An expandible sleeve (10, 22, 50) for rejoining and/or bracing damaged connective tissue (16, 42) such as ligaments, tendons, muscles and the like is formed from a plurality of elongate members (12, 24, 52) of biocompatible material which is interwoven into an open mesh structure (20) which concurrently undergoes axial expansion and radial contraction when subjected to axial loads. The expandible sleeve allows small movements and small axial loads to be transferred through the damaged connective tissue thereby promoting rapid restoration and rehabilitation of the damaged tissue, while transferring larger, potentially injurious, axial loads around the damaged connective tissue and through the sleeve. The invention provides a device and method whereby restoration of damaged connective tissue can be more easily achieved, and which is generally less intrusive and traumatic than conventional techniques.
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DEVICE AND METHOD FOR RESTORATION OF CONNECTIVE TISSUE

FIELD OF THE INVENTION

This invention relates to a device and method for rejoining and/or bracing damaged connective tissue such as ligaments, tendons, muscles and the like. More particularly the invention relates to an extensible sleeve which will contract radially in response to axially applied tension so as to firmly grip portions of a connective tissue adjacent to damaged or severed tissue to redistribute relatively large tensile loads through the sleeve around the damaged tissue.

BACKGROUND OF THE INVENTION

Prior techniques for restoring severed or damaged connective tissue have generally involved relatively intrusive and complex procedures wherein damaged connective tissue is excised and replaced with prosthetic tissue which is anchored to bones such as by surgical staples, screws or the like, or have involved knotting or suturing the severed tissue together.

For example a common procedure for repairing a severed anterior cruciate ligament (ACL) involves excising the damaged ACL and replacing it with a prosthesis. After the damaged ACL is excised from the body, a hole is drilled through the femur and another hole is drilled through the front of the tibia. The prosthesis is then threaded through the holes in the bones and attached at one end to the outside of the femur with a surgical screw, staple or other anchoring means, and the other end of the prosthesis is similarly anchored to the tibia. The procedure is relatively intrusive and involves a considerable amount of trauma and discomfort to the patient. The patient is generally provided with a bent knee case which immobilizes the joint for about 3 weeks during which time considerable atrophy occurs.
Additionally, regrowth of tissue occurs in a randomly oriented manner which is not conducive to providing rapid restoration and rehabilitation. Moreover, synthetic prostheses generally have a limited useful life such as from about 4 to about 14 years, after which they must be replaced.

Another common method of repairing a damaged ACL is the patellar tendon graft technique wherein the surgeon threads part of the patellar tendon through holes drilled in the bones. The surgeon first divides the patellar tendon into thirds and detaches the middle third from the tibia by peeling it back. The middle third of the patellar tendon is then inserted through a hole drilled in the femur, threaded through a hole drilled in the tibia and surgically anchored to the tibia surface. This method has the advantage of utilizing autogenous tissue, but generally has all of the other disadvantages associated with prosthetic ACL repair.

Other methods of repairing damaged or severed connective tissue involve tying the ends of severed connective tissue into a knot or suturing severed or damaged tissue together. For example, tendons that control finger movement, when severed, are often rejoined by a technique which generally involves locating the severed ends and tying them in a knot. This procedure is relatively simple, but causes considerable stiffness and discomfort due to shortening of the length of the tendon and the presence of a lump at the knot. The stiffness and discomfort associated with the knotting technique may not always be conducive to rapid recovery and accelerated therapy.

Suturing techniques are also often used to repair tendons. Suturing avoids the stiffness problem associated with the knotting technique, but prolonged immobilization and therapy are required to prevent the sutures from tearing through the connective tissues. The tensile strength of connective tissue which has been
sutured together is generally very low, such as about 20% or less of its normal strength, immediately after surgery. Accordingly, it would be highly desirable to provide an orthopaedic device and simplified procedure for rejoining severed connective tissue, or for strengthening damaged connective tissue, to facilitate anastomosis and recuperation thereof, while reducing trauma and discomfort to the patient, and while promoting rapid rehabilitation.

