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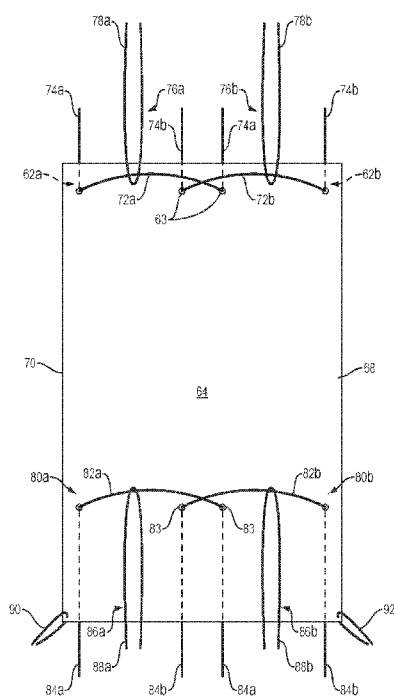


FIG. 4B

(57) Abstract: Systems and methods for knotless tissue repair employ a first suture construct routed through a tissue in a first inverted mattress stitch, including a loop portion and two free limbs. The loop portion of the first suture construct so routed is positioned adjacent to a superior surface of the tissue and the free limbs of the first suture construct so routed extend through an inferior surface of the tissue. A second suture construct, separate from the first suture construct, is inserted within the loop portion of the first suture construct such that two free limbs of the second suture construct extend from the loop portion of the first suture construct. The second suture construct comprises a plurality of braided filaments and possesses a substantially rectangular cross-sectional profile, and does not include a suture core surrounded by the braided filaments.



SYSTEMS FOR KNOTLESS TISSUE REPAIR

BACKGROUND

The shoulder joint, also referred to as the glenohumeral joint, is the joint located
5 between the glenoid cavity (a part of the scapula) and the head of the humerus (the upper arm
bone). The glenoid cavity is shallow, covering only about a third of the head humeral head.
As a result, the glenoid cavity provides relatively little bony constraint upon motion of the
humerus. Instead, a group of muscles and tendons attached to the humeral head, collectively
referred to as the rotator cuff, function to stabilize the glenohumeral joint and assist in
10 performing arm motions such as lifting and rotation.

The rotator cuff may become torn from overuse or injury, with at least a portion of the
tendons of the rotator cuff detached from the humeral head. Left untreated, the rotator cuff
tear may enlarge over time and, in extreme cases, the rotator cuff tendons may become
completely severed from attachment with the humerus. A torn rotator cuff compromises
15 stabilization of the glenohumeral joint and increases the likelihood of glenohumeral joint
dislocation, where the humerus is forced from its normal anatomical position with respect to
the glenoid socket. Thus, while not life threatening, rotator cuff injuries can cause pain and/or
restricted movement (even immobilization, in extreme cases) of the glenohumeral joint,
impacting a patient's lifestyle.

20 A variety of techniques have been developed for rotator cuff repair. For example,
transosseous equivalent repair has become popular for medium to large rotator cuff repairs.
This repair technique involves tying medial row knots in at least one strand of suture from
two or more medial row anchors. Subsequently, loose limbs of suture extending from the
knot are spanned over to the lateral row to provide a broad area of compression over the
25 rotator cuff. The sutures are formed into knots to secure their position with respect to the
anchors. This technique, however, is problematic when conducted arthroscopically. Notably,
given the relatively small amount of space in which arthroscopic procedures are formed, tying
knots under these conditions is technically challenging. As a result, the likelihood that a
surgeon commits an error in tying knots arthroscopically may be increased, as compared to
30 non-arthroscopic repair techniques. Such errors may, in turn, create a potential point of
failure and/or delay during such operations.

An alternative knotless technique, referred to as Speedbridge™ (Arthrex, Inc., Naples, FL, USA), has been developed for use using the FiberTape® (Arthrex, Inc., Naples, FL, USA) product. FiberTape® is a composite suture composed of a multi-strand core of ultra-high molecular weight polyethylene (UHMWPE) with a braided jacket of polyester and

5 UHMWPE. The FiberTape® is passed through the rotator cuff at the medial row location and spanned down to a second set of knotless anchors laterally. No medial row knot is tied, as the FiberTape® product cannot be tied arthroscopically. However, the use of FiberTape® can be problematic in that it may have abrasive qualities.

10 When complete rotator cuff repair is not technically achievable, another method of repair, known as a superior capsular reconstruction (SCR), may be employed as an alternative treatment. SCR places a tissue graft into the subacromial space spanning the humeral head and the glenoid neck. However, current solutions for arthroscopic SCR are difficult to perform due to intensive suture management and complicated steps. Such complexity makes the procedures less reproducible because of the number of steps involved and the possible
15 pitfalls along the way.

Accordingly, there is a continued need for improved surgical techniques for arthroscopic, knotless rotator cuff repair.

SUMMARY

20 Embodiments of the present disclosure are directed to improved systems and methods for arthroscopic joint repair. Accordingly, certain embodiments of the disclosed methods are directed to systems and methods for arthroscopic rotator cuff repair. It has become recognized that increased suture contact area and distribution of pressure upon the rotator cuff repair surgery may aid post-operative healing. Accordingly, embodiments of the disclosed
25 repair advantageously may employ one or more braided suture constructs that provide greater contact area and pressure distribution with soft tissue, than comparable, alternative suture systems.

Further embodiments of the systems and methods for knotless tissue repair of this disclosure may include one or more of the following, in any suitable combination.

30 In one example, the method of this disclosure includes routing a first suture construct through a tissue in a first inverted mattress stitch, including a loop portion and two free limbs.

The loop portion of the first suture construct is positioned adjacent to a superior surface of the tissue and the free limbs of the first suture construct extend through an inferior surface of the tissue. The method also includes inserting a second suture construct, separate from the first suture construct, within the loop portion of the first suture construct such that two free limbs
5 of the second suture construct extend from the loop portion of the first suture construct. The second suture construct is made from a plurality of braided filaments and possesses a substantially rectangular cross-sectional profile, and does not include a suture core surrounded by the braided filaments. The method also includes securing the free limbs of the first suture construct to a humeral head at a selected medial location with respect to the tissue without
10 forming a knot with the free limbs of the first suture construct, and approximating the tissue down to the humeral head at the selected medial location. Finally, the method includes extending the free limbs of the second suture construct to one or more selected lateral locations with respect to the tissue, whereby at least a portion of the tissue is urged laterally, and securing the free limbs of the second suture construct to the humeral head at the one or
15 more selected lateral locations without forming a knot with the free limbs of the second suture construct. The portion of the second suture construct extending between the selected medial location and the one or more selected lateral locations contacts the superior surface of the tissue.

In further examples of the method, securing the free limbs of the first suture construct
20 to the humeral head includes inserting at least a portion of each of the free limbs of the first suture construct into a first knotless suture anchor and implanting the first knotless suture anchor into the humeral head at the selected medial location. In further examples, securing the free limbs of the second suture construct to the humeral head includes inserting at least a portion of the free limbs of the second suture construct into a second knotless suture anchor
25 and implanting the second knotless suture anchor into the humeral head at the selected lateral location. In further examples, routing the first suture construct through the tissue includes routing a first pair of suture constructs through the tissue, each one of the first pair of suture constructs having a loop portion. Inserting the second suture construct within the loop portion of the first suture construct includes inserting a second pair of suture constructs within the
30 loop portions of the first pair of suture constructs, respectively. In examples, the tissue is a rotator cuff or a graft.

In further examples, the method includes routing a third suture construct through the tissue in a second inverted mattress stitch, including a loop portion and two free limbs. The loop portion of the third suture construct so routed is positioned adjacent to the superior surface of the tissue and the free limbs of the first suture construct so routed extend through the inferior surface of the tissue. The method also includes inserting a fourth suture construct, separate from the third suture construct, within the loop portion of the third suture construct such that two free limbs of the fourth suture construct extend from the loop portion of the third suture construct. The method further includes securing the free limbs of the third suture construct to a glenoid at a selected glenoid location with respect to the tissue without forming a knot with the free limbs of the third suture construct, and approximating the tissue down to the glenoid at the selected glenoid location. Finally, the method includes extending the free limbs of the fourth suture construct to the one or more selected lateral locations with respect to the tissue, whereby at least a portion of the tissue is urged laterally, and securing the free limbs of the fourth suture construct to the humeral head at the one or more selected lateral locations without forming a knot with the free limbs of the fourth suture construct. The portion of the fourth suture construct extending between the selected glenoid location and the one or more selected lateral locations contacts the superior surface of the tissue.

In yet further examples, securing the free limbs the third suture construct to the glenoid includes inserting at least a portion of each of the free limbs of the third suture construct into the third knotless suture anchor, and implanting the third knotless suture anchor and free limbs of the third suture construct into the glenoid at the selected glenoid location. Securing the free limbs of the fourth suture construct to the humeral head includes inserting at least a portion of the free limbs of the fourth suture construct into the second knotless suture anchor. Routing the third suture construct through the tissue includes routing a third pair of suture constructs through the tissue, each one of the third pair of suture constructs having a loop portion. Inserting the fourth suture construct within the loop portion of the third suture construct includes inserting a fourth pair of suture constructs within the loop portions of the third pair of suture constructs, respectively. In examples, the method further includes routing a first lateral suture and a second lateral suture through opposing corners of the tissue such that two free limbs of each of the first and second lateral sutures extend from the superior surface of the tissue. In examples, the method further includes securing the free limbs of the

first lateral suture and the second lateral suture to the humeral head at the one or more selected lateral locations with respect to the tissue after said routing without forming a knot with the free limbs of the first lateral suture and the second lateral suture. In examples, securing the free limbs of the first lateral suture and the second lateral suture to the humeral
5 head includes inserting at least a portion of the free limbs of the first lateral suture and the second lateral suture into the second knotless suture anchor.

