) 2.5–3.8	
Median follow-up time (range)	60 (55–65) months				
Patients with Meniscal injury	15 (28.8%)			13 (26.0%)	
Medial	10			8	
	P.M	M.S		P.M.	M.S
	8	2		7	1
Lateral	6			5	
	P.M.		M.S	P.M.	M.S
	4		2	4	1
Both	1			0	
Patients available for final assessment	P.M.		M.S	P.M.	M.S
	2		–	–	–
	52			50	

ACL anterior cruciate ligament, *ALL* anterolateral ligament, *P.M.* partial meniscectomy *M.S.* meniscal sutures

clinical assessments were performed by orthopaedic surgeon who did not participate in the surgeries. The instrumented laxity testing using a KT-1000 arthrometer (MED metric, San Diego, California, USA) [1, 20, 32] was performed by a third surgeon. The functional outcomes of the patients have been assessed using Lysholm knee scoring scale, Tegner activity score and International Knee Documentation Committee Scale (IKDC) score [7].

Surgical technique

Both the gracilis and semitendinosus tendons were harvested. In group A, the gracilis tendon was set aside for possible augmentation if needed, and a standard diagnostic arthroscopy was carried out. The ACL footprints were identified. ACLR was performed by the (all-inside technique) using the semitendinosus tendon. The ACL graft was quadrupled, the graft size ranged from 8 to 11 mm in diameter and 7–7.5 cm in length and was fixed on the tibial and femoral sides using an adjustable suspensory ACL TightRope® RT device (Arthrex, Naples, FL, USA) [44]. Following ACLR (all-inside technique), patients in group B underwent minimally invasive ALL reconstruction. The gracilis graft was doubled; the graft ranged from 4.4 to 5.5 mm in diameter with a total length of 10 cm.The proximal socket of the ALL was made on the lateral femoral condyle just proximal and posterior to the proximal attachment of the lateral collateral ligament [8, 22, 29, 36, 44, 46]. The ALL graft was secured into this socket using a 4.75 mm-diameter bioabsorbable fully threaded knotless anchors (BioComposite SwiveLock®; Arthrex, Naples, FL, USA). The distal attachment of the ALL was marked halfway between the fibular head and Gerdy's tubercle. After securing the graft in the femoral socket, it was passed underneath the ITB, and the graft was secured into its tibial bone sockets under 0°–15° of flexion. Partial meniscectomy was performed for 15 medial and 8 lateral menisci. The rest of the injuries, however, were repaired using the FasT-Fix technique (Smith and Nephew, Andover, Massachusetts, USA).

Postoperative rehabilitation

Postoperatively, the patients were allowed partial weight bearing as tolerated with crutches. Closed kinetic chain quadriceps exercises were started immediately, while cycling was allowed at the 4th postoperative week. Three months following the surgery, running was allowed. Participation in pivoting sports was not allowed before the 9th postoperative month. Weight-bearing was not allowed in patients who underwent meniscal repair for 4–6 weeks postoperatively and knee flexion was limited to 90°.

Statistical analysis

A statistical power analysis was performed for sample size estimation; the effect size (ES) in this study was 0.55 which was considered to be a medium ES according to Cohen's (1988) criteria. With alpha = 0.05 and