SUMMARY OF THE INVENTION

The invention provides an alternative method and device for repair and restoration of fully or partially separated or severed connective tissue such as ligaments, tendons, muscles and the like. The device is an expansible sheath or sleeve which is either preassembled prior to surgery or assembled around the damaged connective tissue during surgery, and which serves to hold separated ends of connective tissue together and redistribute tensile loads around damaged tissue to facilitate healing and restoration thereof. The connective sheath or sleeve of the invention is formed from one or more flexible elongate members, such as filaments, wires, ribbons, strips or the like, which are formed into an open mesh. More particularly, the sleeve is generally comprised of a plurality of helically wound flexible elongate members of biocompatible material interwoven into an open mesh structure generally resembling a construct commonly known as a "Chinese finger trap". The connective sleeve of the invention when subjected to axial loading, i.e. tensile forces generally parallel to the axis of the sleeve, concurrently undergoes longitudinal expansion and radial contraction, whereupon connective tissue enveloped within the sleeve is firmly gripped and tensile forces are transmitted or redistributed to the sleeve. The material from which the sleeve is fabricated can generally be any material having suitable mechanical properties, such as tensile
strength and modulus, and which exhibits good biocompatibility properties, such as non-antigenic and non-carcinogenic behavior.

The invention provides surgeons and particularly orthopaedic surgeons with an alternative procedure for healing separated connective tissue which reduces or eliminates the need for intrusive techniques involving the use of natural or synthetic prostheses and the usual steps associated with such procedures including the use of prostheses fixation devices such as surgical staples, screws or anchors which are used to secure a prosthesis to a bone. The invention also generally avoids steps involving drilling into bone and threading connective tissue or prosthesis therethrough. The expansible orthopaedic sleeve and methods of the invention provide means by which separated connective tissue can be more easily rejoined for anastomosis thereof without significantly reducing the length of the connective tissue thereby eliminating the need for surgical techniques which involve tying or knotting the ends of severed connective tissue and thereby avoid stiffness problems which can be associated with such techniques. The orthopaedic sleeve of the invention provides an effective means for redistributing potentially injurious, tensile stresses around severed or damaged connective tissue by gripping the adjacent undamaged connective tissue more tightly and transferring a greater proportion of the tensile load through the sleeve and around the damaged or severed tissue as the tensile load is increased. The invention thereby generally overcomes the problems usually associated with suturing techniques for rejoining severed or damaged connective tissue, and provides greater initial strength than suturing techniques.

Because the invention generally utilizes fewer components, requires fewer steps, and is less intrusive than prior surgical techniques, the patient experiences reduced trauma and discomfort, reduced exposure to
antigenic reactions or infection, and quicker healing and restoration of the damaged or severed connective tissue. Because the methods and device of the invention provide higher tensile strength, especially during the early post operative period as compared with conventional surgical techniques and devices, it may be unnecessary to immobilize joints associated with the damaged connective tissue, or to at least substantially lessen the type or time of immobilization required, thereby reducing atrophy and facilitating accelerated therapy, healing and restoration of the damaged tissue. Specifically, the invention allows for small relative movement (such as 1-2 millimeters) between the severed ends or damaged area of a connective tissue and permits limited axial loads to be transferred through the damaged connective tissue thereby promoting rapid restoration and rehabilitation of the damaged tissue, while transferring larger, potentially injurious, axial loads around the damaged connective tissue and through the sleeve. The invention, therefore, permits early cyclic stressing of the damaged tissue. This cyclic stressing of the tissue during healing promotes regrowth and proper orientation of new tissue thereby facilitating a rapid recovery.