Examples of a suture/tissue construct for use in a knotless tissue repair of this disclosure include a tissue having a superior surface and an inferior surface. The construct also includes a first suture construct routed through the tissue at a selected medical location
10 with respect to the tissue in a first inverted mattress stitch, including a loop portion and two free limbs. The loop portion of the first suture construct so routed is positioned adjacent to the superior surface of the tissue and the free limbs of the first suture construct so routed extend through the inferior surface of the tissue. The construct also includes a second suture construct, separate from the first suture construct, inserted within the loop portion of the first
15 suture construct such that two free limbs of the second suture construct extend from the loop portion of the first suture construct. The second suture construct is made of a plurality of braided filaments and possesses a substantially rectangular cross-sectional profile, and does not include a suture core surrounded by the braided filaments. In examples, the first suture construct includes a first pair of suture constructs, each one of the first pair of suture
20 constructs having a loop portion. In examples, the second suture construct includes a second pair of suture constructs, each one of the second pair of suture constructs inserted within the loop portions of the first pair of suture constructs, respectively. In examples, the tissue is a rotator cuff or a graft.

In further examples, the suture/tissue construct includes a third suture construct routed
25 through the tissue at a selected glenoid location with respect to the tissue in a second inverted mattress stitch, including a loop portion and two free limbs. The loop portion of the third suture construct so routed is positioned adjacent to the superior surface of the tissue and the free limbs of the first suture construct so routed extend through the inferior surface of the tissue. The construct also includes a fourth suture construct, separate from the third suture
30 construct, inserted within the loop portion of the third suture construct such that two free limbs of the fourth suture construct extend from the loop portion of the third suture construct.

In examples, the third suture construct includes a third pair of suture constructs, each one of the third pair of suture constructs having a loop portion. In examples, the fourth suture construct includes a fourth pair of suture constructs, each one of the fourth pair of suture constructs inserted within the loop portions of the third pair of suture constructs, respectively.

- 5 In further examples, the construct includes a first lateral suture and a second lateral suture routed through opposing corners of the tissue such that two free limbs of each of the first and second lateral sutures extend from the superior surface of the tissue. In examples, construct is preassembled prior to introduction of the construct into a joint space.

- 10 When used in embodiments of the disclosed rotator cuff repair method, the braided suture construct may distribute forces to underlying soft tissue more uniformly, and over a greater area, than alternative suture systems, which is expected to lead to improved clinical outcomes following rotator cuff repair. It is also anticipated that the braided suture construct system may also lower the pressure applied upon the soft tissue, reducing vascular constriction, and reducing the likelihood of tissue tearing when routed through, and applying
15 force upon, soft tissue. Advantageously, each of these characteristics may further support healing.

BRIEF DESCRIPTION OF THE DRAWINGS

- 20 The foregoing and other objects, features and advantages will be apparent from the following more particular description of the embodiments, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the embodiments.

Figure 1 is a schematic illustration of a torn rotator cuff;

- 25 Figures 2A-E are schematic illustrations of an embodiment of a knotless rotator cuff repair technique employing a braided suture construct;

Figures 3A-C are schematic illustrations of another embodiment of a knotless rotator cuff repair technique employing a braided suture construct; and

- 30 Figures 4A-F are schematic illustrations of an embodiment of a knotless superior capsular reconstruction technique employing a braided suture construct.

DETAILED DESCRIPTION

In the description that follows, like components have been given the same reference numerals, regardless of whether they are shown in different examples. To illustrate an example(s) in a clear and concise manner, the drawings may not necessarily be to scale and certain features may be shown in somewhat schematic form. Features that are described and/or illustrated with respect to one example may be used in the same way or in a similar way in one or more other examples and/or in combination with or instead of the features of the other examples.

The terms “comprise,” “include,” and/or plural forms of each are open ended and include the listed parts and can include additional parts that are not listed. “And/or” is open ended and includes one or more of the listed parts and combinations of the listed parts.

A schematic illustration of a damaged glenohumeral joint 10, including a rotator cuff 12 and a head of the humerus (i.e., humeral head 14) is shown in Figure 1. A superior surface 16 of the rotator cuff 12 is visible, while an opposing, inferior surface 18 is not visible. The joint damage is manifested as partial tear 20 in the rotator cuff 12, where a portion of the tendons at the ends of the rotator cuff 12 are severed from the humeral head 14. While the tear 20 of Figure 1 is illustrated as a partial tear, embodiments of the disclosure may also be employed for repair of full rotator cuff tears, as necessary.

With reference to Figures 2A-2E, embodiments of a method for repairing a damaged rotator cuff 12, such as that of Figure 1, will now be discussed. However, it may be understood that the disclosed embodiments may be employed in other types of joint repair involving soft tissue to bone fixation without limit. Embodiments may include, but are not limited to, Achilles tendon repair, patellar tendon repair, and hip abductor repair.

As illustrated in Figure 2A, embodiments of the method include routing a first suture construct 22 through the rotator cuff 12. In an embodiment, a plurality of portals 24 may be formed through the rotator cuff 12, either before or during such routing, extending between the superior surface 16 and inferior surface 18 of the rotator cuff 12. The positions of the portals 24 may be suitable for subsequent placement at a desired medial location of the humeral head 14, as further described below. In an embodiment, the first suture construct 22 may be routed through the rotator cuff 12 in a “mattress stitch,” as known in the art. In certain embodiments, the mattress stitch may be a horizontally inverted mattress stitch,

although other mattress stitches, such as a vertically inverted mattress stitches, are possible.

After routing through the rotator cuff 12, a portion of the first suture construct 22 forms a loop 26 positioned adjacent to the superior surface 16 of the rotator cuff 12. Free limbs 28 of the first suture construct 22 further extend from the loop 26 and through the inferior surface 18 of the rotator cuff 12. With reference to Figure 2B, embodiments of the method may further include inserting a second suture construct 30 within the loop 26 of the first suture construct 22. Non-limiting examples of inserting the second suture construct 30 within the loop 26 of the first suture construct 22 may include tying, looping or weaving the second suture construct 30 within the loop 26 of the first suture construct 22. After this insertion, two free limbs 30 of the second suture construct 30 extend from the loop 26 of the first suture construct 22.

The first suture construct 22 and the second suture construct 30 may be formed from non-absorbable, sterile surgical sutures, although very slow resorption type sutures could also be used. In an embodiment, the first suture construct 22 may consist essentially of a #2 suture, as known in the art. In a further embodiment, the second suture construct 30 may comprise a braided suture construct, woven from a plurality of filaments. In further embodiments, the second suture construct 30 may consist essentially of the braided suture construct, without a separate suture core. The filaments may be formed from a polymer (e.g., ultra-high molecular weight polyethylene). In certain embodiments, this braided suture architecture exhibits a generally flat (e.g., rectangular) cross-sectional profile. In further embodiments, the braided suture architecture may possess a width within the range between about 1.85 to about 2.5 mm. In an embodiment, the braided suture architecture may possess a width of about 2 mm. In additional embodiments, the braided suture architecture may possess a height within the range between about 0.15 to about 0.45 mm. In an embodiment, the braided suture architecture may possess a height of about 0.3 mm. In certain embodiments, the braided suture construct may satisfy the U.S. Pharmacopeial Convention (USP) average knot-pull tensile strength requirements for nonabsorbable #2 suture as given in the USP Monograph USP 37-NF32:2014 "Nonabsorbable Surgical Suture." In certain embodiments, the average knot-pull tensile strength of the braided suture construct may fall within the range between about 88 N to about 156 N. Non-limiting examples of the braided suture construct may include, but are not limited to, ULTRATAPE (Smith & Nephew, Inc., Memphis, TN,

USA). In additional embodiments, both the first suture construct 22 and the second suture construct 30 may be formed from this braided suture construct.

With reference to Figure 2C, embodiments of the method may further include securing the free limbs 28 of the first suture construct 22 to the humeral head 14. In an embodiment, the free limbs 28 of the first suture construct 22 are secured to the humeral head 14 after inserting the second suture construct 30 within the loop 26 of the first suture construct 22. In an alternative embodiment, the free limbs 28 of the first suture construct 22 are secured to the humeral head 14 before inserting the second suture construct 30 within the loop 26 of the first suture construct 22 by engaging the second suture construct 30 on the top of the first suture construct 22 before securing the first suture construct 22 to the rotator cuff 12. For example, securing the first suture construct 22 to the humeral head 14 may include selecting a desired medial location 35 of the humeral head 14. At least a portion of the free limbs 28 of the first suture construct 22 may be inserted into a medial row anchor 34. The medial row anchor 34 may be subsequently implanted into the desired medial location 35. The medial row anchor 34 may be a knotless suture anchor, many examples of which are known in the art. Accordingly, in certain embodiments, securing the first suture construct 22 to the humeral head 14 may not include forming a knot with the free limbs 28 of the first suture construct 22. Rather, the free limbs 28 of the first suture construct 22 may be frictionally secured to the medial row anchor 34 by pressure exerted upon the free limbs 28. Such pressure may be exerted by the medial row anchor 34, the surrounding bone, or combinations thereof.

