ABSTRACT

Objective: This study compared the clinical and radiological results of the arthroscopic transosseous (ATO) and transosseous-equivalent (TOE) double-row rotator cuff repair techniques.

Methods: Prospective data collected from patients treated with ATO (32 women and 7 men, mean age: 57.03±6.39 years) and TOE (36 women and 8 men; mean age: 57.86±7.81 years) techniques were retrospectively evaluated. The visual analog scale score, Constant score, and Oxford shoulder score were used to assess the clinical results. Anchor pullout on standard anteroposterior shoulder radiographs and rotator cuff re-tear on magnetic resonance images were examined at the final follow-up to evaluate the radiological results. Rotator cuff re-tears were graded as per the classification system described by Sugaya et al.

Results: The mean follow-up duration was 33.3±11.8 months. No difference was observed in the demographic data of the two groups. Significant improvement was observed in the postoperative shoulder scores of the groups; however, no difference was observed between the groups. Re-tear was detected in 10 patients of the TOE group and 9 patients of the ATO group. Age, tear size, and retraction level could cause re-tear.

Conclusion: In the treatment of rotator cuff tears, the ATO and TOE techniques may achieve considerable improvements in shoulder functions in the short term.

Level of Evidence: Level III, Therapeutic study

Introduction

Rotator cuff repair techniques have been developed since many years (1). The open transosseous repair technique was first defined by McLaughlin (2). With the development of arthroscopy and implants, mini open, arthroscopic single-row (SR) and double-row (DR) repair methods, arthroscopic transosseous-equivalent (TOE) suture bridge technique, and arthroscopic transosseous technique (ATO) with or without implants have been defined over the years (3-5). These changes were aimed at achieving better bone tendon healing and better functional results. Several biomechanical studies have indicated that the DR technique is superior to the SR technique because of enhanced footprint coverage, better construct stability with higher ultimate tensile load, and decreased gap formation (6-10). Moreover, compared with the DR technique, the TOE technique is a stronger method and achieves superior restoration of the footprint (11). Although some studies have revealed contradictory results, no clinically meaningful difference has been determined between the two techniques in level-1 randomized studies (12, 13).

The transosseous technique has become popular again owing to weak bone stock at the footprint, increasing pullout rates of anchors, remaining anchors at the footprint making revision more difficult in re-tear cases, high costs of using multiple anchors, and the development of devices that allow arthroscopic tunnel opening and suture passing (14-19). The ATO technique can be used with or without implants. In particular, the suture used in the technique without implant can cause bone laceration. An implant has been developed to prevent this complication and improve repair durability (1). Sharc-FI (NSC Lab, Carpi, Italy) allows the use of...
the ATO technique, and some devices help open a transosseous tunnel. Accordingly, medial and lateral row repair, similar to the TOE technique, as well as suture bridge can be performed. Although one study has reported on the results of the ATO technique with implant, to our knowledge, no comparative study exists.

This study aimed to compare the clinical and radiological results of the TOE and ATO techniques with implant in the short term.

**Materials and Methods**

Prospective data collected from patients treated with rotator cuff repairs using the ATO and TOE techniques between January 2013 and October 2017 were retrospectively evaluated. The operations were performed by two experienced surgeons (AF and MU). TOE and ATO implant repair techniques were used in 142 patients at our clinic for rotator cuff tear diagnosis. The patients were divided into TOE and ATO groups depending on the technique used.

The inclusion criteria were as follows: patient aged 18–65 years, according to Cofield (20) classification, those with medium, full thickness, isolated supraspinatus, or supraspinatus with infraspinatus extension tear, arthroscopic biceps tenotomy, or tenodesis and acromioplasty. Furthermore, patients with subscapularis tear; SLAP lesion, excluding type 1 and 2; SLAP repair; teres minor tear; irreparable tear; grade 3 fatty infiltration; frozen shoulder; arthrosis; osteonecrosis; osteomyelitis; and a history of shoulder surgery were excluded. A total of 39 ATO and 44 TOE patients were eventually evaluated on the basis of these criteria. Informed consent and institutional review board approval were obtained for the study.

