Arthroscopic trans-osseous rotator cuff repair

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Summary

***Background*: Mechanical factors are at the basis of any tendon healing process, being pressure an aspect able to positively influence it. For this reason transosseous rotator cuff repair represents the gold standard procedure for patients affected by a cuff tear, maximizing the tendon footprint contact area and reducing motion at the tendon to bone interface.**
***Methods:* The Authors present an all arthroscopic suture bridge-like transosseous repair with the preparation of a single transosseous tunnel performed thanks to a precise dedicated instrument (Compasso®) and one implant (Elite-SPK®) with the use of only 3 suture wires. In addition this technique permits to accurately prepare the bony side of the lesion without any risk or complication, such as anchor pull-out and greater tuberosity bone osteolysis.**
***Conclusions:* However, even if this technique seems less demanding, the arthroscopic transosseous repair is still an advanced procedure, and should be performed only by well prepared arthroscopic shoulder surgeons.**
Level of evidence: V.

KEY WORDS: arthroscopy, repair, rotator cuff, shoulder, tear, tendon, trans-osseous technique.

Introduction

Arthroscopic rotator cuff (RC) repair techniques have evolved significantly during the last decades[1]. However the occurrence of re-tear[2] or non-healing[3] is still high, and numerous variables are to be considered in order to make an adequate surgical choice[4]. Different kinds of suture configurations were developed in the last years trying to optimize RC tendon healing biology at the repaired site[5-7]. At first, the double-row techniques added a row of suture anchors fixation lateral to the conventionally placed medial row that had represented the standard fixation strategy for arthroscopic RC repairs[8]. Later, in an effort to combine the stronger biomechanical repair of the double-row configuration with the increased tendon-bone interface pressure benefits, the transosseous-equivalent (TOE) suture bridge repair was developed[9,10].
This technique preserves the suture limbs of the medial row bridging them over the tendon's native insertion with fixation in the lateral humeral cortex providing also an optimal load sharing. Several studies reported the biomechanical superiority of TOE RC repair over the standard double row and single-row repair techniques due to the ability to provide compression through the footprint by increasing the contact area. This is achieved by connecting the medial and lateral rows, thus exerting compression throughout the repair, instead of only at the anchor insertion points[2,9-11].
However, failures at the medial row with a well-attached tendon on the great tuberosity have been reported with the TOE technique[12,13].
Moreover other anchor-related complications (pull out in presence of poor bone stock, greater tuberosity bone osteolysis, difficult revision, increased cost) called into question the use of anchor fixation for RC repair[14,15].
For these reasons, the best arthroscopic technique has not yet been established and open transosseous (TO) RC repair is to be considered the gold standard procedure[15]. As recently established, mechanical factors are at the basis of any healing process, being pressure an aspect able to positively influence the healing process[16]. The TO technique permits to maximize the tendon footprint contact area[2] and to reduce motion at the tendon to bone interface[17]. In addition to this mechanical aspect, TO technique permits to accurately prepare the bony side of the lesion without any risk or complication, such as anchor pull-out and greater tuberosity bone osteolysis[15,18].
In an attempt to overcome the limitations of anchor repair, arthroscopic TO anchorless RC repair techniques have recently been developed[6,14,15,17-19] (Tab. I).

Table I. Arthroscopic trans-osseous rotator cuff repair techniques recently published for the treatment of full-thickness tendon tear.

Authors	Year	N° of tunnel	N° of sutures	Instrumentation
H Frick[11]	2010	1 or more	1-3 for each tunnel	Bone needle
R Garofalo[12]	2012	1 or more	2-3 for each tunnel	ArthroTunneler
S Kuroda[17]	2013	3	5	Drill guide + 3 k-wires
EM Black3	2015	2	6	ArthroTunneler
M Aramberri-Gutierrez[1]	2015	1(medial calcar)	2(1 soft anchor)	ACL-guide
BA Flanagin[9]	2016	1 or 2	3 or 6	ArthroTunneler

In this paper a novel and reproducible all-arthroscopic TO anchorless technique that replicates the TOE suture bridge repair is reported. This novel technique avoids all the disadvantages related to anchor fixation. The principle is to combine the double-row suture bridge fixation with the classic TO approach of suture fixation as performed in the open rotator cuff repair.