Still referring to Figure 2C, embodiments of the method may further include approximating the rotator cuff 12 down to the humeral head 14 at the selected medial location 35. In an embodiment, the rotator cuff 12 is approximated to the humeral head 14 by pulling on the free limbs 28 either before or after the insertion of the free limbs 28 into the medial row anchor 34 (or both before and after micro-adjustments of rotator cuff 12 reduction). Once the rotator cuff 12 is reduced to the humeral head 14 and the medial row anchor 34 is inserted into the humeral head 14, the medial row tendon (not shown) is secured with a locking mechanism. In another example, such approximation may be performed after securing the first suture construct 22 to the humeral head 14. In alternative embodiments, such approximation may be performed before securing the first suture construct 22 to the

humeral head 14. Advantageously, this provides a “knot-like” point of fixation at the medial location 35.

With reference to Figure 2D, the two free limbs 32 of the second suture construct 30 are extended towards one or more selected lateral locations 36. So extended, the free limbs 32 of the second suture construct 30 exert a reduction force (F) on the rotator cuff 12 and urge at least a portion of the rotator cuff 12 laterally. As illustrated in Figure 2E, in certain embodiments, both of the free limbs 32 of the second suture construct 30 may be extended towards the same lateral location 36. Once positioned, the second suture construct 30 may be secured to the humeral head 14. For example, a portion of the free limbs 32 of the second suture construct 30 may be inserted into a lateral row anchor 38. In embodiments, the lateral row anchor 38 may be a knotless suture anchor. Accordingly, in certain embodiments, securing the second suture construct 30 to the humeral head 14 may not include forming a knot with the free limbs 32 of the second suture construct 30. Rather, the free limbs 32 of the second suture construct 30 may be frictionally secured to the lateral row anchor 38 by pressure exerted upon the free limbs 32. Such pressure may be exerted by the lateral row anchor 38, the surrounding bone, or combinations thereof. The lateral row anchor 38 may be subsequently implanted into the desired lateral location 36. Once the second suture construct 30 is secured at the one or more selected lateral locations 36, a portion of the second suture construct 30 extends between the selected medial location 35 and lateral location 36, overlying and contacting the superior surface 16 of the rotator cuff 12. The pressure applied by the second suture construct 30 upon the rotator cuff 12 urges the rotator cuff 12 into contact with the humeral head 14, facilitating repair of the tear 20.

In alternative embodiments of the method, more than one first suture construct 22 and second suture construct 30 may be employed for rotator cuff repair. For example, as illustrated in Figure 3A, two pairs of first suture constructs 22a,b and second suture constructs 30a,b may be employed. In alternative embodiments, the number of first and second suture construct pairs may be increased, without limit. Each pair of first suture constructs 22a,b and second suture constructs 30a,b may be secured to the humeral head 14 in the same manner as discussed above with respect to Figures 2A-2E. Figure 3B shows a closed system with the free limbs 28a of first suture construct 22a routed to a first medial row anchor 34a, and the free limbs 28b of first suture construct 22b routed to a second medial row anchor 34b. The

free limbs 32a of second suture construct 30a are routed to a first lateral row anchor 38a, and the free limbs 32b of second suture construct 30b are routed to a second lateral row anchor 38b. Figure 3C shows a suture bridge-like interconnection in which the free limb 32a1 of second suture construct 30a and the free limb 32b1 of second suture construct 30b are routed to the first lateral row anchor 38a, and the free limb 32a2 of second suture construct 30a and the free limb 32b2 of second suture construct 30b are routed to the second lateral row anchor 38b.

Turning now to Figures 4A-F, an example of a method of SCR for repairing a glenohumeral joint will now be discussed. The methods of SCR of this disclosure are similar to the methods described above with respect to Figures 1-3C, except as described below. It may be also be understood that the disclosed embodiments may be employed in other types of joint repair involving soft tissue to bone fixation without limit.

With reference to Figure 4A, a glenohumeral joint 50 of the human musculoskeletal system is illustrated. The joint 50 includes multiple bones, including a scapula 52 and a humerus 54, which may articulate relative to one another. For example, the joint 50 includes a ball and socket joint formed between a head 56 of the humerus 54 and a glenoid 58, which is a cup-like recession of the scapula 52 configured to receive the humeral head 56. A capsule 60 generally covers the joint 50 and is surrounded and reinforced by various muscles, tendons and ligaments that are responsible for keeping the adjoining bones of the joint 50 together. The joint 50 may become unstable if there is significant disruption of the articulating bones (e.g., the humerus 54 and the glenoid 58), the capsule 60, or other surrounding muscles, tendons and/or ligaments. For example, the joint 50 could become unstable in response to an irreparable rotator cuff tear. In Figures 4B-D, the bones of the joint 50 are omitted from the figures for ease of illustration.

With reference to Figure 4B, embodiments of the method of SCR include routing a first pair of suture constructs 62a,b through a graft 64, such as a dermal graft. In an embodiment, a plurality of portals 63 may be formed through the graft 64, either before or during such routing, extending between the superior surface 68 and the inferior surface 70 of the graft 64. The positions of the portals 63 may be suitable for subsequent placement at a desired glenoid location of the glenoid 58 (Figure 4A), as further described below. In an embodiment, the first pair of suture constructs 62a,b may be routed through the graft 64 in a

mattress stitch. After routing through the graft 64, a portion of the first pair of suture constructs 62a,b forms a first pair of loops 72a,b positioned adjacent to the superior surface 68 of the graft 64. Free limbs 74a,b of the first pair of suture constructs 62a,b further extend from the loops 72a,b and through the inferior surface 70 of the graft 64. In the example of Figure 4B, the mattress stitches may be routed through the graft 64 such that the loops 72a,b overlap to further aid in compression of the graft 64. In other embodiments (not shown) the mattress stitches may be routed through the graft 64 such that the loops 72a,b share a common portal 63 near the center of the graft 64. Embodiments of the method may further include inserting a second pair of suture constructs 76a,b within the respective loops 72a,b of the first pair of suture construct 62a,b. After this insertion, two free limbs 78a,b of the second pair of suture construct 76a,b extend from the respective loops 72a,b of the first pair of suture constructs 62a,b.

Still referring to Figure 4B, embodiments of the method may further include routing a third pair of suture constructs 80a,b through the graft 64. In an embodiment, a plurality of portals 83 may be formed through the graft 64, either before or during such routing, extending between the superior surface 68 and the inferior surface 70 of the graft 64. The positions of the portals 83 may be suitable for subsequent placement at a desired medial location of the humeral head 56 (Figure 4A), as further described below. In an embodiment, the third pair of suture constructs 80a,b may be routed through the graft 64 in a mattress stitch. After routing through the graft 64, a portion of the third pair of suture constructs 80a,b forms a second pair of loops 82a,b positioned adjacent to the superior surface 68 of the graft 64. Free limbs 84a,b of the third pair of suture constructs 80a,b further extend from the loops 82a,b and through the inferior surface 70 of the graft 64. In the example of Figure 4B, the mattress stitches may be routed through the graft 64 such that the loops 82a,b overlap to further aid in compression of the graft 64. In other embodiments (not shown) the mattress stitches may be routed through the graft 64 such that the loops 82a,b share a common portal 83 near the center of the graft 64. Embodiments of the method may further include inserting a fourth pair of suture constructs 86a,b within the respective loops 82a,b of the third pair of suture constructs 80a,b. After this insertion, two free limbs 88a,b of the fourth pair of suture constructs 86a,b extend from the respective loops 82a,b of the third pair of suture constructs 80a,b. In further embodiments, two lateral sutures 90, 92 can optionally be attached to opposing corners of the graft 64. The

lateral sutures 90, 92 may include individual suture strands, multiple suture strands, suture tape or any other suture-like product. The lateral sutures 90, 92 are attached to the graft 64 such that two suture limbs extend from the superior surface 68 graft 64. For example, a “luggage tag” stitch may be used, as known in the art. Advantageously, it is contemplated that all sutures shown in Figure 4B could be passed through the graft 64 prior to introduction of the graft 64 into the endoscopic subacromial space, including the lateral sutures 90, 92. This is especially beneficial since passing the lateral sutures 90, 92 in the graft 64 is difficult given the thickness of the graft 64.

With reference to Figure 4C, embodiments of the method may further include securing the free limbs (not shown) of the pair of first suture constructs 62a,b to the glenoid 58. For example, securing the first pair of suture constructs 62a,b to the glenoid 58 may include selecting a desired glenoid location of the glenoid 58. At least a portion of the free limbs of the first pair of suture constructs 62a,b may be inserted into at least one glenoid row anchor (not shown). The glenoid row anchor may be subsequently implanted into the desired glenoid location. The glenoid row anchor may be a knotless suture anchor. Accordingly, in certain embodiments, securing the first pair of suture constructs 62a,b to the glenoid 58 may not include forming a knot with the free limbs of the first pair of suture constructs 62a,b. In embodiments, the method may further include approximating the graft 64 down to the glenoid 58 at the selected glenoid location. In an embodiment, the graft 64 is approximated to the glenoid 58 by pulling on the free limbs of the first pair of suture constructs 62a,b either before or after the insertion of the free limbs into the glenoid row anchor (or both before and after micro-adjustments of graft reduction). The free limbs 78a1,a2,b1,b2 of the second pair of suture constructs 76a,b are then extended towards one or more selected lateral locations 96 on the humerus 54. Once positioned, the second pair of suture constructs 76a,b may be secured to the humeral head 56. For example, a portion of the free limbs 78a1,a2,b1,b2 of the second pair of suture constructs 76a,b may be inserted into three lateral row anchors 100, 102, 104. However, it is contemplated by this disclosure that more or fewer than three lateral row anchors may be used. In embodiments, the lateral row anchors 100, 102, 104 may be a knotless suture anchors. Accordingly, in certain embodiments, securing the second pair of suture constructs 76a,b to the humerus 54 may not include forming a knot with the free limbs 78a,b of the second pair of suture constructs 76a,b. The lateral row anchors 100, 102, 104

may be subsequently implanted into the desired lateral location 96. Once the second pair of suture constructs 76a,b is secured at the one or more selected lateral locations 96, a portion of the second pair of suture constructs 76a,b extends between the glenoid 54 and the lateral location 96 of the humerus, overlying and contacting the superior surface 58 of the graft 64.