**Surgical techniques**

All the surgeries were performed under general anesthesia and in the beach chair position. First, diagnostic arthroscopy was performed; thereafter, entry was made to the subacromial space. Bursectomy was performed, and a rotator cuff tear was revealed. The arthroscope was moved to the lateral portal, and the tear type, size, and retraction degree were identified (Figure 1a, b). When necessary, the rotator cuff was released from the supraglenoid area and rotator interval. The footprint and tear ends were refreshed using a shaver blade and punch. When required, biceps tenodesis with anchor or biceps tenotomy was performed for patients with biceps structural lesion, instability, or subluxation.

In terms of repair with the TOE technique, two standard pieces of metallic 5-mm anchors (each loaded with two pieces of reinforced suture) were placed (Twinfix, Smith & Nephew) at the medial row. With the use of various suture passer devices, the sutures were passed through the rotator cuff and tied. The suture ends at the medial row were loaded to the 5.5-mm knotless anchor (Footprint, Smith & Nephew) and placed at the lateral of tuberculum majus to create a lateral row and suture bridge. A single anchor was used for the lateral order tears of 1 and 2 cm, and two knotless anchors were used for tears sized 3 cm. One from each suture of the knots at the medial row with four ends was loaded to the single knotless anchor of the lateral row, and the other empty sutures were cut. In cases where double knotless anchors were used in the lateral row, all the suture ends knotted at the medial row were loaded and placed to the knotless anchor (Figure 2).

**Main Points**

- This is the one of the small number of studies which compared ATO and TOE techniques in the literature.
- Significant functional and radiological results were achieved with both techniques in the short term. Also better functional results were determined in patients with rerupture in ATO group.
- Although no difference was observed in the re-tear rates of the groups, better functional results were determined in patients with re-tear in ATO group.
In terms of the ATO technique, an implant entrance was opened at a distance of 18-20 mm distal to the lateral tubercular corner, with an alignment of the middle of the tear side. Then, a transosseous tunnel was opened using a tool loaded with a carrier suture at its end. The exit location was close to the cartilage border. Two reinforced sutures were loaded to the transosseous implant (Sharc-FT, NCS lab, Carpi, Italy). Four ends of these sutures were passed through the tunnel via the carrier suture (Figure 3). These sutures were drawn from the anterior portal, and the implant was placed on the cortex. Using suture passer devices, the sutures coming from the tunnel were passed through the rotator cuff and tied. One end of each suture tied at the medial row was passed through the hole behind the implant and tied with the other end. Thus, the lateral row repair and suture bridge were completed (Figure 4).

Minimal anteroinferior acromioplasty was performed, and coracoacromial ligament was protected in both the techniques.

Rehabilitation
A standard program was applied for both the groups. A shoulder sling with abduction pillow was used by the patients for four weeks postoperatively. Elbow, wrist, and hand exercises were started on the first day. Passive range of movement (ROM) exercises were started in the 3rd week after the surgery. Active-assisted exercises were started after the 4th week, and active exercises were started after the 6th week. Strengthening exercises were started after the 8th week. The patients were allowed to return to sports and perform high-level activities after the 6th month.

Outcome assessment
Clinical and radiological assessments were performed by two surgeons experienced in the field of shoulder surgery (AO, OT); all decisions were based on a joint consensus. Based on the patient’s medical records as well as radiological (magnetic resonance imaging: MRI) and surgery records, the tear type, size, retraction level, fatty degeneration degree on MRI, intra-joint additional pathology (SLAP1 and 2) existence, additional procedures (biceps tenotomy or tenodesis, acromioplasty), and complications were evaluated and recorded. The tear type was determined according to the Ellman and Garstman classification (21). The tear size was determined as the value measured by the probe during the surgery. Preoperative coronal magnetic resonance (MR) cross-sections and the surgery records were evaluated for retraction level, and evaluation was made according to Patte classification (22). The Thomazeau method was used for fatty degeneration in T1 sagittal MR cross-sections (23).

