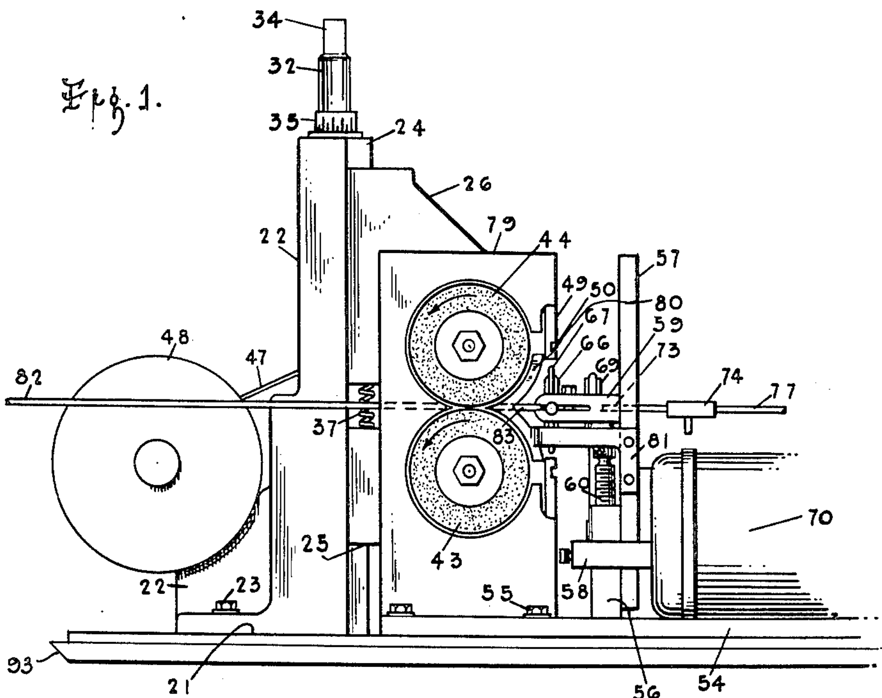
PRECISION GRINDING OF SURGICAL SUTURES

Original Filed April 23, 1959 4 Sheets-Sheet 1

Fig. 1.



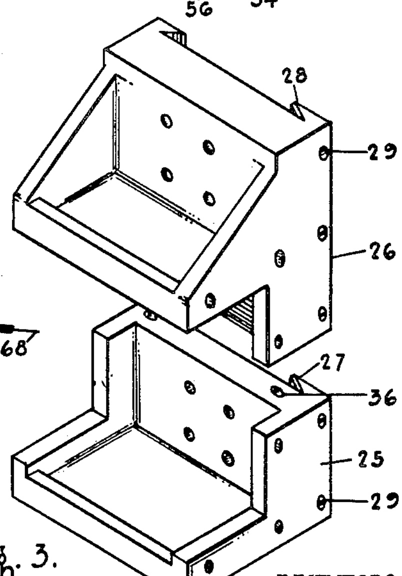
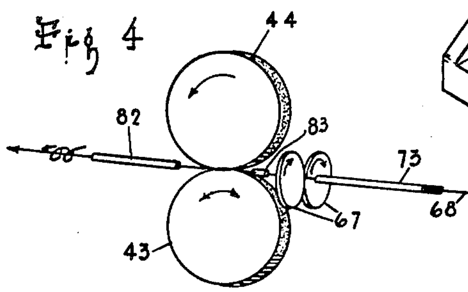


Fig 4



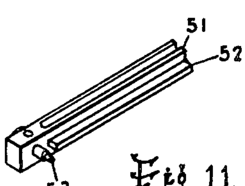


Fig. 11.

Fig. 3.

