COMPARISON OF FOOTPRINT PROPERTIES: SINEFIX™ VS. ADVANCED SUTURE ANCHOR CONSTRUCTS

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ABSTRACT

The anatomical footprint represents the original insertion site of rotator cuff tendons on the humeral head and serves as a critical landmark for successful repair. Understanding and recreating this footprint through advanced repair techniques, particularly double-row repairs and suture bridge constructs, has become fundamental to achieving optimal biomechanical restoration and clinical outcomes. This paper examines the anatomical significance of the footprint, the evolution of repair techniques designed to address it, the ongoing challenges in achieving complete footprint coverage, and how the SINEFIX implant addresses these problems.

INTRODUCTION

Rotator cuff tears represent one of the most common causes of shoulder pain and dysfunction, affecting millions of patients worldwide. Factors that influence the healing of the rotator cuff include blood supply, compression of the tendon, repeated microtrauma, and tension at the repair site.[1] Another key factor is the concept of the anatomical footprint—the exact location where the rotator cuff tendons naturally attach to the greater tuberosity of the humerus.

WHAT IS THE FOOTPRINT?

The rotator cuff footprint refers to the anatomical insertion area of the rotator cuff tendons on the greater tuberosity of the humeral head. Based on detailed anatomical studies, the area of insertion of the three tendons on the greater tuberosity averages 6.24 cm^2 (±2.04 cm^2), with the supraspinatus insertion measuring 1.55 cm^2 (±0.66 cm^2) and the infraspinatus insertion measuring 1.76 cm^2 (±0.40 cm^2).[2]

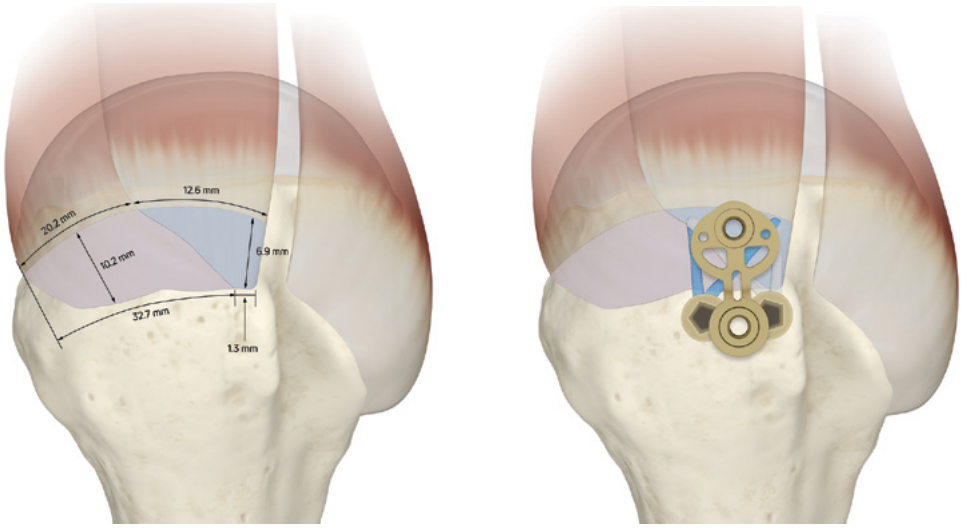

FIGURE 1
Size of the SINEFIX implant and a suture bridge on the supraspinatus footprint to scale[3-7]

Supraspinatus footprint: the supraspinatus occupies a small triangular area (Figure 1) with an anteroposterior length of about 12.6 mm at its medial (articular) edge, narrowing to ~1 mm laterally, and a maximal mediolateral width of only ~6–7 mm.[3]

Figure 1 illustrates the configuration of both a suture bridge construct and the SINEFIX implant, applied to the anatomical dimensions of the supraspinatus footprint. The blue triangular area represents the anatomical insertion site of the supraspinatus tendon, while the purple trapezoid shape depicts the corresponding footprint of the infraspinatus tendon.

EVOLUTION OF REPAIR TECHNIQUES

Single-Row Limitations

Traditional single-row repairs have inherent limitations in footprint restoration. When repairing a rotator cuff using a single row of suture anchors the normal footprint of the rotator cuff is not restored.[8] These repairs provide only “point” fixation of the rotator cuff and restore significantly less of the anatomic footprint compared to more advanced techniques.