For clinical assessment, the visual analog scale (VAS), constant, and Oxford shoulder scores were evaluated based on the preoperative and last follow-up records of the patients.
For radiological assessment, anchor pullout was examined on standard anteroposterior shoulder radiography (Figure 5), and re-tear was assessed using MR images (Figure 6) taken during the last checkup. Rotator cuff re-tear as a repair failure was graded as per the classification system described by Sugaya et al. (24). Sugaya type III is defined as insufficient thickness without discontinuity and suggests a partial tear (Figure 7). Type IV indicates a minor discontinuity and suggests a small tear. Type V is defined as a major discontinuity and represents an obvious tear. In this study, Sugaya type III MRI findings suggesting a partial tear were assigned to the failed repair group. This is because numerous studies have indicated that postoperative Sugaya type III lesions could develop into obvious tears (25, 26).

**Statistical analysis**

All statistical analyses were performed using the Statistical Package for Social Sciences version 20.0 (IBM Corp.; Armonk, NY, USA). The normality of the data was determined using the Shapiro Wilk test. The descriptors were presented as the mean±SD or as frequency tables for quantitative and qualitative parameters, respectively. Differences between the ATO and TOE groups were reviewed either using the Student’s t-test or Mann–Whitney U test. Pearson’s Chi-square test and Fisher’s exact tests were used to compare the qualitative data of the groups. Paired sample t-test was used to evaluate the change in the quantitative data over time. A logistic regression model was constructed using the parameters of age, sex, tear type, size, retraction level, fatty degeneration degree, re-tear existence, biceps tenotomy, and tenodesis existence using the Enter method. Power analysis was determined as 95% in all analyses, and p≤0.05 was considered to indicate statistical significance.

**Results**

The mean follow-up duration was 33.3±11.8 months. No difference was observed between the two groups in terms of the distribution of demographic data, tear type and size, fatty degeneration degree, intra-joint additional pathology (SLAP 1 and 2) existence, and additional procedures (biceps tenotomy or tenodesis, acromioplasty) (Table 1).

Considerable improvements were noted in the VAS, Constant, and Oxford shoulder scores after the surgery. However, no difference was observed in the preoperative and postoperative scores between the groups (Table 2).

Re-tear was identified in the MR examination of patients during their final follow-up; in the TOE group: 10 (Sugaya type III), in the ATO group: 8.
In the final follow-up, the Constant and Oxford shoulder scores of the patients with re-tear were 64.4 and 25.9 in the TOE group and 76.33 and 37.2 in the ATO group, respectively. Considerable improvements were observed in the functional scores of patients with a re-tear after the surgery; however, improvement in the ATO group was more significant than that in the TOE group (p<0.05).

After testing for multicollinearity, the factors that could cause re-tear were investigated for both the groups using multivariate logistic regression analysis. Age, tear size, and retraction level were significantly associated with cuff repair failure in both the groups (p<0.05).

With respect to the complications, a superficial infection was found in one patient of the TOE group, which was treated with antibiotic therapy. Cortical penetration of implant occurred in one patient of the ATO group.
Various re-tear rates have been reported in numerous studies based on the fixation method. Plachel et al. stated that an overall re-tear rate of 33% was obtained in patients treated with ATO repair, with an average follow-up duration of 15 years (33). Bau-

Discussion

The most important finding of this study was the similar clinical success rate at a mean follow-up duration of 33.3±11.8 months in patients with rotator cuff rupture treated using ATO and TOE techniques. No difference was observed in the re-tear rates of the groups. However, the Oxford shoulder scores of those in the ATO group with re-tear improved more than those in the TOE group.

Traditional open transosseous repair gives excellent results for the fixation of the tendon to the bone and has represented the gold standard for rotator cuff repair with excellent long-term results (21). With the development of devices that allow arthroscopic transosseous repair, the ATO technique is now being preferred because of its biological and biomechanical features (27-29). Moreover, the TOE technique could support biological healing at a repaired rotator cuff tendon insertion by increasing the contact pressure between the repaired tendon and footprint, as in the traditional open transosseous repair (4, 11). A recent comparative study has revealed that TOE repair resulted in a significantly higher mean failure load than ATO repair in a cadaveric model (30). Additionally, the TOE technique has superior repair reduction and tendon bone contact capacity (31, 32). Thus, ATO and TOE techniques represent high capability of restoration of the footprint anatomy, and a comparison of these techniques did not yield any clinical or radiological difference in our study.