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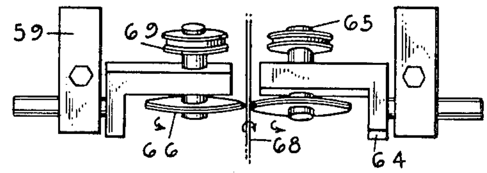

Fig. 6

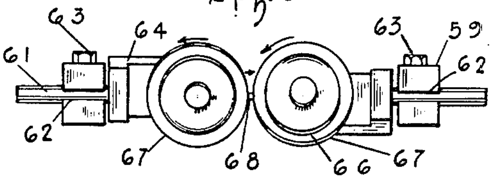

Fig. 7

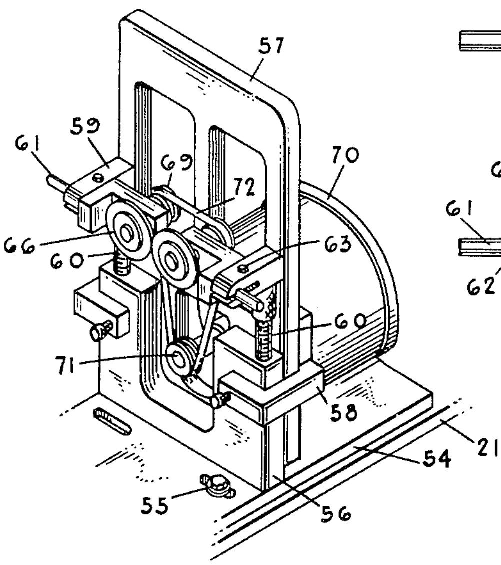

Fig. 5

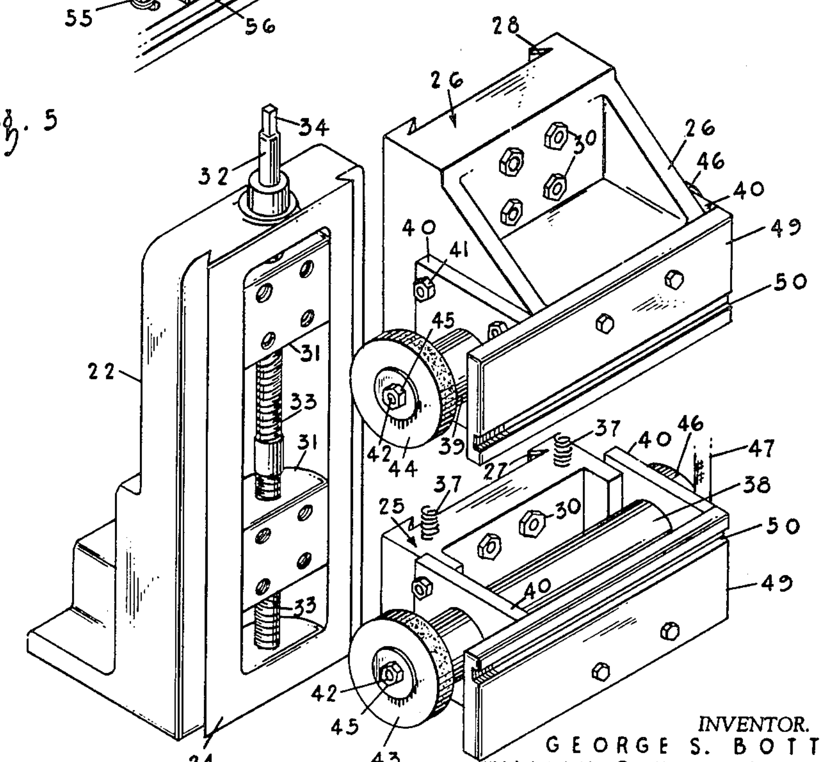

Fig. 2

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Dec. 4, 1962 G. S. BOTT ETAL 3,066,452

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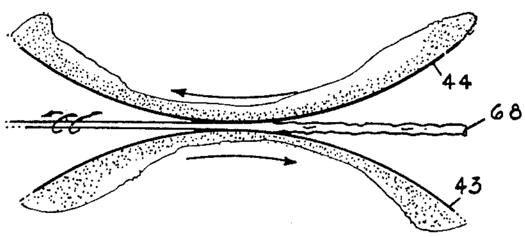

Fig. 12.

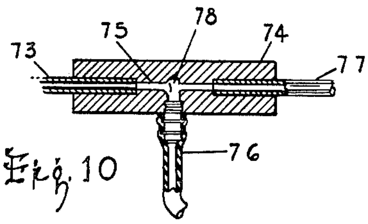

Fig. 10

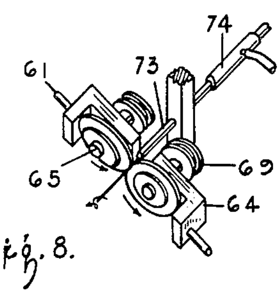

Fig. 8.