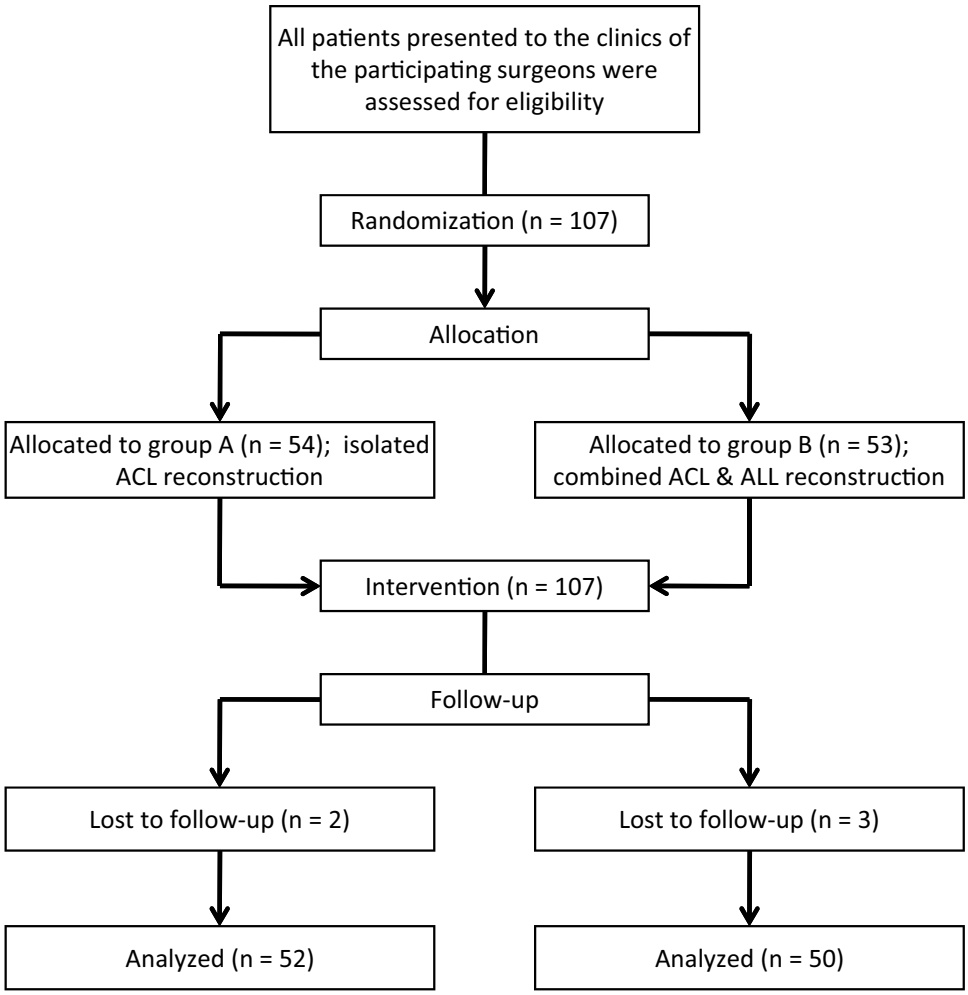

Fig. 1 Flowchart of the trial

power = 0.8, the projected sample size needed with this ES (G*Power 3.1) was $n = 105 \pm 2$ for this group comparison. The data were analysed using SPSS 17.0 software (SPSS Inc, Chicago, Illinois, USA). Fischer's exact test was used to study the association between two qualitative variables. Qualitative and quantitative variables were assessed using the Mann–Whitney *U* test. A *p* value of < 0.05 was considered the cut-off level for statistical significance.

Results

The clinical outcomes are summarized in Table 2. Although patients in group B showed better postoperative values according to ADT, the results of Lachman's test were found statistically non significant (n.s). Regarding the postoperative pivot shift, normal results were observed in 43 (82.7%) and 48 (96.0%) patients in group A and group B, respectively ($p < 0.001$). Moreover, none of the patients in group B had grade II or III pivot shifts, while 5 (9.6%) patients in group A had grade II or III pivot shifts $p < 0.001$.

Regarding the final result of the treated meniscal injuries all patients were returned to sports activity without any residual complaints.

Table 3 demonstrates the results of the instrumented knee laxity test performed using a KT-1000 arthrometer. Preoperatively, the median translation was 10.2 ± 0.8 (3.8–10.0) mm for group A, and 11.5 ± 0.8 (4.3–10.0) mm for group B (n.s.). Postoperatively, the median translation was 2.5 ± 0.7 (1.2–6.1) mm, and 1.2 ± 0.7 (1.2–3.2) mm for patients in group A and B, respectively ($p < 0.001$). Five (9.6%) patients in group A had an anterior translation greater than 5 mm, while none of the patients in group B showed such translation $p < 0.001$. The functional outcomes are presented in Table 4. No statistically significant differences were found in neither the Lysholm knee score nor the Tegner activity score (n.s.) between the two treatment groups postoperatively. Forty-four (84.6%) patients in group A and 48 (96.0%) patients in group B had normal IKDC scores ($p < 0.001$). Five patients in group A and no patients in group B had IKDC scores of grade C or D. No patients in either groups had

Table 2 Clinical findings of the two groups of patients treated with either combined reconstruction of the anterior cruciate ligament (ACL) and anterolateral ligament (ALL) or isolated ACL reconstruction

Clinical test	Treatment group		*p* value*
	Group A	Group B	
	52 (100%)	50 (100%)	
Anterior drawer test – postoperative			
Negative	45 (86.5)	47 (94.0)	(n.s.)
Grade I	4 (7.7)	3 (6.0)	
Grade II	2 (3.8)	0 (0.0)	
Grade III	1 (1.9)	0 (0.0)	
Lachman's test – postoperative			
Negative	44 (84.6)	48(96.0)	(n.s.)
Grade I	6 (11.5)	2 (4.0)	
Grade II	2 (3.8)	0 (0.0)	
Grade III	0 (0.0)	0 (0.0)	
Pivot shift – preoperative			
Normal	0 (0.0)	0 (0.0)	(n.s.)
Grade I	0 (0.0)	0 (0.0)	
Grade II	7 (13.4)	2 (4.0)	
Grade III	45 (86.5)	48 (96.0)	
Pivot shift – postoperative			< 0.001
Normal	43 (82.6)	48 (96.0)	
Grade I	4 (7.7)	2 (4.0)	
Grade II	3 (5.8)	0 (0.0)	
Grade III	2 (3.8)	0 (0.0)	