Various re-tear rates have been reported in numerous studies based on the fixation method. Plachel et al. stated that an overall re-tear rate of 33% was obtained in patients treated with ATO repair, with an average follow-up duration of 15 years (33). Bau-

Table 2. Comparison of functional outcomes between groups and in-groups

| Variable         | ATO repair (n=39) | TOE repair (n=44) | p    |
|------------------|------------------|------------------|------|
| VAS score        |                  |                  |      |
| Preoperative     | 8.10±1.35        | 8.20±1.23        | 0.720|
| Postoperative    | 3.15±1.23        | 3.18±1.13        | 0.914|
| p                | <0.001           | <0.001           |      |
| Constant score   |                  |                  |      |
| Preoperative     | 31.59±6.07       | 33.48±7.03       | 0.197|
| Postoperative    | 88.56±9.85       | 87.23±14.62      | 0.631|
| p                | <0.001           | <0.001           |      |
| Oxford shoulder score |        |                  |      |
| Preoperative     | 16.51±4.24       | 16.14±4.65       | 0.702|
| Postoperative    | 42.87±5.00       | 40.48±8.89       | 0.130|
| p                | <0.001           | <0.001           |      |

patient of the ATO group; however, it did not cause any failure. No anchor pullout or implant failure was observed in any patient.

Liu et al. achieved significant healing in the shoulder and pain scores of 27 patients treated with the ATO technique, with a minimum follow-up duration of 2 years (37). Plachel et al. reported good functional results with a high satisfaction rate at an average follow-up of 15 years (33). Randelli et al. could not determine any difference between the ATO and anchor repair techniques in terms of pain, function, and integrity (35). In a prospective study of the ATO technique with implant, Baudi et al. achieved significant improvements in the shoulder functions of 34 patients within an average follow-up of 18.6 months (1). Flanagin et al. stated that the ATO rotator cuff repair technique led to a statistically significant midterm improvement in the ROM and a satisfactory midterm subjective outcome score in 108 patients (38). Fox et al. achieved good short-term result in 50 patients treated with ATO using the button technique (39). Kuroda et al. used the ATO technique without implant on 380 patients and identified significant healing in the shoulder functions at an average follow-up of 3.3 years and found a re-tear in 24 patients (29). We achieved significant improvement in the shoulder functions of both the groups; however, no significant differences were observed between the groups. When the shoulder functions of the patients with re-tear were evaluated, the patients in the ATO group had better functional results than those in the TOE group. This situation can be explained by the fact that six patients with re-tear in the ATO group were Sugaya Type III. Sugaya III patients are actually regarded as being healthy in many studies (34). However, due to the potential of full layer progress of this pattern in the future, it must be accepted as a re-tear. Further, failures usually occur as tears at the musculotendinous junction and medial row anchor pullout in the TOE group (40). This failure type may be worsened by the functional results because of total failure of repair (Sugaya IV and V).

The failure is usually at the tendon level in repairs with anchor; however, it occurs at the tunnel in the transosseous technique
In the latest techniques, tunnel placement extending to the footprint's medial that covers a large area has reduced tunnel breakage complications (37). Caldwell et al. reported that cortical augmentation could increase the suture pullout strength by approximately two-fold (43). The use of bone augmentation to avoid suture pullout is well supported in several biomechanical studies (44, 45). The advantages of the implant that we used in the ATO group are reported as cortical fixation, the extension capacity of suture passers up to the medial, and traction-compression effect in the system because of the sutures passing via the hole behind the implant and the reduction of movement at tendon-footprint interface (1). No intraoperative bone laceration was observed in any patient. Only one patient's implant had cortical penetration, which was solved by turning the implant 90° and placing it on the cortex.