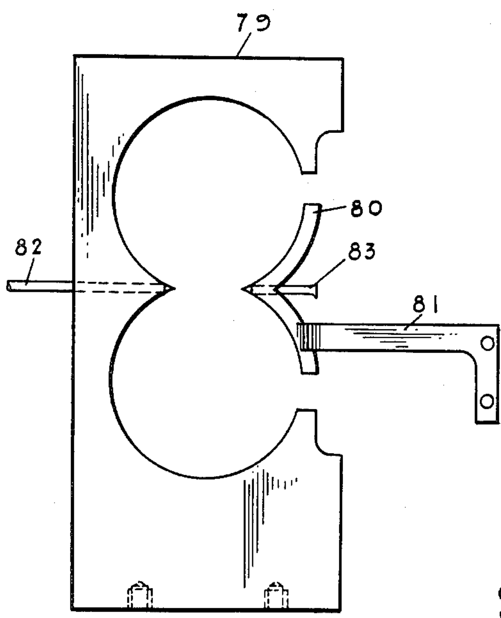

Fig. 9.

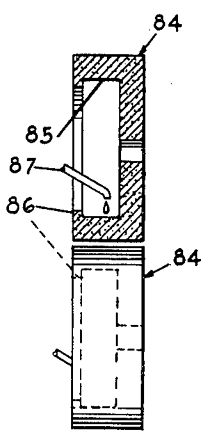

Fig. 13.

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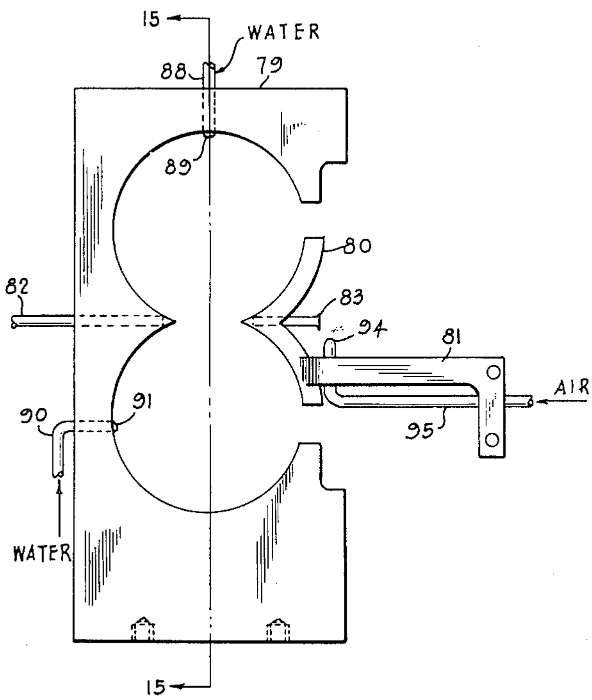

Fig. 14

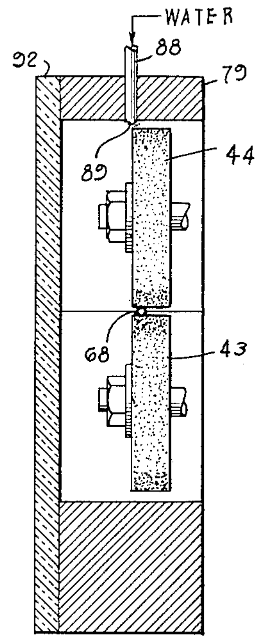

Fig. 15

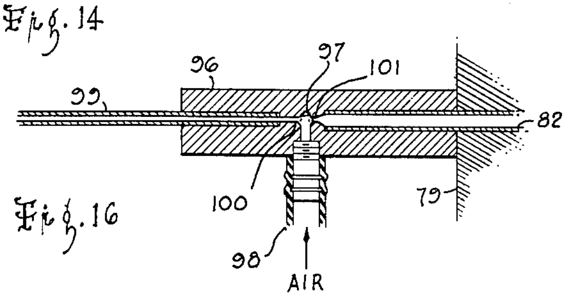

Fig. 16

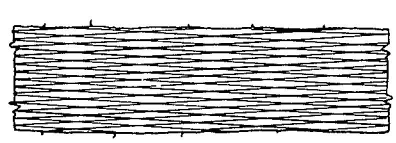

Fig. 17

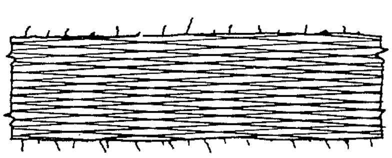

Fig. 18

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3,066,452
Patented Dec. 4, 1962