The sheath of the invention could be provided in a variety of standard sizes for common procedures involving ligament repair, for example a longitudinal length of about 1-2 cm, and an inner diameter of about 1/2 cm could be provided for repair of anterior cruciate ligaments, achilles tendons, palmar flexors and extensors, etc. In addition these might be used for connection between muscle and tendon. These measurements are given for the non-compressed length of the sheath (i.e., when the sheath is neither under tension or compression).
BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a connective sleeve in accordance with the principles of the invention;

FIG. 2 illustrates the sleeve of FIG. 1 used to rejoin the severed ends of an anterior cruciate ligament;

FIG. 3 is a plan view of an open mesh structure which is joinable at its sides to form an expandible sleeve in accordance with the principles of the invention;

FIG. 4 illustrates the use of the open mesh structure of FIG. 3 for bracing a damaged connective tissue to protect and facilitate healing thereof;

FIG. 5 shows an alternative embodiment of the invention provided with knurls or serrations to improve contact between the connective tissue and the sleeve;

FIG. 6 shows an alternative embodiment wherein the sleeve is composed of wire or filament elongate members; and

FIG. 7 is a transverse cross section of an expandible sleeve which is formed by joining the sides of an open mesh structure using an integral interlocking means comprising a rib and mating groove.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The fabrication of, and the mechanical principles associated with, an expandible sleeve generally similar to the construct known as a "Chinese finger trap" is well known to the mechanical arts. It has heretofore gone unrecognized that such devices could be suitably sized and fabricated from biocompatible materials, and used for rejoining or bracing severed or damaged connective tissue to effect healing and restoration thereof.

The expandible or expandable sleeve of the invention is generally indicated in FIG. 1 by reference numeral 10. The sleeve 10 is an open mesh generally
cylindrical construction which optionally can include a spiral cut opening in the wall which will permit the sleeve to be put onto a non-severed, injured tissue. The sleeve 10 is constructed so that it will extend in the direction of its longitudinal axis and will constrict radially substantially uniformly in response to a tensioned load in the longitudinal direction. By "open mesh" it is meant that the sleeve has open areas which enable the interwoven elongate members to scissor relative to each other. Thus, the sleeve can be a cylindrically curved open mesh wall which is either tubular or spiral cut. Preferably, the sleeve is comprised of a plurality of counter-helically wound flexible elongate members 12 which are interwoven into an open mesh structure, or alternatively a uniform net-like construct in which the relative angle between connected elements changes in response to a load in the longitudinal direction. The sleeves are generally constructed from an even number of elongate members, such as 2, 4, 6 or 8, half of which are helically wound about an axis in one direction, the other half of which are wound about the axis in the opposite direction. The elongate members 12 can each be folded over upon themselves at an acute angle and then woven together such as into what is commonly known as a "basket-weave", with the free ends being folded back or tucked in or otherwise suitably secured to prevent unravelling. Other alternative constructs comprised of layers of opposing helically wound woven elongate members or netting which achieve the desired result of providing a sleeve 10 which, when subjected to tension generally along the longitudinal direction, undergoes concurrent longitudinal expansion and radial contraction to constrict and firmly grip an object enveloped therein are suitable for use with the invention.

The flexible longitudinal members 12 are preferably strips, ribbons, wires, filaments or the like. In order to maximize the distribution of forces
over the interface between the sleeve 10 and the tissue enveloped therein, the elongate members 12 preferably have a flat cross-section such as ribbons or strips. When wires or filaments are used, it is preferred that the wires have a non-circular cross-section, such as a flattened elliptical shape wherein the flattened surfaces face the longitudinal axis of the sleeve so as to increase the area of contact between the elongate members 12 and the tissue enveloped by the sleeve 10 to distribute forces over a greater area of tissue and to prevent the elongate members from cutting into the connective tissue.

The elongate members 12 are woven into an open mesh cylindrical structure having openings in the side walls 14 to allow the overlapping or crossed elongate members 12 to move relative to one another to permit concurrent longitudinal expansion and radial contraction of the sleeve 10 when tensile loads are applied approximately longitudinally to the sleeve. These openings 14 permit extrinsic fluid transport to allow the injury site access to healing nutrients which help repair cells. Further the woven sheath compresses and extends creating small relative movements between the strips of material from which it is woven. This motion encourages ingrowth of collagenous fibers along the surface of the sheath itself so as to encapsulate and anchor the sheath to the injured tissue, thus reinforcing the injury site and reducing the chance of a repeat injury.

