

METHOD AND APPARATUS FOR FORMING BARBED SUTURES

FIELD OF THE INVENTION

This invention relates to a method and apparatus for forming barbed sutures.

BACKGROUND OF THE INVENTION

A barbed suture is a suture having barbs along its length. Barbed sutures have been used to close wounds and, more recently, to effect tissue lifts in medical aesthetics procedures that are rapidly gaining in popularity world-wide.

There is thus a need for a method and apparatus for forming barbed sutures in a cost and time effective way that produces robust sutures having uniformly formed barbs thereon, in order to meet the demand for barbed sutures in the medical aesthetics industry as well as for other medical uses.

SUMMARY OF INVENTION

According to a first exemplary aspect, there is provided an apparatus for forming barbed sutures, the apparatus comprising: a suture frame configured for presenting a plurality of lengths of suture on which barbs are to be formed; a bending mechanism configured to bend the plurality of lengths of suture to present a bent part of each length of suture for cutting; a cutting assembly configured to cut into a convex surface of the bent part of each length of suture to form a barb on the bent part of each length of suture; an indexing block configured to support the suture frame and the cutting assembly, the indexing block comprising an indexing mechanism configured to lock the suture frame and the cutting assembly in a cutting position and to effect relative stepwise movement between the suture frame and the cutting assembly to allow a plurality of barbs to be formed at intervals apart on each length of suture.

The bending mechanism may comprise a press rod configured to downwardly displace the plurality of lengths of suture in the suture frame; and a ridge provided below the plurality of lengths of suture in the suture frame and configured to contact and support the plurality of lengths of suture such that each length of suture is bent about the ridge when the plurality of lengths of suture have been displaced by the press rod.

The press rod may be provided on the cutting assembly below a cutting blade provided on the cutting assembly, and the ridge may be provided on the indexing block.

The ridge may be provided on a suture support of the indexing block, the suture support further having a suture holding surface configured for holding a held part of each length of suture thereagainst by the press rod.

- 5 The suture support may be configured such that a portion of each length of suture between the bent part and the held part does not contact any surface during displacement of the plurality of lengths of suture by the press rod.

- 10 The cutting assembly may be configured to cut into the convex surface of the bent part of each length of suture is in a direction parallel to a surface of each length of suture.

- 15 The suture frame may comprise opposing side bars and opposing end bars that are connected to define a space therewithin, and wherein dowel pins are provided on each of the opposing end bars such that the plurality of lengths of suture can be provided in the space by winding a single length of suture in a zig-zag manner from one end bar to the other end bar about successive dowel pins.

- 20 The indexing mechanism may comprise a forward-lock cam provided on the indexing block, the forward-lock cam configured to move the suture frame one step forward with each rotation of the forward-lock cam, and a toothed section provided on the suture frame and a tooth catch provided on the indexing block, wherein the toothed section and tooth catch are configured such that the tooth catch engages a tooth of the toothed sections to prevent movement of the suture frame in a backward direction when the suture frame is in the cutting position.

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- 30 The indexing mechanism may further comprise a raise-lower cam provided on a same shaft as the forward-lock cam, the raise-lower cam configured to raise the cutting assembly during forward movement of the suture frame, the raise-lower cam further configured to lower the cutting assembly to the cutting position and the forward-lock cam further configured to lock the cutting assembly in the cutting position when the raise-lower cam and the forward-lock cam are rotated in a reverse direction.

- 35 The suture frame, the indexing block and the indexing mechanism may be configured to allow the suture frame to be assembled with the indexing block in a flipped configuration without removing the plurality of lengths of suture from the suture frame, so as to present a

second side of each of the plurality of lengths of suture to be cut into, thereby allowing barbs to be formed on two diametrically opposite sides of each of the plurality of lengths of suture.

5 The suture frame may be configured such that a plurality of barbs formed on the second side of each length of suture when the suture frame is assembled with the indexing block in the flipped configuration is staggered from a plurality of barbs already formed on a first side of each length of suture.

10 According to a second exemplary aspect, there is provided a method of forming barbed sutures, the method comprising the steps of: a) bending a plurality of lengths of sutures to present a bent part of each length of suture for cutting; b) cutting with a cutting assembly into a convex surface of the bent part of each length of suture to form a barb on the bent part of each length of suture; c) effecting a relative stepwise movement between the plurality of
15 lengths of suture and the cutting assembly in a direction parallel to the plurality of lengths of suture; and repeating steps a) to c) to form a plurality of barbs that are intervals apart on each length of suture.