5 Still in reference to Figure 4C, embodiments of the method may further include securing the free limbs (not shown) of the third pair of suture constructs 80a,b to the humerus 54. For example, securing the third pair of suture constructs 80a,b to the humerus may include selecting a desired medial location 106 of the humerus 54. At least a portion of the free limbs of the third pair of suture constructs 80a,b may be inserted into at least one medial
10 row anchor (not shown). The medial row anchor may be subsequently implanted into the desired medial location 106 of the humerus 54. In embodiments, the medial row anchor may be a knotless suture anchor. Accordingly, in certain embodiments, securing the third pair of suture constructs 80a,b to the humerus 54 may not include forming a knot with the free limbs of the third pair of suture constructs 80a,b. In embodiments, the method may further include
15 approximating the graft 64 down to the humerus 54 at the selected medial location 106 by pulling on the free limbs of the third pair of suture constructs 80a,b either before or after the insertion of the free limbs into the medial row anchor (or both before and after micro-adjustments of graft reduction). The free limbs 88a1,a2,b1,b2 of the fourth pair of suture constructs 86a,b are extended towards the one or more selected lateral locations 96 on the
20 humerus 54. Once positioned, the fourth pair of suture constructs 86a,b may be secured to the humeral head 56. For example, a portion of the free limbs 88a1,a2,b1,b2 of the fourth pair of suture constructs 86a,b may be inserted into at least one of the lateral row anchors 100, 102, 104. However, it is contemplated by this disclosure that the portion of the free limbs 88a,b may be secured to one or more additional lateral anchors, not shown. Once the fourth pair of
25 suture constructs 86a,b is secured at the one or more selected lateral locations 96, a portion of the fourth pair of suture constructs 86a,b extends between the medial location 106 and the lateral location 96 of the humerus 54, overlying and contacting the superior surface 58 of the graft 64.

Notably, in Figure 4C, both of the free limbs 78a2 and 78b1 of the second pair of
30 suture constructs 76a,b are shown as inserted into the same lateral row anchor 102, while free limb 78a1 is inserted into lateral row anchor 100 and free limb 78b2 is inserted into the lateral

row anchor 104. Additionally, both of the free limbs 88a2 and 88b1 of the fourth pair of suture constructs 86a,b are inserted into lateral row anchor 102, while free limb 88a1 is inserted into lateral row anchor 100 and free limb 88b2 is inserted into the lateral row anchor 104. Finally, lateral row suture 90 is inserted into lateral row anchor 100, while lateral row suture 92 is inserted into lateral row anchor 104. However, other suture/anchor configurations are contemplated by this disclosure without limit. For example, in Figure 4D, only two lateral row anchors 100, 104 are used. Free limbs 78a1 and 78b1, as well as lateral suture 90, are attached to lateral row anchor 100, while free limbs 78a2 and 78b2, as well as lateral suture 92, are attached to lateral row anchor 104.

It will be appreciated that many variations of the methods described above with regard to Figures 4A-C are contemplated by this disclosure. In one non-limiting example, shown in Figure 4E, only the first pair of suture constructs 62a,b, the second pair of suture constructs 76a,b, the third pair of suture constructs 80a,b, and the lateral sutures 90, 92 are used to secure the graft 64 using three lateral row anchors (not shown). In another non-limiting example, shown in Figure 4F, the second pair of suture constructs 76a,b could be omitted, and the fourth pair of suture constructs 86a,b used instead, along with two lateral row anchors 100, 104. However, it is contemplated that other combinations of suture constructs, lateral sutures, and lateral anchors, could be used to secure the graft 64.

One skilled in the art will realize the invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the invention described herein. Scope of the invention is thus indicated by the appended claims, rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

CLAIMS

What is claimed is:

1. A method of tissue repair, comprising:
 - 5 routing a first suture construct through a tissue in a first inverted mattress stitch, including a loop portion and two free limbs, wherein the loop portion of the first suture construct so routed is positioned adjacent to a superior surface of the tissue and the free limbs of the first suture construct so routed extend through an inferior surface of the tissue;
inserting a second suture construct, separate from the first suture construct, within the
10 loop portion of the first suture construct such that two free limbs of the second suture construct extend from the loop portion of the first suture construct, wherein the second suture construct comprises a plurality of braided filaments and possesses a substantially rectangular cross-sectional profile, and does not include a suture core surrounded by the braided filaments;
15 securing the free limbs of the first suture construct to a humeral head at a selected medial location with respect to the tissue after said routing without forming a knot with the free limbs of the first suture construct;
approximating the tissue down to the humeral head at the selected medial location;
extending the free limbs of the second suture construct to one or more selected lateral
20 locations with respect to the tissue, whereby at least a portion of the tissue is urged laterally;
and
securing the free limbs of the second suture construct to the humeral head at the one or more selected lateral locations without forming a knot with the free limbs of the second suture construct;
25 wherein the portion of the second suture construct extending between the selected medial location and the one or more selected lateral locations contacts the superior surface of the tissue.
2. The method of Claim 1, wherein securing the free limbs of the first suture construct to
30 the humeral head comprises:

inserting at least a portion of each of the free limbs of the first suture construct into a first knotless suture anchor; and

implanting the first knotless suture anchor into the humeral head at the selected medial location.

5

3. The method of Claim 1, wherein securing the free limbs of the second suture construct to the humeral head comprises:

inserting at least a portion of the free limbs of the second suture construct into a second knotless suture anchor; and

10 implanting the second knotless suture anchor into the humeral head at the selected lateral location.

4. The method of Claim 1, wherein routing the first suture construct through the tissue comprises routing a first pair of suture constructs through the tissue, each one of said first pair of suture constructs comprising a loop portion.

15

5. The method of Claim 4, wherein inserting the second suture construct within the loop portion of the first suture construct comprises inserting a second pair of suture constructs within the loop portions of the first pair of suture constructs, respectively.

20

6. The method of Claim 1, wherein the tissue is a rotator cuff.

7. The method of Claim 1, wherein the tissue is a graft.

25 8. The method of Claim 1, further comprising:

routing a third suture construct through the tissue in a second inverted mattress stitch, including a loop portion and two free limbs, wherein the loop portion of the third suture construct so routed is positioned adjacent to the superior surface of the tissue and the free limbs of the first suture construct so routed extend through the inferior surface of the tissue;

inserting a fourth suture construct, separate from the third suture construct, within the loop portion of the third suture construct such that two free limbs of the fourth suture construct extend from the loop portion of the third suture construct;

securing the free limbs of the third suture construct to a glenoid at a selected glenoid location with respect to the tissue after said routing without forming a knot with the free limbs of the third suture construct;

approximating the tissue down to the glenoid at the selected glenoid location;

extending the free limbs of the fourth suture construct to the one or more selected lateral locations with respect to the tissue, whereby at least a portion of the tissue is urged laterally; and

securing the free limbs of the fourth suture construct to the humeral head at the one or more selected lateral locations without forming a knot with the free limbs of the fourth suture construct;

wherein the portion of the fourth suture construct extending between the selected glenoid location and the one or more selected lateral locations contacts the superior surface of the tissue.

9. The method of Claim 8, wherein securing the free limbs of the third suture construct to the glenoid comprises:

inserting at least a portion of each of the free limbs of the third suture construct into a third knotless suture anchor; and

implanting the third knotless suture anchor into the glenoid at the selected glenoid location.

10. The method of Claim 8, wherein securing the free limbs of the fourth suture construct to the humeral head comprises inserting at least a portion of the free limbs of the fourth suture construct into the second knotless suture anchor.

11. The method of Claim 8, wherein routing the third suture construct through the tissue comprises routing a third pair of suture constructs through the tissue, each one of said third pair of suture constructs comprising a loop portion.

12. The method of Claim 11, wherein inserting the fourth suture construct within the loop portion of the third suture construct comprises inserting a fourth pair of suture constructs within the loop portions of the third pair of suture constructs, respectively.

5 13. The method of Claim 1, further comprising:

routing a first lateral suture and a second lateral suture through opposing corners of the tissue such that two free limbs of each of the first and second lateral sutures extend from the superior surface of the tissue; and

10 securing the free limbs of the first lateral suture and the second lateral suture to the humeral head at the one or more selected lateral locations with respect to the tissue after said routing without forming a knot with the free limbs of the first lateral suture and the second lateral suture.