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PRECISION GRINDING OF SURGICAL SUTURES

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Original application Apr. 23, 1959, Ser. No. 808,349. Divided and this application Mar. 5, 1962, Ser. No. 177,366
17 Claims. (Cl. 51—88)

This invention relates to a method and apparatus for the rapid precision grinding, feeding, sizing and polishing of surgical sutures and the like in which the suture strand is positively retained and rapidly rotated about its own axis while it is fed positively longitudinally through the bite of grinding wheels, operating nearly longitudinally of the suture, and more particularly with water as a grinding medium.

This application is a division of our application Serial No. 808,349, filed April 23, 1959, which is a continuation-in-part of our application Serial No. 732,382, filed May 1, 1958, now abandoned.

As used herein the term "sutures" includes ligatures. The technical distinction to the medical profession is that sutures are used to sew, whereas ligatures are used to tie off. The same strand of catgut or similar material may be used interchangeably for both purposes. Similarly, the method and apparatus of the present invention may be used to grind flexible materials other than catgut and may be used to grind such materials for uses other than in sutures, as for example, strings for musical instruments, strings for sport equipment such as tennis rackets, badminton rackets, etc. or for other purposes for which such strands are desirable.

Such strands of catgut or related materials are usually comparatively short, 5 foot lengths being conveniently processed, and because derived from natural sources, are of somewhat uneven diameter, and perhaps not even of circular cross-section. A circular cross-section is usually preferred, and the sizes must be within certain standards, set forth, for example, in the U.S. Pharmacopoeia.

It is desirable that the suture be of uniform cross-section. For a homogeneous material the tensile strength of a strand is determined by the minimum cross-section, and yet the usability and tissue damage is controlled by the maximum cross-section. Further, for classification under the U.S. Pharmacopoeia standards, the maximum diameter sets the size, and the minimum cross-section determines the strength. Hence, for maximum strength within a given size range, it is necessary that the suture be of uniform circular cross-section which is as nearly as feasible the maximum diameter permitted within the suture size; so that within manufacturing limitations, the minimum cross-section is equal to a circular area whose diameter is the maximum diameter of the suture size. The surgical suture may be made from collagen strands, slit as ribbons from suitable animal tissues, and twisted together; or the suture may be fabricated by spinning and adhesively uniting suitable collagenous fibers or by regenerating solutions or suspensions of collagen.

It has been recognized within the art that such methods of fabrication, particularly those using ribbons of animal tissues, yield a string having thick and thin portions. It has also been recognized that it is desirable that such strands be sized to uniform diameter. Such early patents as Hull, U.S. Patent 642,452, January 30, 1900, "Machine for Grinding and Rounding Strips of Rawhide or Other Material" show sizing of tissue strands. Since that time many efforts have been made to grind

strands of sutures or suture material both by rotating the strand against sand paper, or by attempting to position the strand adjacent a moving abrasive surface. In general attempts to position a flexible suture against a flat grinding surface have met with the insurmountable problem that the flexibility of the suture permits grinding of not only the high points but also adjacent areas. The problem of grinding wtih rotating wheels has normally encountered the problem of juxtaposition of tangent circles under such conditions that minor errors in placement introduce errors in sizing, with related problems of positional control.

The sizes of sutures in common use vary from a #6–0 wtih a diameter of 0.002 inch to 0.004 inch by steps of two to four thousandths of an inch up to a #6 with a maximum size of 0.036 inch, although both larger and smaller sutures are listed in the Pharmacopoeia. A very common size is 00 with a size of from 0.010 to 0.013 inch. With a material as flexible as catgut, it can be seen that the control and handling of strands this small introduce complications because of the flexibility of the strand.

Also the strands of surgical catgut forming the sutures are normally comparatively short, as they are usually sold in about five foot lengths, and are necessarily manufactured, when of plies, from plies whose maximum length is determined by the raw material which, for example, when of beef gut, has a maximum length of about 100 feet. Usually it is convenient to cut longer strands into 5 foot length sutures and then classify as to size these 5 foot lengths, as adjacent sections may be sized differently.