The method may further comprise, prior to step a), mounting the plurality of lengths of sutures on a suture frame, the suture frame comprising opposing side bars and opposing
20 end bars that are connected to define a space therewithin, wherein the mounting comprises winding a single length of suture in a zig-zag manner from one of the end bars to the other of the end bars about successive dowel pins provided on the opposing end bars such that the plurality of lengths of suture are provided in the space.

25 The method may further comprise flipping the plurality of lengths of suture over to present a diametrically opposite side of the plurality of lengths of suture to be cut into; and repeating steps a) to c).

The method may further comprise g) cutting each of the plurality of lengths of suture away
30 from the suture frame.

Step g) may comprise cutting across the plurality of lengths of suture along one of the end bars.

35 The cutting in step b) may be in a direction parallel to a surface of each length of suture.

According to a third exemplary aspect, there is provided a barbed suture formed using the apparatus of the first aspect and the method of the second aspect, wherein a first plurality of barbs formed at intervals along a first half of the barbed suture between a midpoint and a first end of the barbed suture faces towards the first end of the barbed suture, and wherein a second plurality of barbs formed at intervals along a second half of the barbed suture between the midpoint and a second end of the barbed suture faces towards the second end of the barbed suture.

A plurality of barbs formed along one side of the barbed suture may be staggered from a plurality of barbs formed along a diametrically opposite side of the barbed suture.

BRIEF DESCRIPTION OF FIGURES

In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

Fig. 1 is a perspective exploded assembly view of an exemplary apparatus of the present invention.

Fig. 2 is a perspective view of the exemplary apparatus before initiating a first cut.

Fig. 3 is a perspective exploded assembly view of the suture frame of the exemplary apparatus having lengths of suture mounted thereon.

Fig. 4 is a perspective view of the suture frame of Fig. 3 after clamping of the lengths of suture to the suture frame.

Fig. 5 is a side view of the suture frame of Fig. 4.

Fig. 6 is a close-up view of a downward facing toothed section on the suture frame of Fig. 5.

Fig. 7 is a close-up view of a tooth catch on a support rail of an indexing block of the exemplary apparatus.

Fig. 8 is a perspective view of the indexing block of the exemplary apparatus.

Fig. 9 is a perspective exploded assembly view of the indexing block of Fig. 8.

Fig. 10 is a perspective view of the exemplary apparatus when moving the suture frame one step along the indexing block.

Fig. 11 is a perspective view of a cutting assembly of the exemplary apparatus.

Fig. 12 is an elevation view of the cutting assembly of Fig. 11.

Fig. 13 is a sectional view taken along A-A as shown in Fig. 12.

Fig. 14 is an elevation view of an adjustment insert of the cutting assembly of Fig. 11.

Fig. 15 is a perspective view of the cutting assembly being lowered to a cutting position.

Fig. 16 is a side schematic view of the cutting assembly in the cutting position.

Fig. 17 is a close-up of a cutting edge of the cutting assembly in the cutting position.

Fig. 18 is a close-up of the cutting edge forming a barb on a length of suture.

Fig. 19 is a close-up of the cutting edge forming a barb on an opposite side of a length of suture.

Fig. 20 is a perspective view of the apparatus after one cutting cycle.

Fig. 21 is a perspective view of cutting the lengths of suture in the suture frame of Fig. 4.

Fig. 22 is a schematic illustration of a barbed suture formed using the apparatus of the present invention.

Fig. 23 is a flow chart of an exemplary method of the present invention.

DETAILED DESCRIPTION

Exemplary embodiments of the method 20 and apparatus 10 will be described with reference to Figs. 1 to 23 below.

As shown in Figs. 1 and 2, the apparatus 10 comprises a removable suture frame 100 configured for mounting therein the sutures 90 on which barbs are to be formed. The apparatus 10 also comprises an indexing block 200 configured for supporting and indexing the suture frame 100 for formation of barbs at fixed intervals along the length of the sutures 90, and for supporting the sutures 90 during barb formation on the sutures 90. The apparatus 10 further comprises a removable cutting assembly 300 configured to engage the indexing block 200 and to effect cuts on the sutures 90 to form the barbs 991, 992.