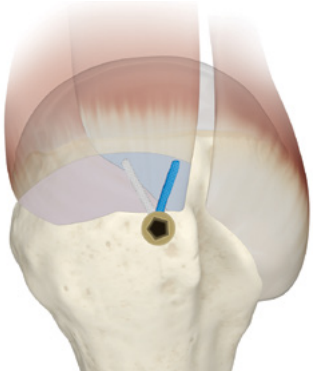

FIGURE 2
Image of a single-row suture construct on the supraspinatus footprint

Double-Row Repairs: Advancing Footprint Coverage

Double-row rotator cuff repair provides secure suture anchor tendon fixation to bone and re-establishes a greater surface of the normal rotator cuff footprint compared to single row.[8] This technique involves placing one row of anchors in the medial aspect of the footprint and another row in the lateral aspect, thereby re-establishing the normal medial-to-lateral width of the rotator cuff footprint and increasing the area of contact for healing.[8] By adding a second row of fixation, the number of fixation points is increased. This enhances the strength of the primary repair, reduces the load borne by each individual suture loop and knot, and lowers the stress at each suture–tendon contact point.[8]

Suture Bridge Technique: Optimizing Footprint Coverage

The suture-bridge technique represents an evolution of double-row repair principles. Double-row suture-bridging arthroscopic rotator cuff repair maximizes footprint restoration and fixation strength.[9] Suture-bridging constructs appear to have substantially improved tendon-healing rates compared with single-row repair.[9]

LIMITATIONS AND CHALLENGES OF CURRENT TECHNIQUES

Despite significant advances in arthroscopic reconstruction techniques, complete restoration of the footprint remains a major challenge. Even highly developed suture bridge procedures can only approximate the native geometry of this area. In order to ultimately achieve the widest possible footprint coverage, the suture bridge technique requires several precisely coordinated steps: precise placement of the medial and lateral anchors, threading of the sutures, knotting them, and finally crossing (bridging) to compress the tendon flap onto the bone surface. This complex procedure significantly prolongs the operation time, drastically increases the cost of the intervention and represents a technically demanding task even for experienced surgeons, where the slightest inaccuracies can compromise the final result.

THE SINEFIX IMPLANT SYSTEM: A NOVEL APPROACH

The SINEFIX implant is engineered to improve footprint coverage in rotator cuff repair through flat fixation with a poly ether ether ketone (PEEK) baseplate. Its streamlined, two step, suture free procedure removes the need for knot tying, potentially enabling surgeons without advanced arthroscopic training to perform rotator cuff repairs with a great footprint coverage area. Measuring 10 mm in width and 9 mm in length (17.7 mm total length), the device offers a generous tendon–bone contact area comparable to the dimensions of a suture bridge with 10 mm distance between the anchors.[10]

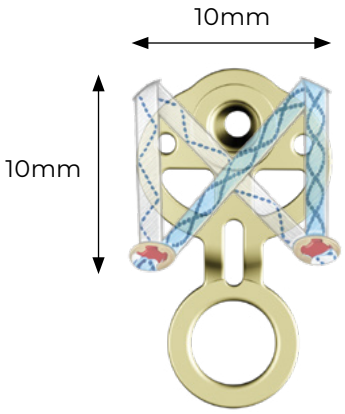

FIGURE 3
Dimensions of the SINEFIX device compared to a suture bridge with 10 mm distance between the anchors.

FOOTPRINT CONTACT AREA IN NUMBERS

A study conducted by Ostrander et al.[5] investigated the contact area of different repair techniques including a double-row, a suture bridge as well as an advanced suture bridge with a third lateral anchor. Figure 4 shows the anchor locations for their experiment.

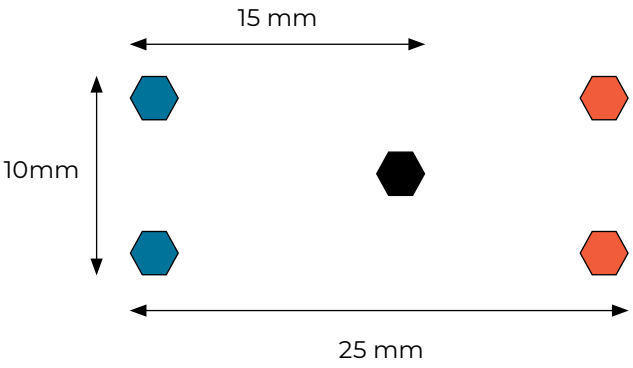

FIGURE 4
Anchor dimensions of the study conducted by Ostrander et al.[5] with the medial anchors in blue, additional anchor in black and the lateral anchors in orange.