This study has certain limitations. First, this retrospective study enrolled a relatively small number of patients and may be underpowered to detect differences in certain factors. Second, although no significant difference was observed in the clinical outcomes of patients with and without bone laceration, a type II error may exist due to the relatively small number of patients. Third, we did not record the operation time; however, based on our experience, both the techniques can be performed within a similar duration. Fourth, we did not compare the invoiced cost of both the techniques. However, the estimated cost of an ATO implant equals the price of three anchors in our country. Generally, both the techniques cost the same, although four anchors are used in the TOE technique.

In conclusion, the ATO and TOE techniques help achieve significant improvements in the shoulder function in the short term. However, studies that constitute longer follow-up periods and include a large series are warranted.

Ethics Committee Approval: Ethics committee approval was received for this study from the Local Ethics Committee of Yıldırım Beyazıt University.

Informed Consent: Written informed consent was obtained from the patient who participated in this study.

Author Contributions: Concept - A.F., M.A.; Design - A.F., M.A.; Supervision - A.F., M.A.; Resources - A.F., M.U.; Materials - A.F., M.U., M.A.; Data Collection and/or Processing - A.F., M.A.; Analysis and/or Interpretation - O.T., A.O., Y.S.; Literature Search - O.T., M.U., M.A.; Writing Manuscript - A.F., M.A.; Critical Review - O.T., A.O., M.U.

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References
1. Baudi P, Dani RE, Campochiaro G, Rebuzzi M, Serafini F, Catani F. The rotator cuff tear repair with a new arthroscopic transosseous system: The Sharc-FT(®). Musculoskelet Surg 2013; 97(Suppl 1): 57-61. [CrossRef]
2. McLaughlin HL. Lesions of the musculotendinous cuff of the shoulder. The exposure and treatment of tears with retraction. Clin Orthop Relat Res 1944; 304: 3-9.
3. Charousset C, Grimberg J, Duranthon LD, Bellaiche L, Petrover D. Can a double-row anchorage technique improve tendon healing in arthroscopic rotator cuff repair?: A prospective, nonrandomized, comparative study of double-row and single-row anchorage techniques with computed tomographic arthrography tendon healing assessment. Am J Sports Med 2007; 35: 1247-53. [CrossRef]
4. Park JY, Lhee SH, Choi JH, Park HK, Yu JW, Seo JB. Comparison of the clinical outcomes of single- and double-row repairs in rotator cuff tears. Am J Sports Med 2008; 36: 1310-6. [CrossRef]
5. Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: Magnetic resonance imaging and early clinical evaluation. Am J Sports Med 2009; 37: 674-82. [CrossRef]
6. Kim DH, ElAttrache NS, Tibone JE, et al. Biomechanical comparison of a single-row versus double-row suture anchor technique for rotator cuff repair. Am J Sports Med 2006; 34: 407-14. [CrossRef]
7. Lorbach O, Bachelier F, Vees J, Kohn D, Pape D. Cyclic loading of rotator cuff reconstructions: Single-row repair with modified suture configurations versus double-row repair. Am J Sports Med 2008; 36: 1504-10. [CrossRef]
8. Ma CB, Comerford L, Wilson J, Puttlitz CM. Biomechanical evaluation of arthroscopic rotator cuff repairs: Double-row compared with single-row fixation. J Bone Joint Surg Am 2006; 88: 403-10. [CrossRef]
9. Nelson CO, Sileo MJ, Grossman MG, Serra-Hsu F. Single-row modified Mason-Allen versus double-row arthroscopic rotator cuff repair: A biomechanical and surface area comparison. Arthroscopy 2008; 24: 941-8. [CrossRef]
10. Smith CD, Alexander S, Hill AM, et al. A biomechanical comparison of single and double-row fixation in arthroscopic rotator cuff repair. J Bone Joint Surg Am 2006; 88: 2425-31. [CrossRef]
11. Park MC, Tibone JE, ElAttrache NS, Ahmad CS, Jun BJ, Lee TQ. Part II: Biomechanical assessment for a footprint-restoring transosseous equivalent rotator cuff repair technique compared with a double-row repair technique. J Shoulder Elbow Surg 2007; 16: 469-76. [CrossRef]
12. Gerhardt C, Hug K, Pauly S, Marnitz T, Scheibel M. Arthroscopic single-row modified Mason-Allen repair versus double-row suture bridge reconstruction for supraspinatus tendon tears: A matched-pair analysis. Am J Sports Med 2012; 40: 2777-83. [CrossRef]
13. McCormick F, Gupta A, Bruce B, et al. Single-row, double-row, and transosseous equivalent techniques for isolated supraspinatus tendon tears with minimal atrophy: A retrospective comparative outcome and radiographic analysis at minimum 2-year followup. Int J Shoulder Surg 2014; 8: 15-20. [CrossRef]
14. Goutallier D, Postel JM, Radier C, Bernageau J, Zilber S. Long-term functional and structural outcome in patients with intact repairs 1 year after open transosseous rotator cuff repair. J Shoulder Elbow Surg 2009; 18: 521-8. [CrossRef]
15. Behrens SB, Bruce B, Zonno AJ, Puller D, Green A. Initial fixation strength of transosseous-equivalent suture bridge rotator cuff repair is comparable with transosseous repair. Am J Sports Med 2012; 40: 133-40. [CrossRef]
16. Motycka T, Kriegleder B, Landsiedl F. Results of open repair of the rotator cuff--a long-term review of 79 shoulders. Arch Orthop Trauma Surg 2001; 121: 148-51. [CrossRef]
17. Cicak N, Klobochar H, Bicanic G, Trsek D. Arthroscopic transosseous suture anchor technique for rotator cuff repairs. Arthroscopy 2006; 22: 565.e1-6. [CrossRef]