The elongate members 12 are generally formed from a biocompatible material having suitable mechanical properties such as flexibility, tensile strength and modulus. Suitable flexibility generally refers to a combination of dimensional and physical properties which allow the elongate members 12 to be helically wound without breaking. The elongate members 12 should preferably have a tensile strength which is at least about equal to or which is slightly greater than the tensile strength of healthy connective tissue of the
type which is to be restored. The elongate members generally have a relatively high modulus which is at least equal to that of healthy connective of the type which is to be restored.

Biocompatibility refers to the absence of any undesired reactions with surrounding tissues, such as antigenic or carcinogenic reactions. Suitable biocompatible materials for use with the invention include for example surgical quality stainless steel or other biocompatible alloys; polytetrafluoroethylene (PTFE), polyethylene terephthalate (PET), polypropylene, polyethylene, polyesters, polyamides or other biocompatible synthetic polymers, as well as other known suitable biocompatible materials such as carbon fibers, reconstituted collagen strips or fibers and the like. Preferred materials for constructing the sleeve include surgical grade stainless steel and any of various biocompatible synthetic polymers. Ribbons or strips, when used as the elongate members, can be either a continuous material such as stainless steel or polymeric ribbon, or can be a fabric formed from a plurality of fibers or filaments woven, knitted or otherwise made into a fabric having suitable properties. When biocompatible polymers are used to form the elongate members, they can either be permanent, non-biodegradable polymers, or slowly biodegrading polymers which can be resorbed into the growing tissue. One attractive option envisioned involves forming collagenous fibers into suitable strips, ribbons or filaments which are used as elongate members which form the sleeve.

Sleeve 10 is used to rejoin severed, torn, ruptured or otherwise separated connective tissues, such as an anterior cruciate ligament 16 as shown in FIG. 2. A sleeve having suitable dimensions for rejoining the severed connective tissues is first prepared or selected. The sleeve should, when subjected to longitudinal compression, have a radius which is large enough to
allow the sleeve to be easily slipped over the severed ends of connective tissue 16 during surgery. The sleeve should fit snugly on the connective tissue when it is decompressed onto the tissue. The sleeve should, when subjected to longitudinal tension, also achieve a radial contraction which causes the sleeve to constrict and firmly grip relatively healthy, undamaged tissue adjacent to the damaged tissue, such that the tensile stresses are directed around the damaged tissue and through the sleeve 10. The sleeve should also be of a suitable length to allow sufficient gripping of the relatively healthy, undamaged tissue to permit the tensile stresses to be transferred to the sleeve 10.

Typical dimension for an unstressed sleeve (i.e., a sleeve which is subjected neither to compressive or tensile forces) for use in the repair of human connective tissue generally include a radius in the range from about 0.1 or 0.2 mm to about 3, 4 or 5 mm and a length of from about 1 or 2 cm up to about 4 or 5 cm, depending upon the particular application. The invention can also be used to aid in the restoration of severed or damaged animal connective tissue, in which case the dimensions of the sleeve will be appropriately selected for the particular application. The thickness of the ribbons, strips, wires, filaments or the like used to form the sleeves, as measured along a radius of the sleeve, is generally from about 0.005 mm up to about 1 or 2 mm, depending on various factors such as the amount of strength needed for the particular application and the type of biocompatible material being used to form the sleeve. Upon axially compressing the sleeve, the radius generally can be increased to a maximum of from about 10 to about 100 percent of its unstressed radius and the length can be decreased by as much as about 10 to about 50 percent of the unstressed length. Upon application of axial tension the radius of the sleeve can be reduced to a minimum of from about 10
to about 50 percent of its unstressed radius and the length can be increased to as much as from about 10 to about 50 percent of the unstressed length. Generally speaking, the sheath should be expandable to a diameter of about 50 percent larger than the width of the tendon to be repaired and should be contractible to no less than about 75 percent of the width of the tendon to be repaired.