Surgical technique

The procedure can be performed depending on anesthesiologist preference under general anesthesia or interscalene brachial plexus block or combined, and in beach-chair position or lateral decubitus according to surgeon request.

The Authors suggest using a 3 portals surgical technique: standard posterior (for the scope), lateral and antero-superior (working) portals. Once the reparability of the RC lesion is assessed we advise firstly to treat possible associated pathology (LHB tenotomy/tenodesis, subscapularis repair).

After tendon and bone preparation for suture (respectively cutting and refreshing the torn tendinous edge and wide surface decortication of the footprint providing maximum spongy bone) is possible to prepare the TO tunnel. A dedicated instrument, named Compasso® (NCS Lab s.r.l. - Medical Devices Factory, Italy) was developed with the aim to simplify and accelerate the operative procedures avoiding pitfalls or damages to soft tissues.

Place the Compasso® (Fig. 1) parallel to the coronal plane with the tip of the proximal punch (part 1 with lanceolate tip) corresponding to the desired exit point of the transosseous tunnel you wish to perform. The angle of insertion of the proximal punch should be between 30° and 45°, depending on the protrusion of the acromion. Use the hammer to sink the proximal punch in the humeral head until it stops and reach the cannula enlargement (mechanical stop). Insert the

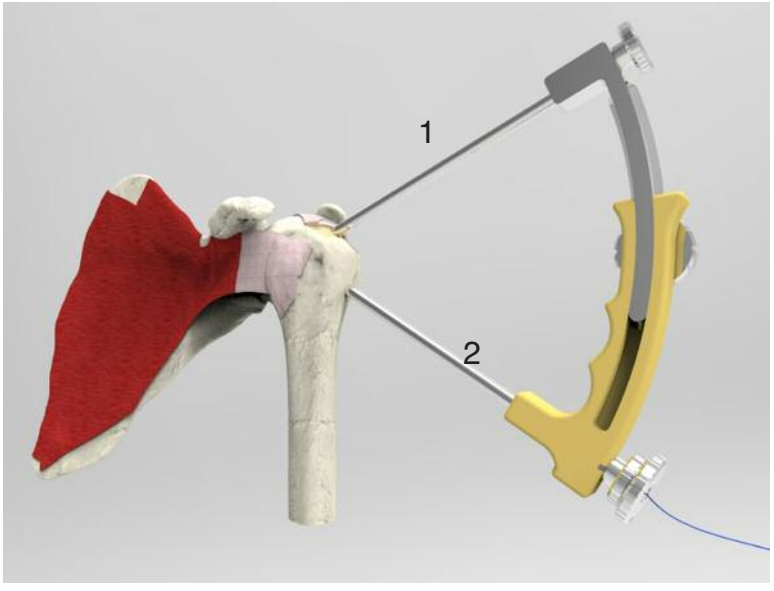
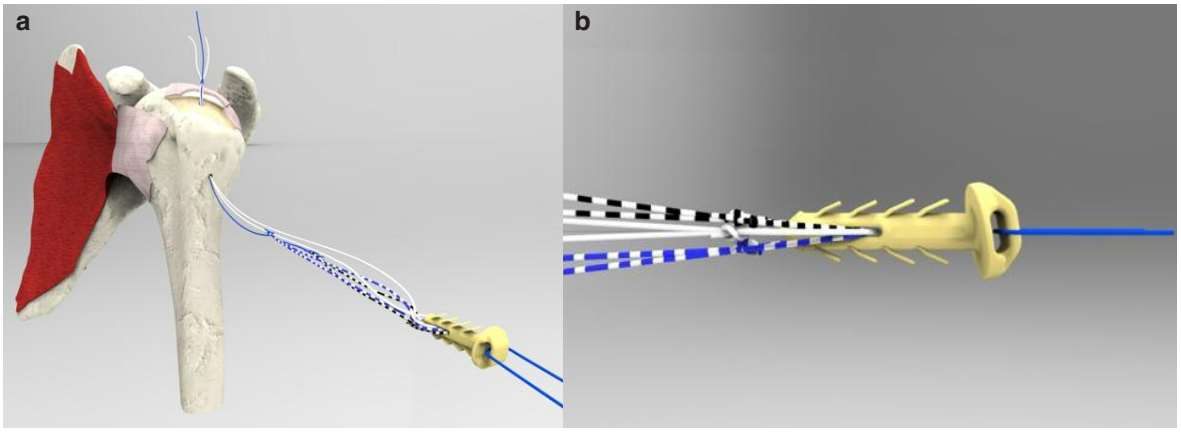