18. Garofalo R, Castagna A, Borroni M, Krishnan SG. Arthroscopic transosseous (anchorless) rotator cuff repair. Knee Surg Sports Traumatol Arthrosc 2012; 20: 1031-5. [CrossRef]

19. Black EM, Lin A, Srikumaran U, Jain N, Freehill MT. Arthroscopic transosseous rotator cuff repair: Technical note, outcomes, and complications. Orthopedics 2015; 38: 352-8. [CrossRef]

20. Cofield RH. Subscapular muscle transposition for repair of chronic rotator cuff tears. Surg Gynecol Obstet 1982; 154: 667-72.

21. Ellman H, Gartsman G. Open repair of full thickness RCT. Philadelphia: Lea and Febiger; 1993. p. 181-202.

22. Patte D. Classification of rotator cuff lesions. Clin Orthop Relat Res 1990; 254: 81-6. [CrossRef]

23. Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F. Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. Acta Orthop Scand 1996; 67: 264-8. [CrossRef]

24. Sugaya H, Maeda K, Matsuki K, Mooriishi J. Functional and structural outcome after arthroscopic full thickness rotator cuff repair: Single row versus dual row fixation. Arthroscopy 2005; 21: 1307-16. [CrossRef]

25. Matthesson G, Beach CJ, Nelson AA, et al. Partial thickness rotator cuff tears: Current concepts. Adv Orthop 2015; 458786. [CrossRef]

26. Kim JH, Hong IT, Ryu KJ, Bong ST, Lee YS, Kim JH. Retear rate in the late postoperative period after arthroscopic rotator cuff repair. Am J Sports Med 2014; 42: 2606-13. [CrossRef]

27. Kim KC, Rhee KY, Shin HD, Kim YM. Arthroscopic transosseous rotator cuff repair. Orthopaedics 2008; 31: 327-30. [CrossRef]

28. Kang L, Henn RF, Tashjian RZ, Green AE. Early outcome of arthroscopic rotator cuff repair: A matched comparison with minior open rotator cuff repair. Arthroscopy 2007; 23: 573-82. [CrossRef]

29. Kuroda S, Ishige N, Mikasa M. Advantages of arthroscopic transosseous suture repair of the rotator cuff without the use of anchors. Clin Orthop Relat Res 2013; 471: 3514-22. [CrossRef]