*p value was measured using Fisher's exact test

immediate postoperative complications that required revision or readmission. Two patients in group B had (type 1) arthrofibrosis that was managed conservatively with an intensive course of physiotherapy, and they achieved full knee range of motion within 4 weeks. Graft failure has been reported in five patients (9.6%) in group A.

Discussion

The most important finding of the present study was that combined ACL and ALL reconstruction can result in favourable clinical and functional outcomes, with no specific complications. This was demonstrated by better postoperative laxity restoration, higher IKDC scores and a lower graft rupture rate. These results were supported by the findings of previously published studies on combined ACL and ALL reconstruction [28–30, 36–39, 46]. In this prospective randomized trial, the outcomes of combined ACL and ALL reconstruction were studied in comparison with those of isolated ACLR in athletes with ACL-deficient knees and high-grade pivot shifts. In the past few decades, many surgical techniques have been developed to improve the functional outcomes of ACLR. Double-bundle reconstruction was found to result in less laxity than single-bundle reconstruction [18, 27]. Despite the excellent outcomes of the available techniques, restoring rotational stability remains a challenge for surgeons [3, 33, 34]. With the addition of lateral extra-articular tenodesis to ACLR, better rotational stability of the knee could be achieved [9, 40, 45]. More recently, attention has been paid to combined ACL and ALL reconstruction [14, 17, 37, 38, 46]. In a case series of 83 patients who underwent combined ACL and ALL reconstruction, significant improvement in clinical and functional outcomes was achieved at a mean follow-up of 32.4 months [38]. The pivot shift test result was normal in 91.6% of these patients and the final IKDC scores were 91.6%. In addition, the mean instrumented anterior knee laxity decreased from 8 to 0.7 mm. At a mean follow-up of 60 months, our results are similar to those of the aforementioned study. In a retrospective study comparing isolated ACLR

Table 3 KT-1000 arthrometer {testing} of the two groups of patients treated with either combined reconstruction of the anterior cruciate ligament (ACL) and anterolateral ligament (ALL) or isolated ACL reconstruction

Instrumented knee-laxity testing	Treatment group		*p* value*
	Group A	Group B	
	52 (100%)	50 (100%)	
KT-1000 arthrometer – preoperative			
< 3 mm	0 (0.0)	0 (0.0)	(n.s.)
3–5 mm	3 (5.8)	2 (4.0)	
> 5 mm	49 (94.2)	48 (96.0)	
Median ± IQR (range)	10.2 ± 0.8 (3.8–10.0)	11.5 ± 0.8 (4.3–10.0)	
KT-1000 arthrometer – postoperative			< 0.001
< 3 mm	42 (80.8)	48 (96.0)	
3–5 mm	5 (9.6)	2 (4.0)	
> 5 mm	5 (9.6)	0 (0.0)	
Median ± IQR (range)	2.5 ± 0.7 (1.2–6.1)	1.2 ± 0.7 (1.2–3.2)	

*p value was measured using the Mann–Whitney U test

Table 4 Functional outcomes of the two groups of patients treated with either combined reconstruction of the ACL and ALL or isolated ACL reconstruction