The suture frame 100 as shown in Fig. 3 preferably comprises two opposing side bars 121, 122 and two opposing end bars 123, 124 that are connected to form a generally rectangular frame 100 defining a space therewithin. The end bars 123, 124 serve to form a leading edge 102 and a trailing edge 102 of the suture frame 100 respectively. In the preferred embodiment, a row of dowel pins 125, 126 are provided on and project perpendicularly from the plane of the frame 100 from each of the end bars 123, 124 respectively. The dowel pins 125, 126 are configured for mounting the sutures 90 between and parallel to the two side bars 121, 122, such that by winding a single length of suture in a zig-zag manner from one end bar 123 to the other end bar 124 about successive dowel pins 125, 126, a plurality of lengths of suture 91 is presented in the space within the suture frame 100. In the preferred embodiment, two adjacent lengths of suture 91 in a hairpin loop around one dowel pin 125 or 126 will form one barbed suture 90, the formation of which will be explained in greater detail below.

A clamping beam 127, 128 is preferably provided for each of the end bars 123, 124 respectively for securing the mounted sutures 90 to the suture frame 100. Each clamping beam 127, 128 is configured to be releasably securable to its corresponding end bar 123, 124, by known means such as screws. Each clamping beam 127, 128 is preferably provided with a plurality of holes 131, 132 that fit over the row of dowel pins 125, 126 respectively. When the clamping beams 127, 128 have been secured to the end bars 123, 124, end loops 93, 94 of suture around the dowel pins 125, 126 respectively become clamped between the clamping beams 127, 128 and the end bars 123, 124, thereby securing the sutures 90 to the suture frame 100, as shown in Fig. 4.

Each side bar 121, 122 is provided with at least one toothed section along its length. In the preferred embodiment, each side bar 121, 122 has at least two toothed sections 133, 134 along its length, the two toothed sections 133, 134 being on opposite sides 135, 136 of the suture frame 100 respectively, as can be seen in Fig. 5. A close-up view of a portion of the toothed section 133 on one of the side bars 121 can be seen in Fig. 6, in which, in the exemplary embodiment, the teeth on the toothed section 133 have a pitch P of 4mm, a height of 1.86mm. Each tooth 139 has a vertical surface 137 and a sloped surface 138 having a slope angle of 365.82° measured from the vertical. The toothed sections 33, 34 preferably have identical tooth pitch and tooth profiles:

Each tooth 139 on the toothed sections 133, 134 of the side bars 121, 122 is configured to engage an upwardly projecting tooth catch 241 (Fig. 7) provided on an upward facing surface 243, 244 of a support rail 245, 246 of the indexing block 200 respectively, as shown in Fig. 8. The apparatus 10 thus comprises two tooth catches 241 configured to engage the toothed sections 133, 134 of each side bar 121, 122. Each tooth catch 241 is preferably provided at a generally central location of each support rail 245, 246. The support rails 245, 246 are mounted parallel to each other on a flat base plate 259 of the indexing block 200, and are configured to support and slidably engage the side bars 121, 122 of the suture frame 100 respectively.

Each tooth catch 241 has a sloped surface 248 preferably having a same slope angle as the sloped surface 138 of each tooth 139 on the toothed sections 133, 134 of the suture frame 100. The sloped surface 138 of each tooth 139 on a downward facing toothed section 133 or 134 of the suture frame 100 (when the suture frame 100 is placed on the indexing block 200) is configured to slidably engage the sloped surface 248 of the tooth catch 241, thereby allowing the suture frame 100 to move in a forward direction parallel to the plurality of

lengths of suture along the indexing block 200, as indicated by the arrow A in Fig. 2. Each tooth catch 241 also comprises a vertical surface 247 configured to engage the vertical surface 138 of a tooth 139. Engagement of the vertical surfaces 137, 247 prevents movement of the suture frame 100 in a backward direction along the indexing block 200. The toothed sections 133, 134 on the suture frame 100 and the tooth catches 241 on the indexing block 200 are thus configured to allow movement of the suture frame 100 in only one direction A along the indexing block 200, and to allow the suture frame 100 to be indexed or moved along the indexing block 200 in a stepwise manner, wherein displacement of the suture frame 100 in each step corresponds to the pitch of the teeth on the toothed sections 133, 134. Indexing of the suture frame 100 is configured to begin from the first teeth 140 of the toothed sections 133, 134 that are located adjacent the leading end bar 123.

By providing toothed sections 133, 134 on opposite sides 135, 136 of the suture frame 100, either side of the suture frame 100 can thus engage the indexing block 200. In this way, opposite sides of each suture length 91 can be presented to face upwards by flipping the suture frame 100 over without removing the plurality of lengths of suture 91 from the suture frame 100.