30. Kilcoyne KG, Guillame S, Hangan CV, Langdale ER, Belkoff SM, Srikumaran U. Anchored transosseous-equivalent versus anchorless transosseous rotator cuff repair: A biomechanical analysis in a cadaveric model. Am J Sports Med 2017; 45: 2364-71. [CrossRef]

31. Jeong JY, Park KM, Sundar S, Yoo JC. Clinical and radiologic outcome of arthroscopic rotator cuff repair: Single-row versus transosseous equivalent repair. J Shoulder Elbow Surg 2018; 27: 1021-9. [CrossRef]

32. Apreleva M, Ozbuydar M, Fitzgibbons PG, Warner JJP. Rotator cuff tears: The effect of the reconstruction method on three-dimensional repair site area. Arthroscopy 2002; 18: 519-26. [CrossRef]

33. Plachet F, Traweger A, Vasvary I, Schanda JE, Resch H, Moroder P. Long-term results after arthroscopic transosseous rotator cuff repair. J Shoulder Elbow Surg 2019; 28: 706-14. [CrossRef]

34. Cho NS, Rhee YG. The factors affecting the clinical outcome and integrity of arthroscopically repaired rotator cuff tears of the shoulder. Clin Orthop Surg 2009; 1: 96-104. [CrossRef]

35. Randelli P, Stoppani CA, Zaoilino C, Menon A, Randelli F, Cabilitz P. Advantages of arthroscopic rotator cuff repair with a transosseous suture technique: A Prospective randomized controlled trial. Am J Sports Med 2017; 45: 2000-9. [CrossRef]

36. Nho SJ, Slabaugh MA, Seroyer ST, Grumet RC, Wilson JB, Verma NN, et al. Does the literature support double-row suture anchor fixation for arthroscopic rotator cuff repair? A systematic review comparing double-row and single-row suture anchor configuration. Arthroscopy 2009; 25: 1319-28. [CrossRef]

37. Liu XN, Yang CJ, Lee GW, Kim SH, Yoon YH, Noh KC. Functional and radiographic outcomes after arthroscopic transosseous suture repair of medium sized rotator cuff tears. Arthroscopy 2018; 34: 50-7. [CrossRef]

38. Flanagan BA, Garofalo R, Lo EY, et al. Midterm clinical outcomes following arthroscopic transosseous rotator cuff repair. Int J Shoulder Surg 2016; 10: 3-9. [CrossRef]

39. Fox MP, Auffarth A, Tauber M, Hartmann A, Resch H. A novel transosseous button technique for rotator cuff repair. Arthroscopy. 2008; 24: 1074-7. [CrossRef]

40. Elbuluk AM, Coxe FR, Fabricant PD, Ramos NL, Alaija MJ, Jones KJ. Does medial-row fixation technique affect the retear rate and functional outcomes after double-row transosseous-equivalent rotator cuff repair? Orthop J Sports Med 2019; 7: doi: 10.1177/2325967119842881. [CrossRef]

41. Burkhart SS, Johnson TC, Wirth MA, Athanasiou KA. Cyclic loading of transosseous rotator cuff repairs: Tension overload as a possible cause of failure. Arthroscopy 1997; 13: 172-6. [CrossRef]

42. Goradia VK, Mullen DJ, Boucher HR, Parks BG, O’Donnell JB. Cyclic loading of rotator cuff repairs: A comparison of bioabsorbable tacks with metal suture anchors and transosseous sutures. Arthroscopy 2001; 17: 360-4. [CrossRef]

43. Caldwell GL, Warner JP, Miller MD, Boardman D, Towers J, Debski R. Strength of fixation with transosseous sutures in rotator cuff repair. J Bone Joint Surg Am 1997; 79: 1064-8. [CrossRef]

44. Salata MJ, Sherman SL, Lin EC, et al. Biomechanical evaluation of transosseous rotator cuff repair: Do anchors really matter? Am J Sports Med 2013; 41: 283-90. [CrossRef]

45. Koh JL, Szomor Z, Murrell GAC, Warren RF. Supplementation of rotator cuff repair with a bioresorbable scaffold. Am J Sports Med 2002; 30: 410-3. [CrossRef]