14. The method of Claim 13, wherein securing the free limbs of the first lateral suture and
15 the second lateral suture to the humeral head comprises inserting at least a portion of the free limbs of the first lateral suture and the second lateral suture into the second knotless suture anchor.

15. A suture/tissue construct for use in a knotless tissue repair, the suture/tissue construct
20 comprising:

a tissue having a superior surface and an inferior surface;

a first suture construct routed through the tissue at a selected medical location with respect to the tissue in a first inverted mattress stitch, including a loop portion and two free limbs, wherein the loop portion of the first suture construct so routed is positioned adjacent to
25 the superior surface of the tissue and the free limbs of the first suture construct so routed extend through the inferior surface of the tissue; and

a second suture construct, separate from the first suture construct, inserted within the loop portion of the first suture construct such that two free limbs of the second suture construct extend from the loop portion of the first suture construct, wherein the second suture
30 construct comprises a plurality of braided filaments and possesses a substantially rectangular

cross-sectional profile, and does not include a suture core surrounded by the braided filaments.

16. The construct of Claim 15, wherein the first suture construct comprises a first pair of suture constructs, each one of said first pair of suture constructs comprising a loop portion.

17. The construct of Claim 16, wherein the second suture construct comprises a second pair of suture constructs, each one of the second pair of suture constructs inserted within the loop portions of the first pair of suture constructs, respectively.

18. The construct of Claim 15, wherein the tissue is a rotator cuff.

19. The construct of Claim 15, wherein the tissue is a graft.

20. The construct of Claim 15, further comprising:

a third suture construct routed through the tissue at a selected glenoid location with respect to the tissue in a second inverted mattress stitch, including a loop portion and two free limbs, wherein the loop portion of the third suture construct so routed is positioned adjacent to the superior surface of the tissue and the free limbs of the first suture construct so routed extend through the inferior surface of the tissue; and

a fourth suture construct, separate from the third suture construct, inserted within the loop portion of the third suture construct such that two free limbs of the fourth suture construct extend from the loop portion of the third suture construct.

21. The construct of Claim 20, wherein the third suture construct comprises a third pair of suture constructs, each one of said third pair of suture constructs comprising a loop portion.

22. The construct of Claim 21, wherein the fourth suture construct comprises a fourth pair of suture constructs, each one of the fourth pair of suture constructs inserted within the loop portions of the third pair of suture constructs, respectively.

23. The construct of Claim 15, further comprising:

a first lateral suture and a second lateral suture routed through opposing corners of the tissue such that two free limbs of each of the first and second lateral sutures extend from the superior surface of the tissue.