Each tooth catch 241 is preferably configured to be able to be depressed into the upward facing surface 243, 244 when the sloped surface 138 of a tooth 139 on the side bars 121, 122 slides against the sloped surface 248 of the tooth catch 241 during forward movement of the suture frame 100. Depression of the tooth catch 241 allows the suture frame 100 to be maintained at a same horizontal level as it moves along the indexing block 200 with minimal upward movement as each tooth 90 passes over a tooth catch 241, providing a smooth operation with minimal generation of impact forces. When a tooth 139 has passed over a tooth catch 241 that has been depressed, the tooth catch 241 is configured to automatically extend from the upward facing surface 243, 244 of the support rail 245, 246 again so that the vertical surfaces 137, 138 of the tooth 139 and the tooth catch 241 engage each other to prevent backward movement of the suture frame 100 along the indexing block 200. Accordingly, each tooth catch 241 is preferably spring-loaded to allow repeated cycles of depression and extension as the suture frame 100 is moved along the indexing block 200. In one embodiment, each tooth catch 241 is provided as an insert 253 placed in a cutout 254 provided on each of the support rails 245, 246 for ease of manufacture and assembly. An exploded assembly view of the indexing block 200 is shown in Fig. 9 for a better understanding and depiction of its component parts.

Movement of the suture frame 100 along the indexing block 200 is achieved by providing on the indexing block 200 a crank 249 connected to a shaft on which forward-lock cams 251 are provided. The crank 249 is provided on the outside of one 245 of the support rails 245, 246. The crank 249 and shaft are preferably located at a generally central location of the support rails 245, 246, with the shaft extending from one support rail 245 to the other 246, and are configured to be rotated about an axis Q perpendicular to the direction of forward movement of the suture frame 100. The forward-lock cams 251 are positioned on the shaft in cut-outs 252 provided in the support rails 245, 246 so that the outer surface 261 of the forward-lock cams 251 contact the downward facing surfaces 135 or 136 of the suture frame 100 when the suture frame 100 is placed on the indexing block 200. The forward-lock cams 251 have a cam profile such that turning the crank 249 anticlockwise to the end of its stroke, as shown by arrow B in Fig. 10, moves the suture frame 100 by one toothed step in the forward direction A. Each forward-lock cam 251 also has an inner surface 262 configured in the form of a hook to secure the cutting assembly 300 in position during cutting, as will be described further below. The forward-lock cams 251, toothed sections 133, 134 and tooth catches 241 thus together form an indexing mechanism of the apparatus 10 that can effect relative stepwise movement between the suture frame 100 and the cutting assembly 300.

As can be seen in Figs. 3 and 4, an outside toothed section 110 is preferably provided on outside surfaces 111 and 112 of the side bars 121, 122 of the suture frame 100 respectively. The outside toothed section 110 preferably has the same tooth pitch and profile as the toothed sections 134, 135 on the side bars 121, 122. The outside toothed section 110 is configured to engage a depressible protrusion 210 provided on the inner vertical surfaces 211, 212 of the support rails 245, 246 of the indexing block 200 respectively, as can be seen in Fig. 9. The depressible protrusion 210 and toothed section 110 are configured engage each other such that the suture frame 100 is prevented from moving up away from the indexing block 200 while still allowing the suture frame 20 to move in the forward direction A relative to the indexing block 200. When the crank 249 is turned, the sloped surfaces of the teeth on the outside toothed section 110 slide against the depressible protrusions 210 to depress them into the support rails 245, 246, thereby still allowing the suture frame 200 to move in the forward direction along the indexing block 200. In a preferred embodiment, the depressible protrusion 210 is in the form of a spring-loaded ball bearing.

Using the apparatus 10, a plurality of barbs that are intervals apart are formed on each length of suture 91 by moving the suture frame 100 stepwise along the indexing block 200 and making controlled cuts into an upward facing surface 903 of each length of suture 91 in

the suture frame 100. To make the cuts, the cutting blade 361 of the cutting assembly 300 is configured to be placed over the lengths of suture 91 in the suture frame 100 and to cut into the upward facing surface 903 of each length of suture 91. As shown in Figs. 11 to 14, the cutting assembly 300 comprises a top block 363 and two side blocks 365, 366 extending
5 downwardly from opposite sides of the top block 363.

When the cutting assembly 300 is assembled with the indexing block 200 and the suture frame 100, the side blocks 365, 366 of the cutting assembly are configured to extend through the suture frame 100 on either side of the sutures 90 mounted in the suture frame
10 100. Bottom surfaces 367, 368 of the side blocks 365, 366 are configured to rest on raise-lower cams 255, 256 respectively. The raise-lower cams 255, 256 are preferably provided on either side of a support block 257 of the indexing block 200, on the same shaft as the forward-lock cams 251. The support block 257 is secured and positioned centrally on the base plate 259 between the support rails 245, 246. The raise-lower cams 255, 256 have
15 cam profiles that are configured to raise the cutting assembly 300 resting on the raise-lower cams 255, 256, as indicated by arrows Y, when the crank 249 is turned anticlockwise, as indicated by the arrow B in Fig. 10. Raising the cutting assembly 300 is so as to prevent the cutting assembly 300 from impeding movement of the suture frame 100 in the forward direction A when the crank 249 is turned anticlockwise, as already described above.