Figure 1. Positioning of the guide (Compasso®) to perform the transosseous tunnel: the tip of the proximal punch (1) corresponds to the desired exit point of the tunnel, while the pin of the distal punch (2) reaches the lateral cortex of humerus. A monofilament shuttle suture is loaded distally and captured by a suture locker proximally.

distal punch (2) inside the distal cannula, then assemble these parts on the main body of Compasso® until the pin of the punch reaches the lateral cortex of humerus. For a correct insertion align the laser marks of cannula and main body. Unscrew the locking ring on the main frame to set the angle between the distal and the proximal cannula so as to place the pin of the distal punch approximately at 12-15 mm from the edge of the greater tuberosity, then tighten the locking ring firmly again, once in the desired optimal position. The cranial-caudal angle can be defined until cannula 2 is inserted into the bone. The anterior-posterior position of the instrument, instead, must be defined before the subcutaneous insertion. Hammer the distal punch (2) to pass the lateral cortex of the humerus for some millimeters, to stabilize the device, then lift the proximal loading punch (1) until the laser mark on it becomes visible. Hammer the distal cannula (2) till it comes in contact with the main body of Compasso®. Remove the distal inner punch from its cannula. Load a monofilament shuttle suture (PDS size USP 1 or 2) through the distal cannula until it stops. Insert the suture locker (part 1 with rounded tip) through the proximal cannula (1), then tighten it to steadily capture the shuttle suture.

Check the optimal engaging of the shuttle suture by pulling the external limb. Remove the distal cannula from the main body of Compasso®. Pull the Compasso® out from the medial access of the transosseous tunnel by dragging with it the shuttle suture. This shuttle could drag the suture wires connected to the front part of the implant, the Elite-SPK® (NCS Lab s.r.l. - Medical Devices Factory, Italy) (Fig. 2a). It is an implant made of PEEK containing two separated eyelets: a rear one, that remains externally on the lateral cortex of the humerus, and a front, smaller one through which sutures are initially loaded. Along the body of the device several stabilising flaps are attached to the main body which, in combination with the wide contact surface beneath the head of the implant, have the function of providing an optimal primary stability (Fig. 2b).

Depending on the tear size a different numbers of sutures can be passed. We recommend to shuttle 3 sutures (of different colours). Before this step to avoid any sliding of the wires, we perform 2 simple knots for each suture, in the front part of the implant (Fig. 2b). All the six stitches are then passed through the cuff (Fig. 3) with different devices according to surgeon preference, from posterior to anterior, and different kinds of suture configurations can be created. The senior surgeon (CC) in collaboration with the engineer (MM) developed the configuration below reported and named 2MC (double MC). Schematically we refer to limb 1 as the most anterior, going to limb 6 for the most posterior. We firstly close the limb 2