Rejoining of severed, torn or otherwise separated connective tissue 16 using the sleeve 10 of the invention is achieved by first exposing and locating the severed ends in accordance with conventional techniques. The sleeve 10 is longitudinally compressed and held in the compressed state by means of, for example, a temporary suture. A first of the severed ends of the connective tissue 16 is threaded through the sleeve 10. After one end of the severed connective tissue 16 is threaded through the sleeve 10, the severed ends of the connective tissue 16 can be sutured together using conventional techniques if the surgeon deems it appropriate. When the connective tissues are sutured together, the sutures are most desirably of the biodegradable variety which break down over a period of time and are resorbed into the tissue. One end of the sleeve 10 is then suitably secured to a relatively healthy, undamaged area of the connective tissue 16 adjacent to one of the severed ends such as by suturing or by using a suitable surgical adhesive. If the severed ends have been sutured together, then it is necessary to remove the temporary suture or other means for compressing the sleeve 10, and desirably pull the sleeve over the second severed end of the connective tissue 16 with sufficient force such that the tissue at the severed ends are slightly under compression, i.e. forced together by the tension of the sleeve 10. The other end of the sleeve is then preferably suitably secured, such as by suturing or by means of a suitable surgical adhesive, to the second severed end of the
connective tissue, thereby providing a brace which will allow the damaged tissue to experience a limited amount of tensile load and a limited amount of movement to promote healing and proper orientation of regrowth tissue, while redirecting larger tensile stresses around the damaged tissue and through the sleeve 10. If the severed ends of the connective tissue 16 have not been sutured together, it will generally be necessary to provide temporary means, such as a clamp, for holding the ends together while the sleeve is being pulled over the second severed end of the connective tissue 16 and secured thereto such as by suturing or with a surgical adhesive.

Although it is envisioned that the ends of the sleeve 10 will normally be secured to the respective ends of the severed connective tissue 16 such as by means of sutures or a suitable surgical adhesive composition, it is possible that the sleeve can be used without securing either or both ends thereof to respective ends of the severed connective tissue. That is to say, it is possible to rely strictly on friction and/or other interactions between the internal surface of the sleeve 10 and the outer surface of the connective tissue.

To facilitate better contact between the connective tissue and the sleeve 10, miniature hooks or barbs 18 can be provided on the internal surface of the sleeve. Other means for improving contact between the connective tissue and the sleeve include providing the internal surface with knurls, serrations 19 or the like as shown in FIG. 5.

While a particularly preferred use for the invention is to rejoin severed or torn connective tissue, the principles of the invention can also be used for aiding in the restoration and healing of partially torn or otherwise damaged connective tissue which has not been completely separated. In accordance with an alternative embodiment of the invention, an open mesh
preform structure 20 which can be formed into an expandable sleeve 22 is shown in FIGS. 3-5. The open mesh structure 20 is comprised of a plurality of interwoven flexible elongate members 24 of biocompatible material. The structure has opposing sides 26 and 28 which are joinable to form an expandable sleeve 22 generally comparable in function to the sleeve 10 of the first embodiment. The primary difference being that the sleeve is fully or partially joined together during the surgery.