The study concluded that the advanced suture bridge had the greatest contact area with a mean dimension of 0.98 ± 0.14 cm^2, followed by the suture bridge with a mean contact area of 0.67 ± 0.19 cm^2. The normal double row had the worst results with a mean contact area of 0.66 ± 0.24 cm^2. In comparison, a Finite Element Analysis of the SINEFIX implant conducted at EndoLab, Munich, showed a contact area between 1.65 and 2.03 cm^2 depending on the force used during insertion. This not only shows that the contact area of the SINEFIX implant is greater than the various suture anchor techniques but is also big enough to fully cover the footprint of the Infraspinatus or Supraspinatus tendons.

FOOTPRINT CONTACT PRESSURE

Footprint contact pressure—defined as the compressive force between the repaired tendon and the underlying bone surface—is a critical biomechanical factor determining the success of rotator cuff repair. The current literature describes that an increased contact pressure at the tendon footprint paired with good biomechanical properties may lead to better clinical results.[11]

Regarding the suture bridge technique, footprint contact pressure has been evaluated in several studies. Ostrander et al. reported a mean contact pressure of 0.38 ± 0.02 MPa in a pressure film study.[5] However, subsequent studies revealed that pressure distribution across the tendon surface is not uniform, with the suture bridge configuration generating localized pressure peaks that may lead to tendon strangulation.[12]

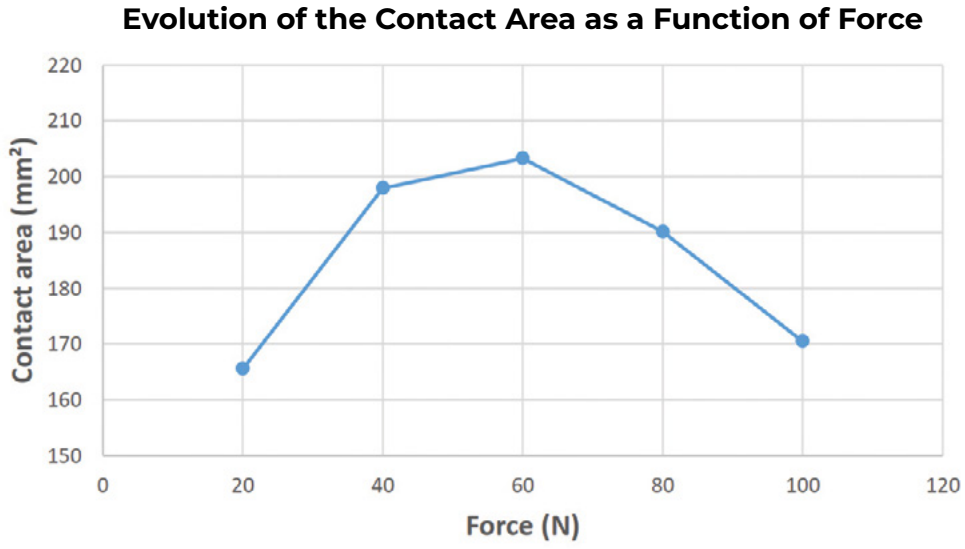

FIGURE 5
Graph showing the relationship between coverage area and insertion force of the SINEFIX implant.

This presents a key challenge: contact pressure must be distributed evenly across the entire tendon footprint to avoid harmful pressure peaks, while maintaining a sufficiently high overall pressure to ensure stable initial fixation.

Finite element analysis (FEA) of the SINEFIX implant demonstrated a homogenous distribution of pressure both on and within the tendon. In addition, the implant generated higher contact pressures at the tendon–humerus interface compared with conventional fixation, while simultaneously increasing the overall contact area. This combination suggests that SINEFIX not only optimizes mechanical coupling between the tendon and the humeral footprint but also mitigates the risk of localized over-pressurization. By avoiding excessive focal loads, the construct may help preserve microvascular circulation and thus promises better outcomes.

CONCLUSION

The anatomical footprint serves as a key role for successful rotator cuff repair, representing not merely an anatomical landmark but a critical determinant of repair success. Double-row repairs and suture bridge techniques have significantly advanced our ability to restore footprint anatomy, leading to improved biomechanical properties and clinical outcomes compared to traditional single-row methods. Nevertheless, these techniques pose a major challenge, especially for those not specialized in arthroscopy or shoulder surgery and overall do not offer a perfect solution, let alone perfect coverage of the footprint. SINEFIX, on the other hand, has comparable dimensions to a standard suture bridge and an even greater contact area, while also being a simple 2-step technique, which opens the door for every orthopedic surgeon to achieve the best possible footprint coverage.

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MKT-WP-20250916 Rev A