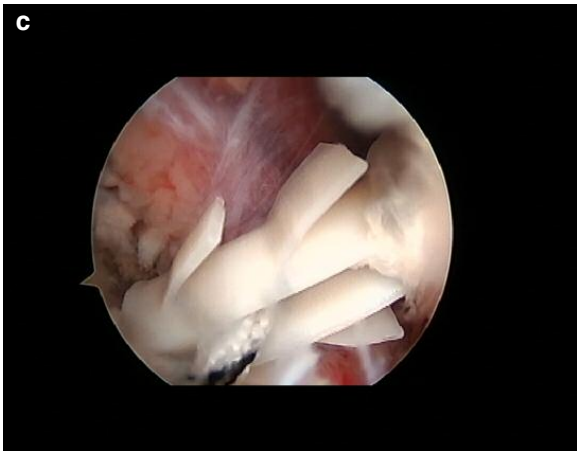


Figure 2 a-c. **a)** The shuttle suture drag the suture wires connected to the front part of the implant, the Elite-SPK®.
b) The Elite SPK® is an implant made of peek containing two separated eyelets: a rear one, that remains externally on the lateral cortex of the humerus, and a front, smaller one through which sutures (in number of 3, of different colours) are initially loaded. To avoid any sliding of the wires, it is better to perform 2 simple knots for each suture. Along the body of the device several stabilising flaps are attached to the main body which, in combination with the wide contact surface beneath the head of the implant, have the function of providing an optimal primary stability.
c) Arthroscopic view (with the scope posterior). Insertion of the Elite SPK® into the TO tunnel through the hole yet performed into the lateral cortex of the humerus. Note the stabilising flaps.

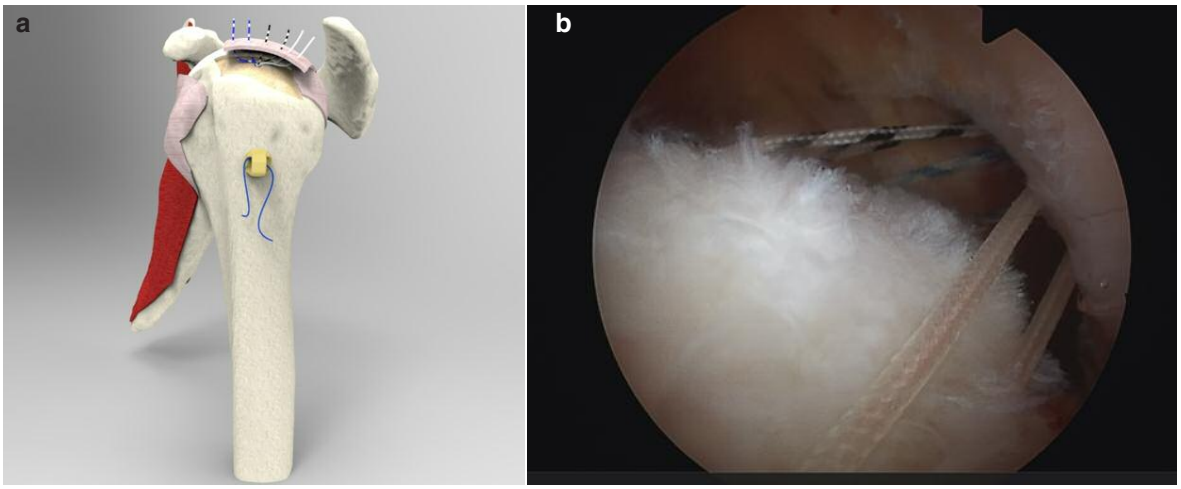


Figure 3 a, b. **a)** All the six stitches are then passed through the cuff (with different devices according to surgeon preference) from posterior to anterior. **b)** Arthroscopic view (with the scope posterior). Note the six stitches passed through the cuff, and all retrieved through the lateral portal.

with 3 (*suture 1*), and later the limb 4 with 5 (*suture 2*) leaving free the limbs 1 and 6 (Fig. 4). After cutting respectively one of the end of suture 1 and 2, we shuttle from anterior to posterior in the external eyelet of the Elite SPK® the limb 1 and the remaining end of suture 1 (Fig. 5). At this point, in order to achieve a repair in closed loop configuration, we tie the knot (laterally) between the limbs 1 and 6, and the remaining limb of suture 1 and 2 (Fig. 6). This represents a very tight and stable repair configuration that permits to completely cover the greater tuberosity. Surgery ends with subacromial decompression if necessary.

Discussion

A larger and more stable tendon-to-bone contact interface during the early phase of the healing process is nowadays a worldwide accepted concept[16,20,21], so that different techniques have been developed to obtain a more anatomic configuration of the RC repair on the footprint providing a better environment for tendon healing.