20 In the exemplary embodiment, vertically oriented guide pins 258 as can be seen in Figs. 8 and 9 may be provide on the base plate 259 to pass through appropriately located holes in both the support block 257 and the cutting assembly 300 to securely position the support block 257 and the cutting assembly 300 relative to the indexing block 200 when the
25 apparatus 10 is assembled for cutting barbs on the sutures 90.

In the exemplary embodiment of the cutting assembly 300 as shown in Figs. 11 to 14, the cutting blade 361 is provided in the space defined between the side block 365, 366 and under the top block 363, such that its at least one cutting edge 364 is perpendicular to the
30 side blocks 365, 366. A suitable mechanism, for example a rack and pinion mechanism, is provided in the defined space to connect the blade 361 with a lever 367 that is pivotably connected to the top block 363 about a pivot point 370. The lever 367 is configured to be rotatable about an axis R perpendicular to the side blocks 365, 366. The lever 367 and blade 361 are connected by the mechanism such that when the cutting assembly 300 is placed
35 over the suture frame 100 onto the support block 257, turning the lever 367 displaces the cutting blade 361 linearly as indicated by arrows X, preferably horizontally. In the preferred

embodiment, the blade 361 is connected to a rack 368 that engages a pinion 369 provided about the pivot point 370, as can be seen in Fig. 13, so that when the apparatus 10 is assembled for forming the barbed sutures, turning the lever 367 clockwise moves the blade 361 in the forward direction A.

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Displacement and alignment of the blade 361 with respect to turning of the lever 367 is configured to be adjustable. This may be achieved by providing an adjustment insert 310 in the cutting assembly 300, as shown in Fig. 14. The adjustment insert 310 preferably comprises a slotted connector 312 connecting the rack 368 with the blade 361, the slotted connector 312 being configured to engage an adjustment screw 314 that adjustably secures the slotted connector 312 to the rack 368. A horizontal slot 316 is provided in the connector 312 to engage the adjustment screw 314. The connector 312 is rigidly fixed to the blade 361 while being adjustably securable to the rack 368 via the slot 316 and the screw 314. By appropriately moving the slot 316 relative to the screw 314, the blade 361 is accordingly moved relative to the rack 368, thereby allowing the blade's displacement and alignment to be adjusted.

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The cutting assembly 300 is further provided with a press rod 320 provided lower and preferably parallel to the cutting edge 364 of the blade 361. The press rod 320 is preferably centrally mounted between the side blocks 365, 366 of the cutting assembly. The press rod 320 is configured to displace the lengths of suture 91 during cutting, as will be described in greater detail below.

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To secure and stabilise the cutting assembly 300 during cutting, the cutting assembly is preferably provided with lock pins 362 that extend perpendicularly from the side blocks 365, 366. The lock pins 362 are configured to be hooked onto by the inner surfaces 262 of forward-lock cams 251 in the indexing block 200, as shown in Fig. 9, when the crank 149 is turned clockwise in the direction C shown in Fig. 15 and the cutting assembly 300 is lowered (as indicated by arrows G) into a cutting position due to the cam profiles of raise-lower cams 255, 256 acting against the lower surfaces 367, 368 of the cutting assembly 300. By hooking the forward-lock cams 251 over the lock pins 362, the cutting assembly 300 is stabilised and prevented from rising during cutting.

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The cutting assembly 300 is further preferably configured to be laterally symmetrical, wherein the cutting blade 361 has two cutting edges 364 as shown in Fig. 13, and the lever 367 is configured to be rotatable in both directions about the pivot 370, as shown in Fig. 11.

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In this way, the cutting assembly 300 can be assembled in either direction with respect to the indexing block 200 and the suture frame 100, while continuing to be able to be operated in the same way in either direction, thereby simplifying assembly and operation of the apparatus 10 for the user.