The open mesh structure 20 is used to aid in the healing of partially torn or otherwise damaged connective tissue 42, which has not been completely severed, by wrapping the open mesh structure around the damaged tissue and connecting individual ends 30a, 30b, 30c, etc. of elongate members 24 on one side 26 of the structure 20 with corresponding or matching ends 34a, 34b, 34c, etc. of another member on the other side 28 to form the sleeve 22 as shown in FIG. 4. The ends 30a, 30b, 30c, etc. and 34a, 34b, 34c, etc. can be connected to one another such as by sutures 36, by interlocking means, such as a rib 38 and groove 40 (as shown in FIG. 7), or a combination thereof. After the ends 30a, 30b, 30c, etc. have been suitably connected to the ends 34a, 34b, 34c, etc. to form sleeve 22, then the ends of the sleeve are pulled apart, preferably while the damaged tissue area is subjected to a small amount of compression, such that the sleeve tightly grips relatively healthy, undamaged areas of the connective tissue 42 adjacent to the damaged area, whereby the damaged tissue may be subjected to relatively small longitudinal tensile stresses which prevent atrophy, facilitate proper orientation of regrowth tissue, and generally promote restoration, while redistributing relatively large longitudinal tensile stresses around the damaged tissue and through the sleeve 22.
An alternative embodiment of the expansible sleeve 50 of the invention is shown in FIG. 6 wherein the elongate members are wires or filaments 52.

The method of the invention can of course be applied to more elaborate and detailed fabrication procedures wherein the sleeve is partially preassembled or fully assembled in situ, the above embodiments merely representing what the inventors currently regard as the most practical modes for practicing the invention.

As will be appreciated by those having skill in the art, the devices and methods of the invention provide a simplified procedure for rejoining severed connective tissue and for bracing damaged connective tissue which is not completely severed. Some of the obvious possible benefits and advantages of the invention include quicker, less invasive procedures, reduced trauma and discomfort to the patient, immediate or nearly immediate limited active mobility which allows for reduced atrophying and accelerated healing and restoration, elimination of casts, splints or other immobilization devices, and reduced risks due to complications or infections.

The sleeve of the invention can either be a permanent, non-biodegradable type which becomes enveloped by the new tissue and which provide permanent strength to the connective tissue, or it can be of the bioabsorbable type which is resorbed into the tissue or broken down and removed from the body over a period of time sufficient to allow complete restoration of the severed or damaged connective tissue.

While one of the important advantages of the invention is that it often eliminates the need for prosthetic connective tissue substitutes, it will be readily appreciated by those skilled in the art that the invention can be used in association with conventional prostheses in certain situations. For example, the orthopaedic sleeve of the invention can be used for joining severed connective tissue to one end of a
prosthesis with the other end of the prosthesis being anchored to a bone in a conventional manner, or two orthopaedic sleeves can be used for connecting separated ends of a connective tissue through an intervening prosthesis.

While in accordance with the patent statutes the best mode and preferred embodiment has been set forth, the scope of the invention is not limited there-to, but rather by the scope of the attached claims.
WHAT IS CLAIMED IS:

1. A sheath for the repair of a connective tissue comprising:
   an open mesh wall curving about a longitudinal axis and having an unstressed length along this axis of from about 1 cm to about 5 cm from a first end to a second end, said first end forming a first opening extending along the interior of said wall to said second end forming a second opening, said first and said second openings each having an unstressed diameter of about 0.02 cm to about 1 cm, the mesh wall being comprised of elongate biocompatible members interconnected so as to permit relative motion between said members and such that the sheath expands longitudinally and contracts radially in response to a tension along the length of the sheath.

2. A sheath as set forth in Claim 1, wherein the mesh wall forms a complete cylinder.

3. A sheath as set forth in Claim 2, wherein the elongate members spiral about said longitudinal axis.

4. A sheath as set forth in Claim 2, wherein said connective tissue is an anterior cruciate ligament and said sheath has a length of from about 1 cm to about 2 cm and said sheath has a diameter of about 0.25 cm to about 0.75 cm in the noncompressed state.

5. A sheath as set forth in Claim 1, wherein said mesh wall is comprised of interconnected intersecting elongate members which can open and close with respect to the point of intersection.
6. A sheath as set forth in Claim 3, wherein said mesh wall is comprised of woven elongate members.