During the last years the demonstration that the suture tension for any TO technique provides a more direct tendon-to-bone compression vector and a larger

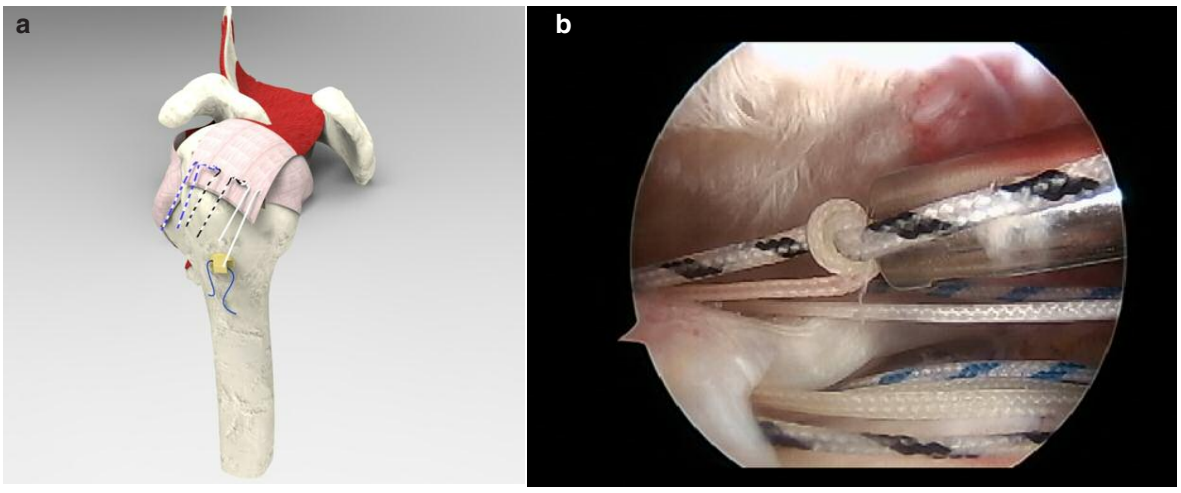


Figure 4 a, b. *2MC suture configuration*. **a)** Schematically we refer to limb 1 as the most anterior, going to limb 6 for the most posterior. Firstly close the limb 2 with 3 (*suture 1*), and later the limb 4 with 5 (*suture 2*) leaving free the limbs 1 and 6. **b)** Arthroscopic view (with the scope posterior). The surgeon firstly ties the knot between the limb 2 with 3.

Figure 5. *2MC suture configuration*. After cutting respectively one of the end of suture 1 and 2, shuttle from anterior to posterior in the external eyelet of the Elite SPK® the limb 1 and the remaining end of suture 1.

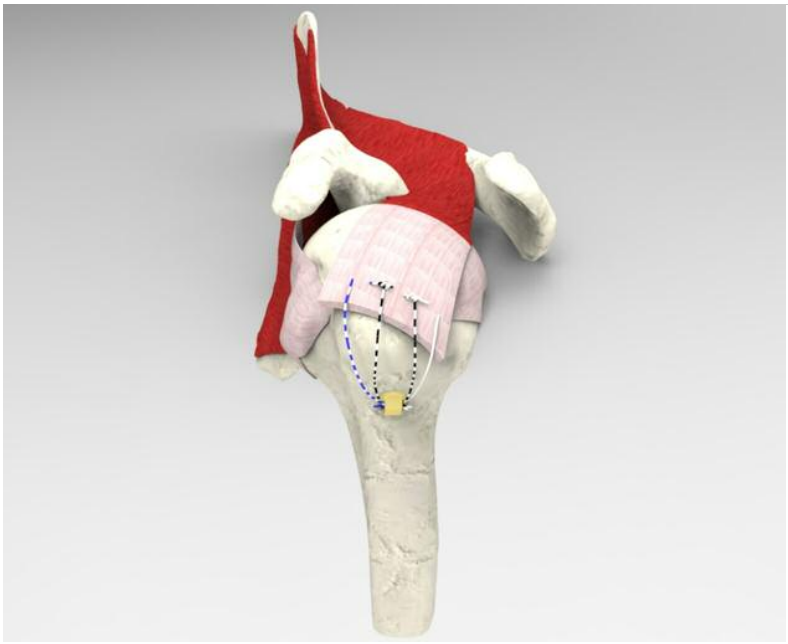


Figure 6. *2MC suture configuration*. At this point, in order to achieve a repair in closed loop configuration, tie the knot (laterally) between the limbs 1 and 6, and the remaining limb of suture 1 and 2.

repair site contact area when compared to the suture anchor technique has lead to the introduction of arthroscopic TO RC repair techniques[9,10].