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To support the lengths of suture 91 during cutting by the cutting blade 361, the support block 257 is provide with a suture support 220 provided below the plurality of lengths of suture 91 in the suture frame 100 and configured to contact a downward facing surface 904 of each length of suture 91 in the suture frame 100 at points 901, 902 during cutting, as can be seen in Figs. 16 to 19. The suture support 220 comprises a raised ridge 221 and a suture holding surface 222. In the exemplary embodiment shown in Figs. 16 to 19, the suture support 220 comprises a ridge 221 that extends over the suture holding surface 222 which slopes downwardly aft of the ridge 221. The ridge 221 is configured to be perpendicular to all the lengths of suture 91 mounted in the suture frame 100 when the suture frame 100 has been assembled with the indexing block 200.

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During cutting of the lengths of suture 91, the cutting assembly 300 is lowered to the cutting position until the press rod 320 contacts, downwardly displaces and holds the lengths of suture 91 in the suture frame 100 against the suture holding surface 222, at a held part 902 on each of the lengths of suture 91, as can be seen in Figs. 17 and 19. Displacing the lengths of suture 91 aft of the ridge 221 results in each of the lengths of suture 91 bending about the ridge 221 (2321) at a bent part 901 that is supported by the ridge 221. By providing the cutting ridge 221 and the press rod 320, the apparatus 10 is thus configured to bend each length of suture 91 to present a bent part 901 of each length of suture 91 for cutting. By appropriately configuring the degree of slope of the suture holding surface 222 of the suture support 220, in the cutting position, each of suture 91 may be bent at an angle ranging between 30° to 80°. In a preferred embodiment, the suture support 220 is configured to effect a 70° bend of length of suture 91 in the cutting position.

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The blade 361 is then displaced linearly in the forward direction by turning the lever 367 clockwise (as described above) to the end of its stroke such that the edge 364 of the blade 361 cuts into the upward facing or convex surface of the bent part 901 of each length of suture 91 (2322). The direction of cut is preferably in a direction parallel to the external surface of each length of suture 91, as can be seen in close up in Fig. 18. The length of cut into the bent part 901 is controllable by adjusting the amount of linear displacement of the blade 361, and the depth of cut is controllable by adjusting the vertical location of the blade

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361 when the cutting assembly 300 is in the cutting position.

A cycle of forming barbed sutures 90 using the apparatus 10 will now be described.

5 A length of suture is wound around the dowel pins 125, 126 of the suture frame 100 in a zig-zag manner and secured to the suture frame 100 by clamping the end bars 123, 124 with the clamping beams 127, 128 respectively, as shown in Fig. 3. This presents a plurality of lengths of suture 91 that can be cut on both sides simply by flipping the suture frame 100 over, as can be seen in Fig. 4.

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The suture frame 100 is then assembled with the indexing block 200 such that the first teeth 140 of the toothed sections 133 on one side 135 of the suture frame 100 are engaged by the tooth catches 241 of the indexing block 200. This presents a first side 903 of each length of suture 91 for cutting by the cutting blade 361. The cutting assembly 300 is then positioned
15 over the suture frame 100 to rest on the raise-lower cams 255, 256, as shown in Fig. 2.

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The crank 149 is then turned clockwise to the end of its stroke as shown in Fig. 15 to lower the cutting assembly 300 and displace the lengths of suture 91 to a cutting position as shown in Fig. 16 and 17, presenting a bent part 902 of each length of suture 91 to be cut by
20 the blade 361 (2321).

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The lever 367 is then turned anticlockwise to the end of its stroke to displace the blade linearly into the bent part 902 of each length of suture 91 by a predetermined displacement to cut into each length of suture 91 to form a barb on each length of suture 91 (2322), as
25 shown in Fig. 18. The lever 367 is then turned clockwise to retract the blade 361 from the cut.

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The crank 149 is then turned anticlockwise to the end of its stroke as shown in Fig. 10 to raise the cutting assembly 300 and index the suture frame 100 one tooth pitch P_T forward (2323) in order to present another part on each of the lengths of suture 91 for cutting and
30 forming a barb thereon. The tooth pitch P_T of the teeth on the toothed sections 133, 134 of the suture frame 100 may range between 0.5 to 5mm. In a preferred embodiment, the tooth pitch P_T is configured to be 1.5mm.

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By repeatedly turning the crank 149 anticlockwise (raise cutting assembly 300 and index suture frame 100) and then clockwise (lower cutting assembly into cutting position) followed
35 by turning the lever 367 clockwise (move blade forward to cut suture) and then anticlockwise

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(retract blade), successive barbs 991 become formed along the length of each length of suture 91 on one side 903 of each length of suture 91 in the suture frame 100.

When the suture frame 100 has been indexed to the last teeth on the toothed sections 133 so that no further forward movement of the suture frame 100 is possible by turning the crank 149, the apparatus 10 has reached the end of one cutting cycle, as shown in Fig. 20. Compared to the apparatus at the start of the cutting cycle as shown in Fig. 2, it can be seen that the suture frame 100 has been moved significantly forward. The cutting assembly 300 and the suture frame 100 are then removed from the indexing block 200.