5

24. The construct of Claim 15 being preassembled prior to introduction of the construct into a joint space.

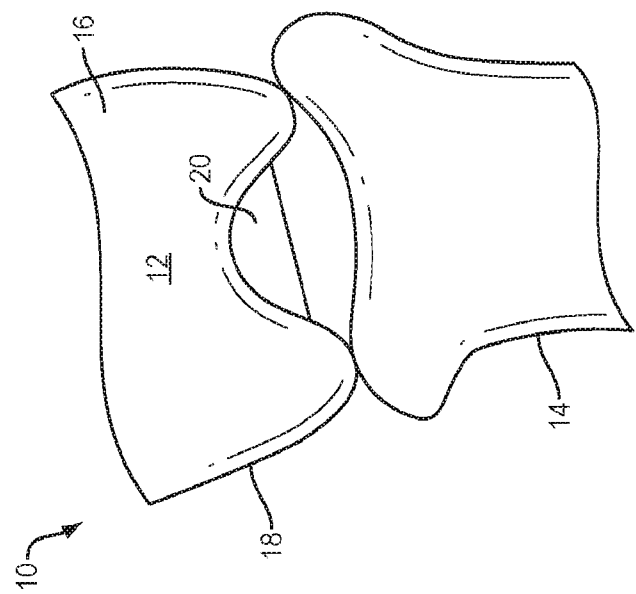


FIG. 1

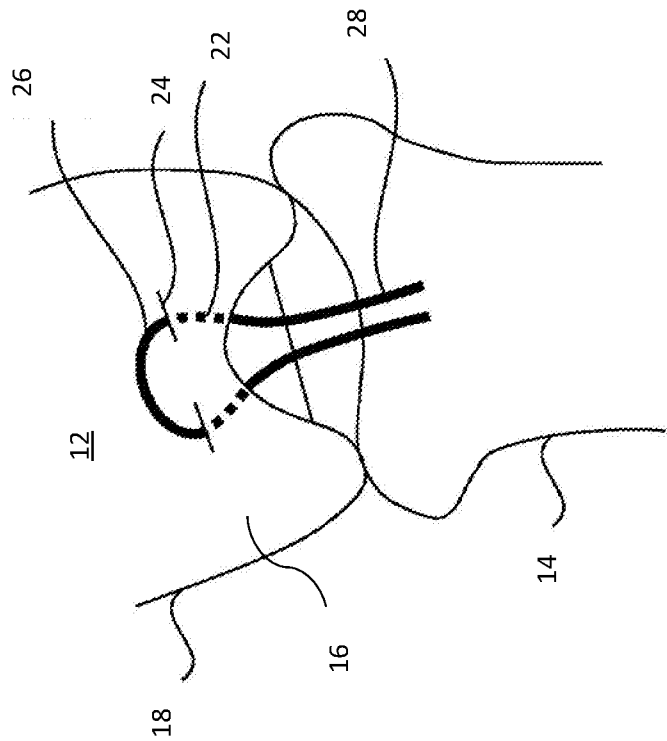


FIG. 2A

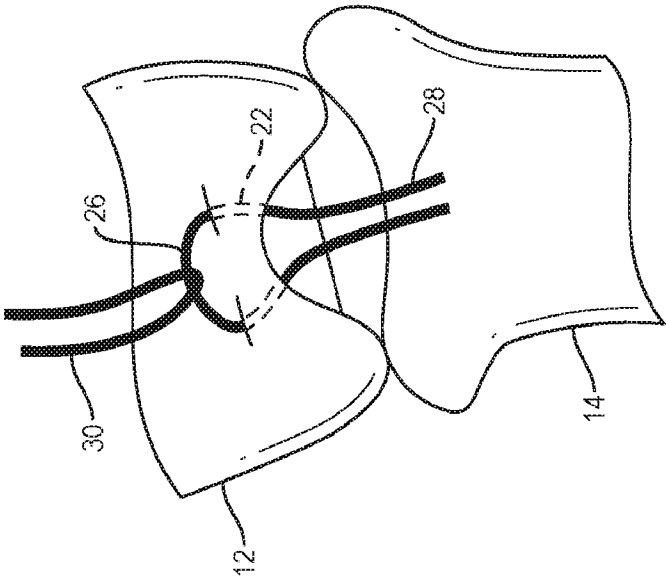


FIG. 2B

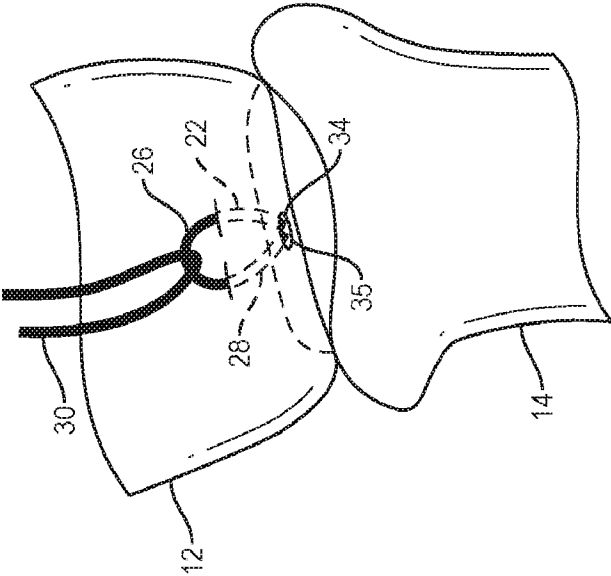


FIG. 2C

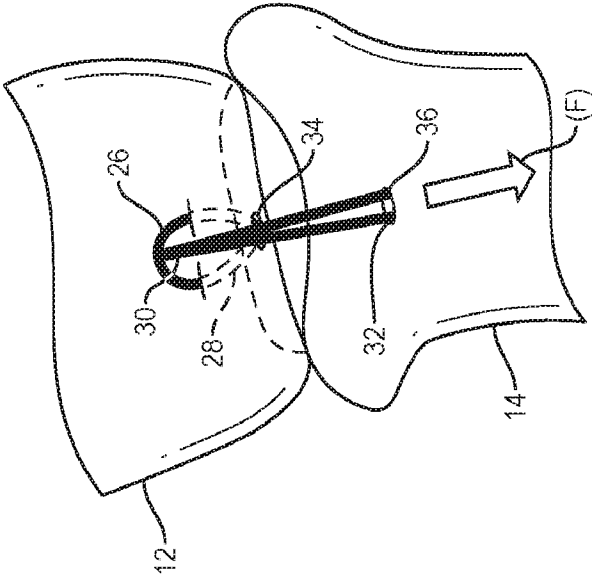


FIG. 2D

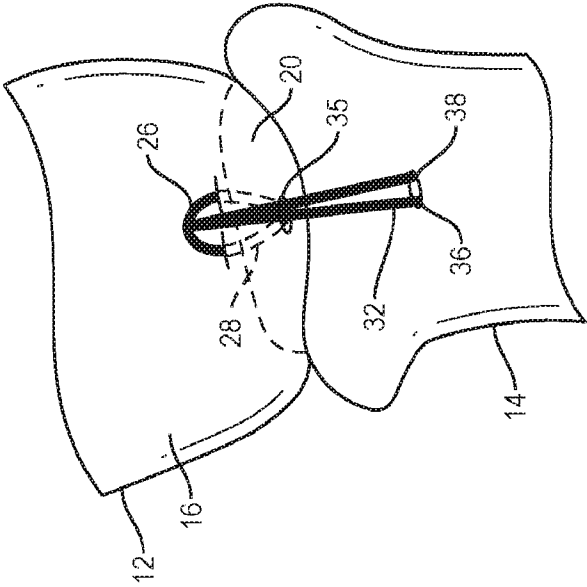


FIG. 2E

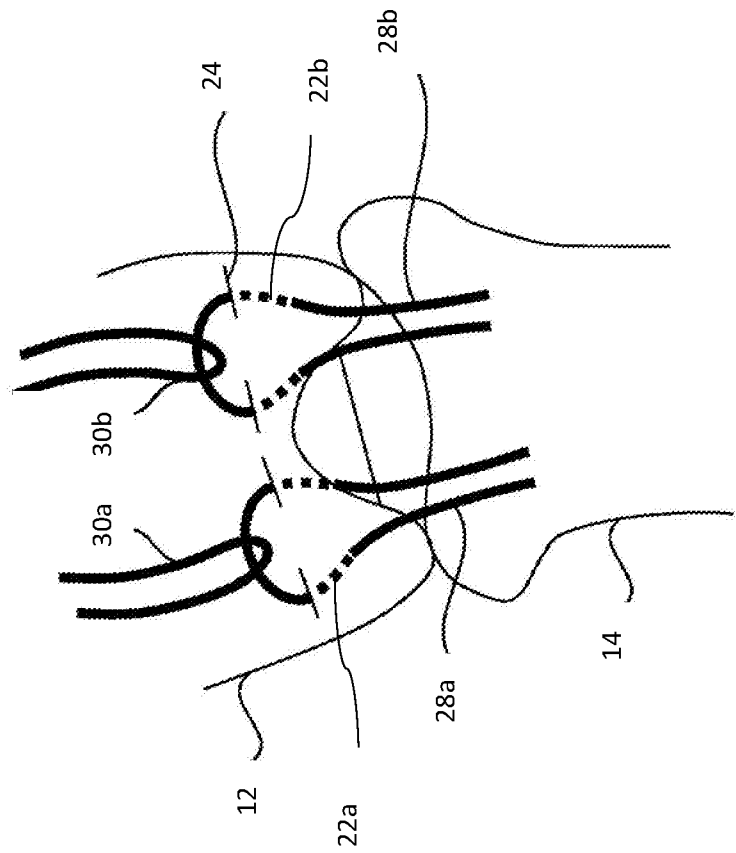


FIG. 3A

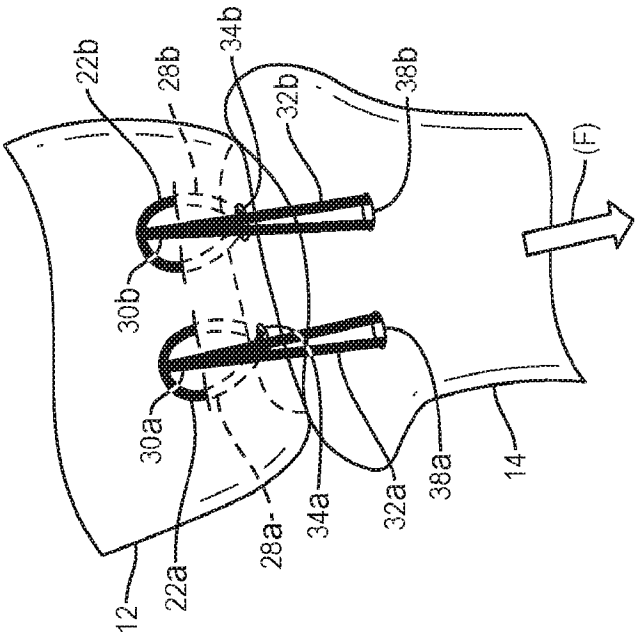


FIG. 3B

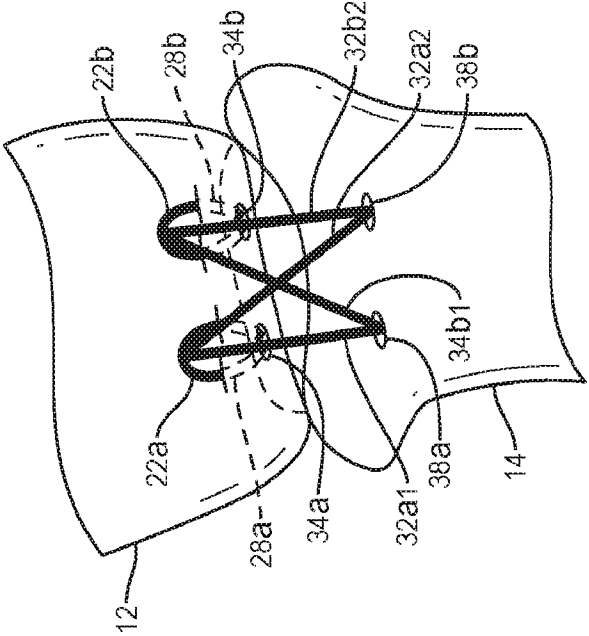


FIG. 3C

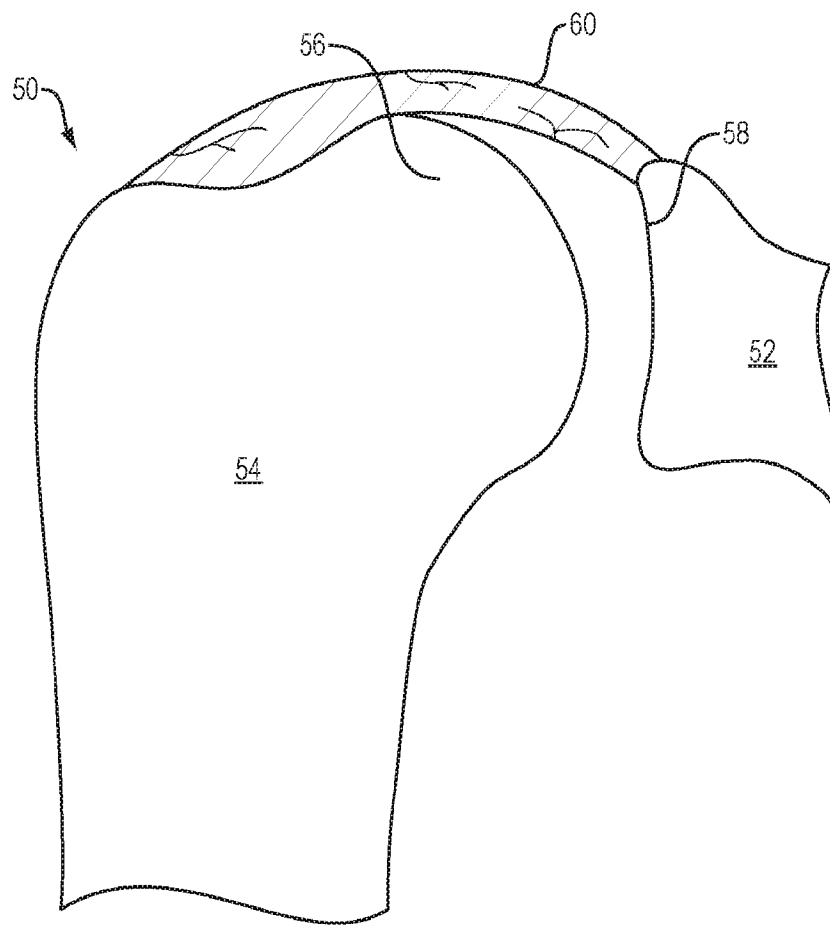


FIG. 4A

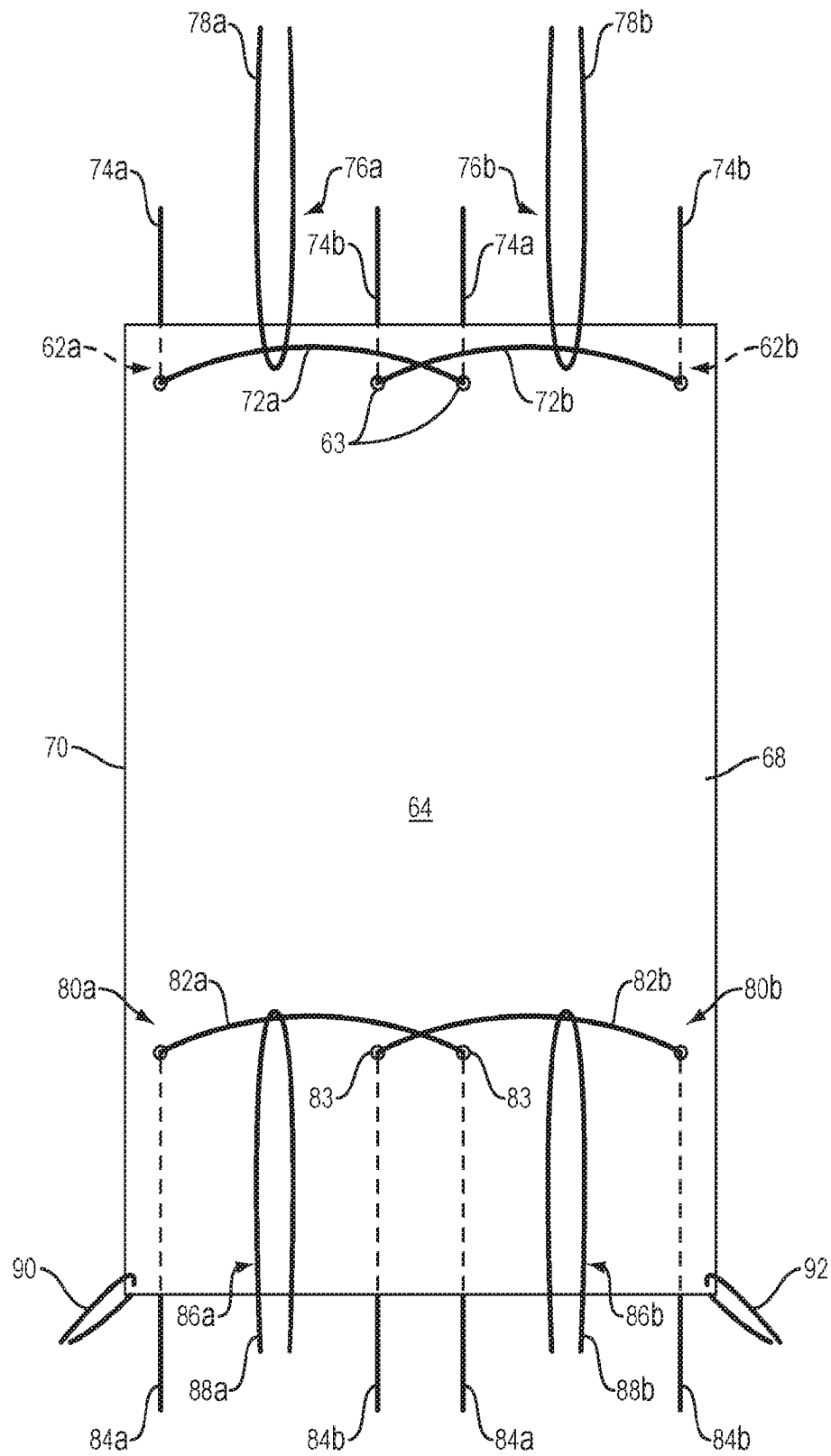


FIG. 4B

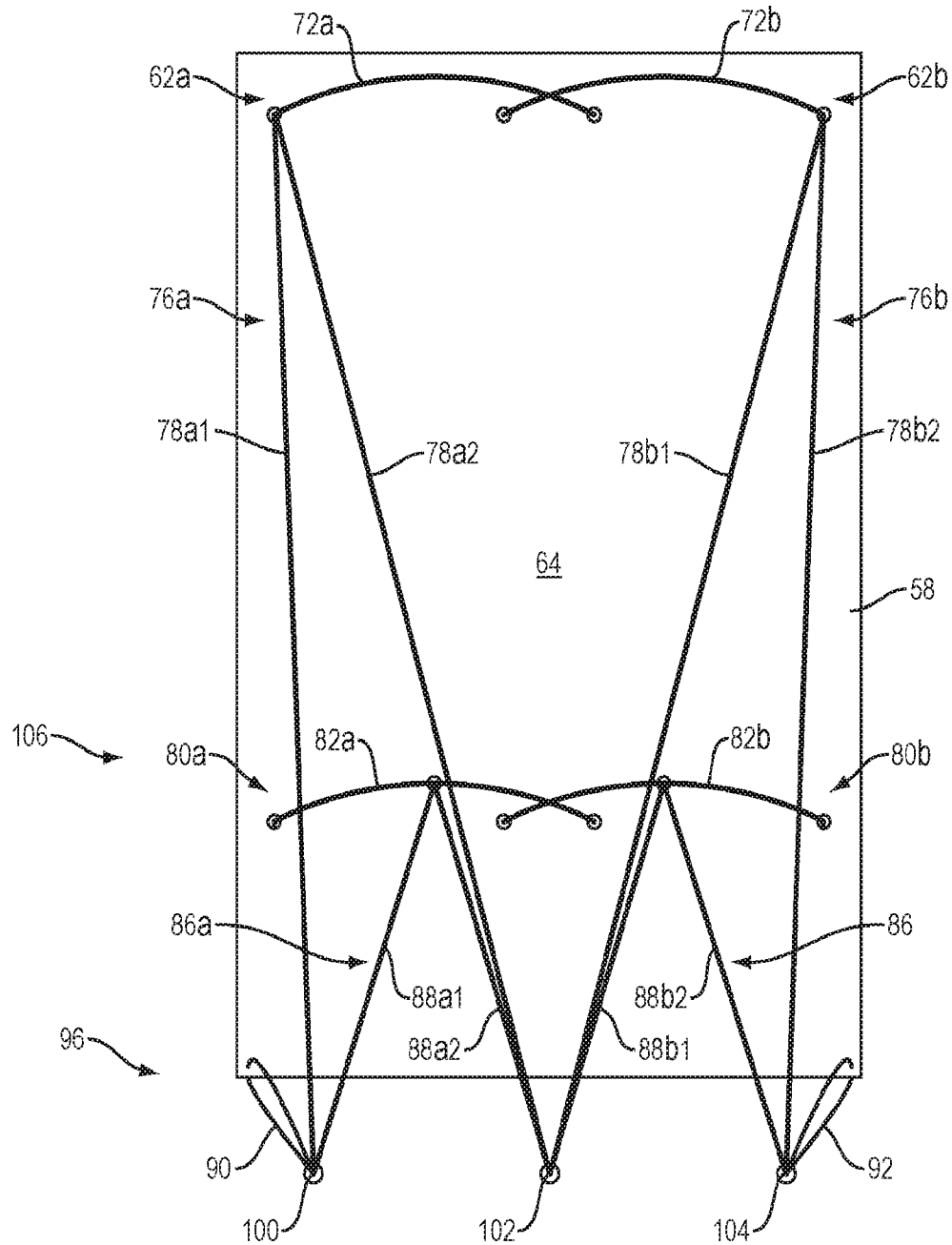


FIG. 4C

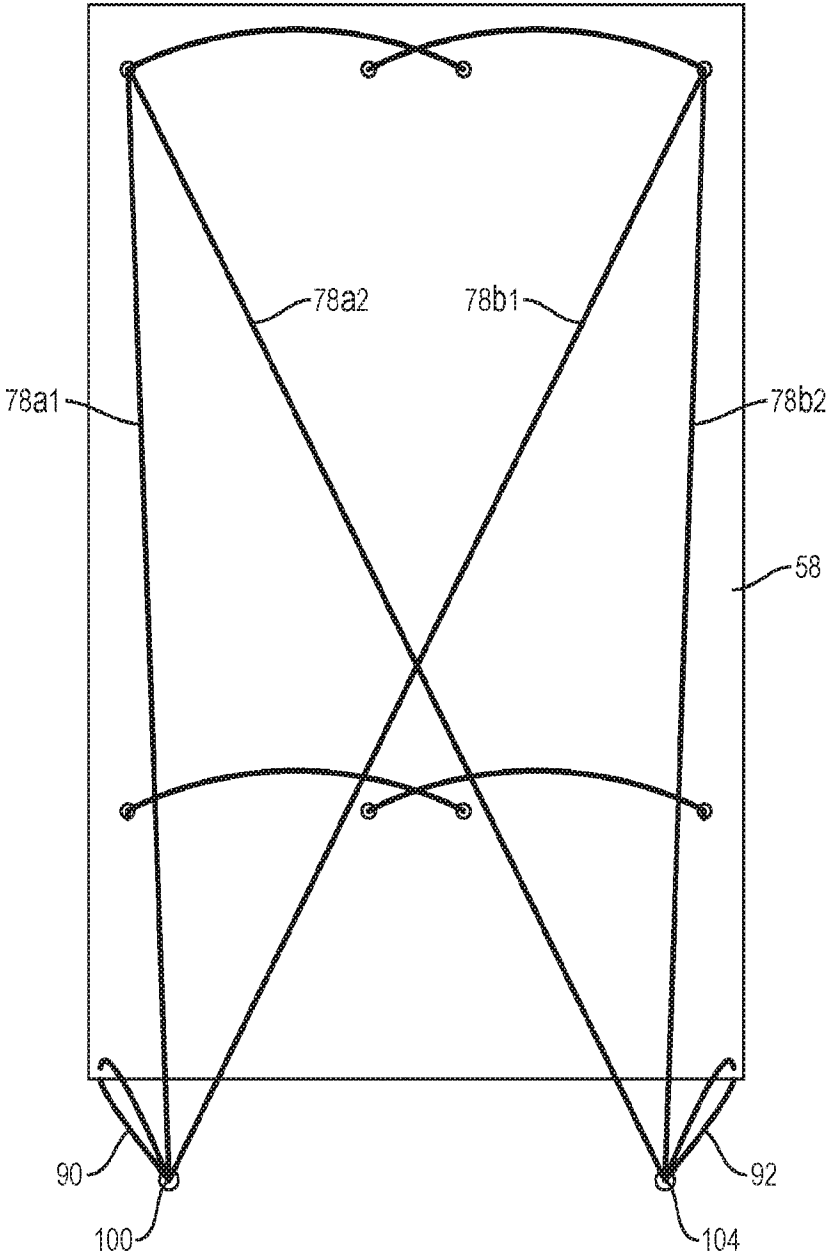


FIG. 4D

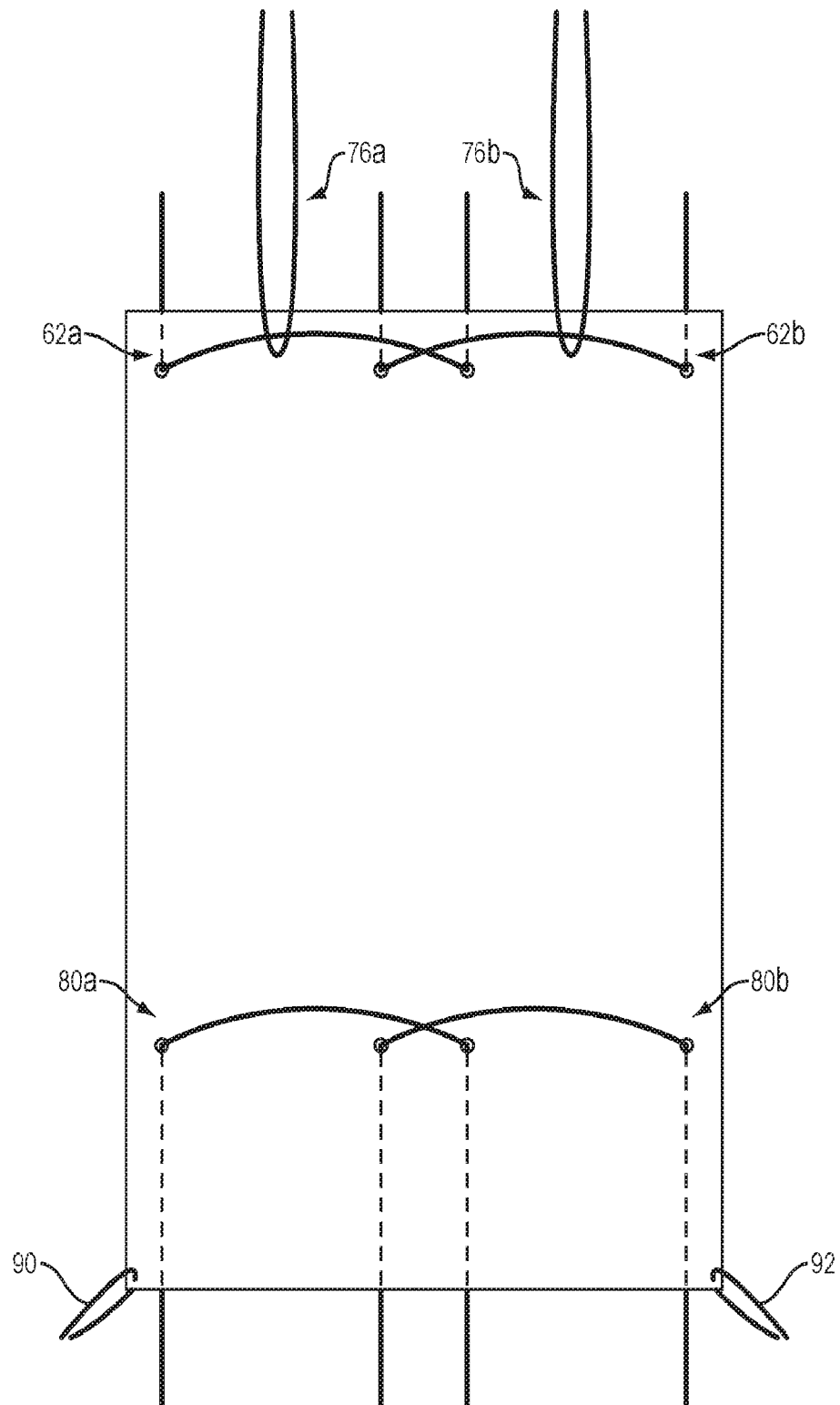


FIG. 4E

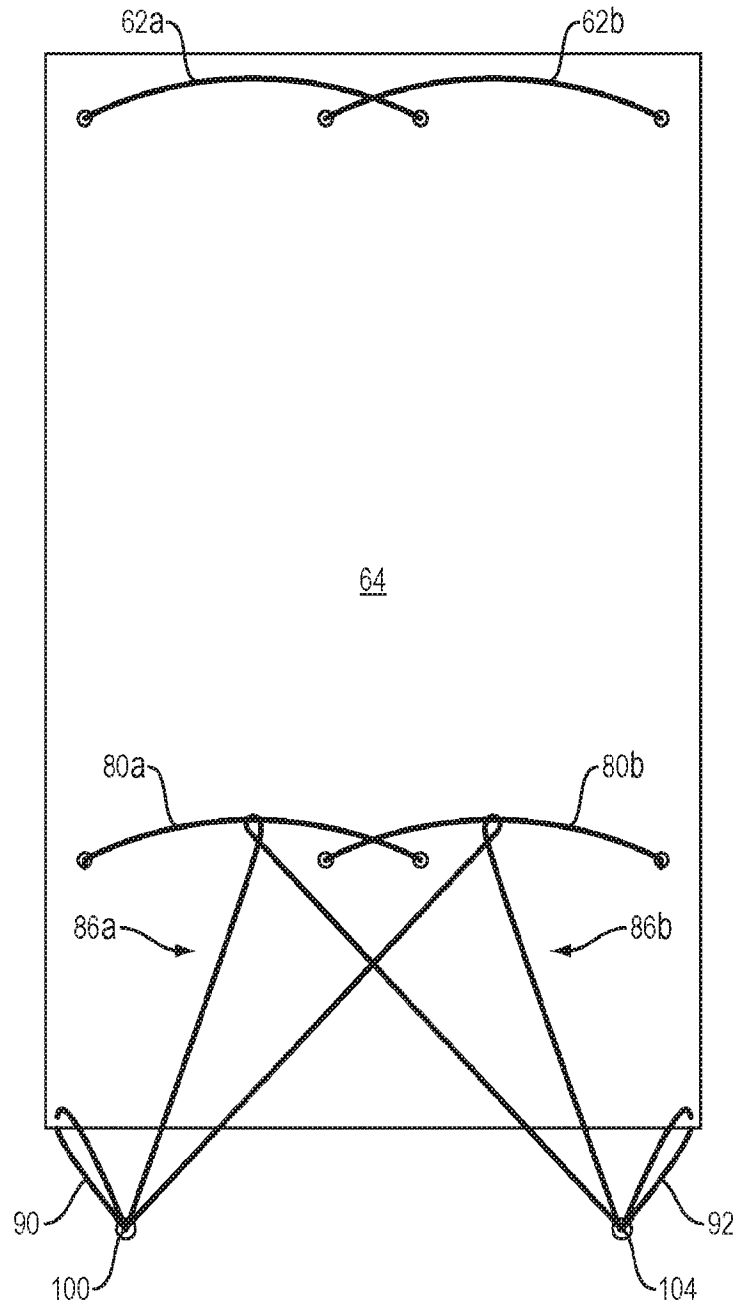


FIG. 4F

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/056093

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61B17/04 A61B17/06 A61F2/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 9 526 489 B2 (ARTHREX INC [US]) 27 December 2016 (2016-12-27)	15-22,24