Several papers in literature deal with this topic, but the general impression is that the arthroscopic TO technique are still technically demanding and with a lot of uncontrollable variables. Numerous dedicated instruments have been employed to create the TO tunnels into the greater tuberosity from the ACL tibial guide to different kinds of needle or tunneler devices[15,22-24]. However, all the arthroscopic TO techniques described until now are complex procedures that requires several surgical steps, the creation of 2 or more TO tunnels and the use of many sutures making these procedures very difficult to reproduce and standardize[6,14,15,18,19].

In addition some complications such as needle breakage, neurological damage or greater tuberosity fracture can be encountered. Moreover, depending on the tear size, in order to equally distribute the forces

on the tendon and to prevent the bone cutting phenomenon, it is mandatory to create more than 1 TO tunnel and use at least 2 or 3 sutures in each tunnel with the risk of suture twist and an increase of the surgical time required.
Using a dedicated and very precise instrument (Compasso®) to create a single TO tunnel and a single implant (Elite-SPK®) with 3 sutures the current technique permits to obtain a wide contact surface between the tendon and the bone with a biomechanical effectiveness comparable with the open TO technique while reducing the complexity and difficulty that is usually encountered with other arthroscopic TO techniques.
The peculiar shape of the implant and its features make it a suture platform that can also be used on very fragile bone tissue without the problem of migration and pull out, providing a reliable fixation. Two of the major problems previously described with arthroscopic TO techniques have been suture abrasion against the bone tunnel which can result in suture rupture, and bone cut in presence of poor bone (cheese cut effect) with damage of the remaining bone integrity and weakening of the tuberosity. With the use of Elite-SPK®, as there is no sliding of the suture wires into the TO tunnel, the risk of suture cut and bone damage is significantly reduced. In addition, while the other arthroscopic TO techniques generate a tendon compression vector directed laterally and tangential to the bone, the tendon compression vector provided by the Elite-SPK® is perpendicular to the footprint resulting in a maximization of the contact area (with an optimal pressure distribution) while reducing sutures-bone tunnel impingement and thus suture abrasion and bone damage. For this reason the Elite-SPK® seems particularly convenient in presence of osteoporotic bone or intraosseous cysts where usually suture anchors fail.
The 2 MC suture configuration allows the surgeon to build a suture-bridge like construct that increases the contact area and optimizes the compression of the tendon on the footprint. In particular, the 2 central double-row sutures provide stability and compression while the most anterior and the most posterior wires once tied together on the lateral aspect of the great tuberosity result in an enveloping effect on the tendon providing a complete coverage of the footprint.
The 2 simple knots for each suture tied in the front part of the implant are essential to avoid any sliding up of the limbs when tying the knot between limb 2 and 3 and limb 4 and 5, permitting a really good contact tendon to bone. Moreover, it is known that the three sutures passed through the TO tunnel share the load on the tendon resulting in a reduction of the local stress spikes at the tendon interface[25].

Conclusion

The current technique allows to perform an all arthroscopic suture bridge-like TO repair with the preparation of a single TO tunnel performed thanks to a precise dedicated instrument (Compasso®) and one implant (Elite-SPK®) with the use of only 3 suture wires. However, even if this technique is less demanding, the arthroscopic TO repair is still an advanced procedure, and should be performed only by well prepared arthroscopic shoulder surgeons.

Ethic

The Authors declare that this research was conducted following basic ethical aspects and international standards as required by the journal and recently updated in[26].

Conflict of interest

Claudio Chillemi declares that he has no conflict of interest. Matteo Mantovani designed and manufactured the Compasso® + Elite-SPK®.
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