The suture frame 100 is then flipped over and again assembled with the indexing block 200 but this time such that the first teeth 140 of the toothed sections 134 on the other side 136 of the suture frame 100 are engaged by the tooth catches 241 of the indexing block 200. In this way, a diametrically opposite second surface 904 of each length of suture 91 is presented for cutting by the cutting assembly 300, without removing each length of suture 91 from the suture frame 100. The cutting assembly 300 is then positioned again over the flipped suture frame 100 to rest on the raise-lower cams 255, 256.

The assembled apparatus 10 is once again operated as described above to create a plurality of barbs 992 on the second side 904 of the lengths of suture 91, as can be seen in Fig. 19, until the end of the second cutting cycle is reached. Thus, forming the barbed sutures 90 uses two cutting cycles of the apparatus 10 with one flip of the suture frame 100 between the two cutting cycles.

The barbs 991, 992 formed on the two diametrically opposite sides 903, 904 (respectively) of each length of suture 91 are oriented in the same direction. Fig. 19 also shows how the ridge 221 and lowered suture support surface 222 together prevent the portion of suture 91 between the bent part 901 and the held part 902 from contacting any surface during cutting by the cutting assembly 60, thereby preventing the already cut barbs 991 on the first or downward facing side 903 of each length of suture 91 from being pressed back into the length of suture 91 and being unable to provide a barb function.

As can be seen in Fig. 5, the toothed sections 133, 134 are configured such that the barbs 991 and 992 are formed in a staggered manner on the two sides 903, 904 of the lengths of suture 91 respectively, as can also be seen in Figs. 19 and 22, so that there is minimized weakening of the length of suture 91 at the points of cut where the barbs 991, 992 are

formed. Staggering the barbs 991, 992 also prevents a barb 991 on the first side 903 of the length of suture 91 from being compressed by the ridge 221 when cutting a barb 992 on the second side 904 of the suture. The barbs 991, 992 are preferably evenly staggered on the two sides 903, 904 of each length of suture 91 such that the barb pitch P_B between successive barbs 991, 992 is half the tooth pitch P_T of the toothed sections 133, 134. In a preferred embodiment, P_B may be 0.75mm.

When the suture frame 100 has been indexed to the last teeth on the toothed sections 134 so that no further forward movement of the suture frame 100 is possible by turning the crank 149, the cutting assembly 300 and the suture frame 100 are again removed from the indexing block 200.

The lengths of suture 91 presented in the suture frame 100 are then fully cut across along one of the end bars 124, as shown in Fig. 21. Unclamping the clamping beams 127, 128 results in a plurality of sutures 90, each suture 90 as shown in Fig. 22 formed from two adjacent lengths of suture 91 in the suture frame 100, wherein a midway part 905 of each suture 90 was hairpin-wound around each of the dowel pins 125 on the other end bar 123 where the lengths of sutures 91 were not cut. Each barbed suture 90 formed from the above described apparatus 10 is symmetrical about a central transverse axis T of the suture 90. The plurality of staggered barbs 991, 992 on the suture 90 face towards each end 910, 920 of the suture 90 from the midway part 905 of the suture 90, as shown in Fig. 22.

Whilst there has been described in the foregoing description exemplary embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention. For example, while the bending mechanism described above comprises the press rod downwardly displacing the lengths of suture in the suture frame against the ridge, in alternative embodiments, other bending mechanisms may be used, for example, by lowering the suture frame so that the lengths of suture are bent against an upstanding edge. While the indexing and the cutting are described above to be actuated by turning the crank and the lever, actuation of these may additionally or alternatively be carried out using automation. While indexing has been described to be performed on the suture frame, in alternative embodiments, the indexing mechanism may be configured to perform indexing on the cutting assembly and suture support while keeping the suture frame stationary in the horizontal direction.