A	column 3, line 23 - column 6, line 6 -----	23
X	US 2013/345749 A1 (SULLIVAN DEREK C [US] ET AL) 26 December 2013 (2013-12-26)	15,18,19
A	figures 60-71 paragraphs [0023], [0144] -----	16,17, 20-24
	-/-	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 January 2019

Date of mailing of the international search report

31/01/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
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Fax: (+31-70) 340-3016

Authorized officer

Lüddemann, Tobias

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/056093

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	MICHAEL J. WENTZELL ET AL: "The Inverting Horizontal Mattress Suture: Applications in Dermatologic Surgery :", DERMATOLOGIC SURGERY., vol. 38, no. 9, 1 September 2012 (2012-09-01), pages 1535-1539, XP055543434, NEW YORK, US ISSN: 1076-0512, DOI: 10.1111/j.1524-4725.2012.02484.x figures 1A-B pages 1-2	15-24
A	----- US 2017/105716 A1 (BURKHART STEPHEN S [US]) 20 April 2017 (2017-04-20) figures 1a,13-15 paragraphs [0060] - [0069], [0106]	15-24
A	----- WO 2017/172688 A1 (SANDERS BRETT [US]) 5 October 2017 (2017-10-05) figure 2 paragraphs [0013] - [0024] -----	15-24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/056093

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-14
because they relate to subject matter not required to be searched by this Authority, namely:
see FURTHER INFORMATION sheet PCT/ISA/210
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 1-14

Claims 1-14 relate to a method for treatment of the human or animal body by therapy or surgery ("routing a first suture construct through a tissue"), practised on the human or animal body (Rule 67.1 (iv) PCT). Consequently, no opinion will be formulated with respect to the industrial applicability of the subject-matter of these claims (Article 34(4)(a)(i) PCT).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/056093

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 9526489	B2	27-12-2016	US 2013296936 A1 07-11-2013
			US 2016310131 A1 27-10-2016
US 2013345749	A1	26-12-2013	NONE
US 2017105716	A1	20-04-2017	NONE
WO 2017172688	A1	05-10-2017	NONE