Knee outcome score	Treatment group		*p* value*
	Group A	Group B	
	52 (100%)	50 (100%)	
Lysholm knee scoring scale – preoperative			
Excellent (95–100)	0 (0.0)	0 (0.0)	(n.s.)
Good (84–94)	0 (0.0)	0 (0.0)	
Fair (65–83)	21 (40.4)	22 (44.0)	
Poor (≤64)	31 (59.6)	28 (56.0)	
Median ± IQR (Range)	74 ± 14.5 (40 – 82)	72 ± 13.5 (40- 83)	
Lysholm knee scoring scale – postoperative			
Excellent (95–100)	44 (84.6)	47 (94.0)	(n.s.)
Good (84–94)	5 (9.6)	3 (6.0)	
Fair (65–83)	3 (5.8)	0 (0.0)	
Poor (≤64)	0 (0.0)	0 (0.0)	
Median ± IQR (Range)	94 ± 4.5 (65 – 100)	96 ± 5.0 (70 – 100)	
Tegner activity score – preoperative			
Median ± IQR (range)	6.9 ± 1.6 (5.0–8.0)	6.4 ± 1.2 (5.0–9.0)	(n.s.)
Tegner activity score – postoperative			
Median ± IQR (range)	7.8 ± 1.4 (6.0–9.0)	7.9 ± 0.8 (5.0–9.0)	(n.s.)
IKDC[a] – preoperative			
Grade A	0 (0.0)	0 (0.0)	(n.s.)
Grade B	0 (0.0)	0 (0.0)	
Grade C	25 (48.1)	23 (46.0)	
Grade D	27 (51.9)	27 (54.0)	
IKDC[a] – postoperative			< 0.001
Grade A	44 (84.6)	48 (96.0)	
Grade B	3 (5.8)	2 (4.0)	
Grade C	3 (5.7)	0 (0.0)	
Grade D	2 (3.9)	0 (0.0)	

**p* value was obtained using the Mann–Whitney *U* test for all variables except the IKDC which was obtained using Fisher's exact test

[a]IKDC = International Knee Documentation Committee subjective knee evaluation form

with combined ACL and ALL reconstruction in patients with chronic ACL tears, the graft rupture rate was reported in 7.3% among the patients treated with isolated ACLR, while there were no cases in the other group [14]. In our study, regarding graft rupture there were five (9.6%) cases in group A and no cases in group B. Similar results were observed in a prospective cohort study that included 502 patients, graft failure rate in the group of patients who underwent combined ALL and ACLR was 2.5–3.1 times less than the rate in the other two ACLR groups (B-PT-B grafts and 4HT grafts) [37]. All these findings support our results and highlight the importance of reconstructing the ALL in appropriate patients with ACL- deficient knees. A prospective randomized trial showed that reconstructing the ALL during ACLR improved the objective and subjective outcomes at a mean follow-up of 27 months [17]. The results of the instrumented knee laxity test were similar to our findings; however, our patients showed significant differences in the pivot shift grade, and IKDC score. Both studies indicate that ALL reconstruction should be considered for specific patients with ruptured ACL. Sectioning the ALL in the ACL-sectioned knee has been found to lead to a mean increases of 3 mm in anterior tibial translation on both anterior stability and simulated pivot-shift testing [2, 30, 39]. Augmented ALL reconstruction with ACLR in a cadaveric setting reduces knee laxity on internal rotation and anterior translation to a level similar to that observed with intact ligaments, except at knee flexion angles between 0° and 20° [28]. When these findings were considered with the improvement in the anterior translation results and the higher percentage of normal results in our patients who underwent combined ACL and ALL reconstruction, the importance of ALL reconstruction cannot be neglected.

A number of limitations do exist in the current study. Unfortunately, due to societal restraints (religious and familial traditions) that can prevent females from participating in competitive sports; very few of females presented with serious related injuries; thus, all our patients were males. Blinding of

the patients or surgeons to the surgical technique was not possible unless unnecessary incisions were made in those patients treated with isolated ACLR. The pivot shift test, albeit very useful for the purpose of this study, is subjective and examiner dependent. Although the two sprinter muscles were sacrificed, there were no residual functional deficits or subjective complaints among our patients [11].

Conclusion

Combined ACL and ALL reconstruction, compared with isolated ACLR resulted in favourable clinical and functional outcomes, as demonstrated by decreased rotational instability and instrumented knee laxity, a lower graft rupture rate and better postoperative IKDC scores.

Author contributions FH—The principal investigator. Participated in designing the study, data collection, data interpretation and writing the paper. Performed all the operations. Approved the final version of the manuscript. AAH—Participated in designing the study, data collection, data interpretation, writing the paper and performed all the statistical tests. Approved the final version of the manuscript. YM—Participated in designing the study, data collection, data interpretation, writing the paper and assisting in the operation room. Performed all the statistical tests. Approved the final version of the manuscript. AS—Participated in designing the study, data collection, data interpretation, writing the paper and assisting in the operation room. Approved the final version of the manuscript. TAE—Participated in designing the study, data interpretation and writing the paper. Approved the final version of the manuscript. MGM—Participated in designing the study, data interpretation and writing the paper. Approved the final version of the manuscript. WS—Participated in designing the study, data collection, data interpretation, writing the paper and assisting in the operation room. Approved the final version of the manuscript. AN—Participated in designing the study, data collection, data interpretation, writing the paper and assisting in the operation room. Approved the final version of the manuscript.

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Compliance with ethical standards

Conflict of interest This research received no conflict of interest.

Ethical approval All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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