1. An apparatus for forming barbed sutures, the apparatus comprising:
 - a suture frame configured for presenting a plurality of lengths of suture on which
 - 5 barbs are to be formed;
 - a bending mechanism configured to bend the plurality of lengths of suture to present a bent part of each length of suture for cutting;
 - a cutting assembly configured to cut into a convex surface of the bent part of each length of suture to form a barb on the bent part of each length of suture; and
 - 10 an indexing block configured to support the suture frame and the cutting assembly, the indexing block comprising an indexing mechanism configured to lock the suture frame and the cutting assembly in a cutting position and to effect relative stepwise movement between the suture frame and the cutting assembly to allow a plurality of barbs to be formed at intervals apart on each length of suture;
 - 15 wherein the suture frame, the indexing block and the indexing mechanism are configured to allow the suture frame to be assembled with the indexing block in a flipped configuration without removing the plurality of lengths of suture from the suture frame, so as to present a second side of each of the plurality of lengths of suture to be cut into, thereby allowing barbs to be formed on two diametrically opposite sides of each of the
 - 20 plurality of lengths of suture.
2. The apparatus of claim 1, wherein the bending mechanism comprises
 - a press rod configured to downwardly displace the plurality of lengths of suture in the suture frame; and
 - 25 a ridge provided below the plurality of lengths of suture in the suture frame and configured to contact and support the plurality of lengths of suture such that each length of suture is bent about the ridge when the plurality of lengths of suture have been displaced by the press rod.
- 30 3. The apparatus of claim 2, wherein the press rod is provided on the cutting assembly below a cutting blade provided on the cutting assembly, and the ridge is provided on the indexing block.
4. The apparatus of claim 3, wherein the ridge is provided on a suture support of the
- 35 indexing block, the suture support further having a suture holding surface configured for holding a held part of each length of suture thereagainst by the press rod.

5. The apparatus of claim 4, wherein the suture support is configured such that a portion of each length of suture between the bent part and the held part does not contact any surface during displacement of the plurality of lengths of suture by the press rod.

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6. The apparatus of any preceding claim, wherein the cutting assembly is configured to cut into the convex surface of the bent part of each length of suture in a direction parallel to a surface of each length of suture.

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7. The apparatus of any preceding claim, wherein the suture frame comprises opposing side bars and opposing end bars that are connected to define a space therewithin, and wherein dowel pins are provided on each of the opposing end bars such that the plurality of lengths of suture can be provided in the space by winding a single length of suture in a zig-zag manner from one end bar to the other end bar about successive dowel pins.

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8. The apparatus of any preceding claim, wherein the indexing mechanism comprises a forward-lock cam provided on the indexing block, the forward-lock cam configured to move the suture frame one step forward with each rotation of the forward-lock cam, and

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- a toothed section provided on the suture frame and a tooth catch provided on the indexing block, wherein the toothed section and tooth catch are configured such that the tooth catch engages a tooth of the toothed sections to prevent movement of the suture frame in a backward direction when the suture frame is in the cutting position.

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9. The apparatus of claim 8, wherein the indexing mechanism further comprises a raise-lower cam provided on a same shaft as the forward-lock cam, the raise-lower cam is configured to raise the cutting assembly during forward movement of the suture frame and to lower the cutting assembly to the cutting position when the raise-lower cam is rotated in a reverse direction, and the forward-lock cam is further configured to lock the cutting assembly in the cutting position when the forward-lock cam is rotated in a reverse direction.

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10. The apparatus of claim 1, wherein the suture frame is configured such that a plurality of barbs formed on the second side of each length of suture when the suture frame is assembled with the indexing block in the flipped configuration is staggered from a

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plurality of barbs already formed on a first side of each length of suture.

11. A method of forming barbed sutures, the method comprising the steps of:

- a) bending a plurality of lengths of sutures to present a bent part of each length of suture for cutting;
- b) cutting with a cutting assembly into a convex surface of the bent part of each length of suture to form a barb on the bent part of each length of suture;
- c) effecting a relative stepwise movement between the plurality of lengths of suture and the cutting assembly in a direction parallel to the plurality of lengths of suture;
- d) repeating steps a) to c) to form a plurality of barbs that are intervals apart on each length of suture;
- e) flipping the plurality of lengths of suture over to present a diametrically opposite side of the plurality of lengths of suture to be cut into; and
- f) repeating steps a) to c).

12. The method of claim 11, further comprising, prior to step a), mounting the plurality of lengths of sutures on a suture frame, the suture frame comprising opposing side bars and opposing end bars that are connected to define a space therewithin, wherein the mounting comprises winding a single length of suture in a zig-zag manner from one of the end bars to the other of the end bars about successive dowel pins provided on the opposing end bars such that the plurality of lengths of suture are provided in the space.

13. The method of claim 11 when dependent on claim 12, further comprising

- g) cutting each of the plurality of lengths of suture away from the suture frame.

14. The method of claim 13, wherein step g) comprises cutting across the plurality of lengths of suture along one of the end bars.

15. The method of any of claims 11 to 14, wherein the cutting in step b) is in a direction parallel to a surface of each length of suture.