7. A sheath as set forth in Claim 5, wherein said elongate members are counter helically wound.

8. A sheath as set forth in Claim 4, wherein said elongate mesh will form a basket weave.

9. A sheath as set forth in Claim 6, wherein said elongate members are flattened elongate strips.

10. A sheath as set forth in Claim 7, wherein said strips are comprised of stainless steel, nylon, polytetrafluoroethylene, silicone or collagen.

11. A sheath as set forth in Claim 8, wherein the interior of said curved mesh wall is roughened.

12. A method of repairing a connective tissue comprising the steps of:
    surgically exposing the injured tissue;
    enveloping the tissue with an open mesh sheath which contracts radially in response to the longitudinal tension and attaching the sheath to the tissue on either side of the injury; and
    surgically closing the operative opening.

13. A method as set forth in Claim 10, further including the steps of compressing the sheath to cause radial expansion prior to enveloping the tissue and of longitudinally expanding the sheath to snugly grip the tissue on either side of the injured area.

15. A method as set forth in Claim 12, further including the step of reattaching the severed tissue.

16. An expansible sleeve for facilitating anastomosis of separated ends of a connective tissue, comprising a plurality of counter-helically wound elongate members of biocompatible material which are interwoven into an open mesh structure, whereby application of tension to said sleeve along a direction parallel with a longitudinal axis of said sleeve results in concurrent axial expansion and radial contraction of said sleeve.

17. An expansible sleeve according to Claim 1, wherein said elongate members have barbs which improve contact between the sleeve and the connective tissue.

18. An expansible sleeve according to Claim 1, wherein said elongate members have internal serrations or knurls to improve contact between the sleeve and the connective tissue.

19. A method of facilitating anastomosis of separated ends of a connective tissue, comprising:

(a) providing a tubular expansible sleeve comprised of a plurality of counter-helically wound elongated members of biocompatible material which are interwoven into an open mesh, said sleeve having a suitable length and radius to allow insertion of each of a pair of separated ends of a connective tissue into a respective end of said sleeve when said sleeve is axially compressed and radially expanded, and to allow firm gripping of respective separated ends of a connective tissue when tension is axially applied to said sleeve to cause axial expansion and radial contraction thereof;
(b) compressing said sleeve in an axial direction to cause sufficient radial expansion thereof to allow insertion of at least one of a pair of separated ends of a connective tissue into a respective end of said sleeve;

(c) inserting said one end into an end of said sleeve and locating said sleeve over both of said ends of a connective tissue; and

(d) applying tension axially to said sleeve to cause axial expansion and concurrent radial contraction thereof, whereby said sleeve radially constricts and firmly grips each of said pair of separated ends of said connective tissue.
**INTERNATIONAL SEARCH REPORT**

### A. CLASSIFICATION OF SUBJECT MATTER
- IPC(6): A61B 17/00; A61F 2/04, 2/08
- US CL: 606/156; 623/12, 13

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)
  - U.S.: 600/37; 606/152, 155, 156; 623/12, 13

- Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
  - NONE

- Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
  - NONE

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>US, A, 3,626,947 (SPARKS ET AL.) 14 December 1971, see figures, and column 3 lines 3-6 and 40-42.</td>
<td>1-8, 10, 12, 31, 15, 16, 19, 9, 11, 14, 17, 18</td>
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<td>US, A, 4,585,458 (KURLAND) 29 April 1986, see figures, Abstract line 5, column 4 lines 16-52, column 5 lines 25-47, and column 7 lines 10-12.</td>
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<td>US, A, 4,301,551 (DORE ET AL.) 24 November 1981, see column 3 line 41 through column 4 line 5.</td>
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**X** Further documents are listed in the continuation of Box C.  See patent family annex.

### Date of the actual completion of the international search
- 30 AUGUST 1995

### Date of mailing of the international search report
- 21 SEP 1995

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<td>Y</td>
<td>US, A, 5,234,448 (WHOLEY ET AL.) 10 August 1993, see Fig. 4.</td>
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