The problem then is to reduce these lengths to a uniform cross-section, preferably just smaller than a maximum diameter of a standard suture specification size.

It has now been found that surgical sutures may be accurately sized by rapidly rotating a suture about its longitudinal axis and passing the suture through the bite of counter-rotating grinding wheels.

The grinding wheels conveniently have parallel axes and are accurately right circular cylinders so that the space between two such wheels is a grinding zone with an accurately defined gap dimension and which has a comparatively wide line of action so that even if the suture being ground deviates markedly from collinearity with the line of feed, the suture is still accurately sized. Rotation and feeding of the suture are conveniently accomplished by passing the suture between two feed wheels having a flexible perimeter and rotating in the same direction, whose axes of rotation are skewed slightly from being parallel with the feed axis of the suture so as to track a slightly helical path along the suture thus giving the suture a high rotational speed and a comparatively slow axial velocity.

The grinding wheels theoretically may be slightly cone shaped and still, by having the adjacent elements of the cones parallel, give two parallel cutting faces through which the suture is passed. It is more convenient, however, to use grinding wheels whose grinding faces are right circular cylinders because such stones are easier to manufacture and dress. The grinding wheels may be natural stones, or of plastic or ceramic bonded grits or other synthetic grinding material. Ceramic bonded grinding wheels which are somewhat porous are usually preferred. Wheels which are designed for cutting softer materials are usually preferred, because the ground off suture material has less tendency to load such wheels. Whereas from very fine to very coarse wheels may be used, wheels of from #60 to #120 mesh grit are conveniently used for a first grind, and from #100 to #150 mesh grit used for a second grind. By using the finer grades of grit, the suture may be adequately finished to size in a single pass. With water as a coolant, a very smooth suture can be obtained in a single pass.

In so far as the grinding action is concerned the same speeds used in metal working are convenient. A wheel surface speed of below about 3000 feet per minute grinds more slowly than is usually desirable, and speeds above 6000 feet per minute are usually discouraged by the manufacturers of grinding wheels because of the danger from centrifugal forces. Much higher speeds give excellent results in grinding, providing the wheel does not explode. The grinding wheels may be supported and spun by any suitable system, one particular system being more fully described in connection with a specific example and drawings later set forth.

The grinding wheels are preferably rotated in the same direction at approximately the same speed. The stresses along the feeding axis of the suture are balanced out by one wheel tending to pull the suture forward and the other one tending to retard the suture. As these forces cancel, the rate of feed of the suture is controlled by an external feed system.

In conventional centerless grinding, the grinding wheel, the regulating wheel, and the ground stock have essentially parallel axes, although slight skews may be used to control the rate of stock advance. In the present instance the suture is fed in the plane of rotation of the grinding wheels, rather than perpendicular thereto, and therefore a more positive feed system is required.

A plurality of rotated wheels are conveniently used to feed the suture and also rotate the suture. By rotating the suture at a speed of from about 20,000 to 70,000 revolutions per minute the suture is ground cylindrically. The grinding action is smoothly distributed around the peripheral surface of the suture and the rapid rotation gives additional rigidity to the suture. The suture is preferably spun at such a speed that it tends to rotate about its minimum axis of inertia and is necessarily spun at a speed not in excess of that at which it would centrifugally disintegrate. A reasonable margin of safety from these limits is preferred with the higher of the above speeds being used for the smaller sutures and slightly lower speeds for larger sutures. The feed wheels preferably have a resilient facing to allow for variations in suture characteristics. An abrasion resistant rubber or plastic is conveniently used for the suture contacting face of the feed wheels. Polyurethanes are particularly useful because of their remarkably long lived resiliency. By having the axes of these wheels slightly skewed as the suture rotates between them, the suture is given a longitudinal advance. By having an adjustable angle of skew, the feed rate can be controlled. More than two feed wheels may be used but two wheels are sufficient to give a well controlled spinning and driving action and the sutures are readily fed into a position where the feed wheels may grasp the sutures.

The method, characteristic features, and scope of this invention are illustrated and more readily understood from the specific embodiment shown in the following description, taken in connection with the accompanying drawings wherein:

FIGURE 1 is a front elevation of the assembled grinding machine.

FIGURE 2 is an exploded pictorial view of the grinding wheel stand and the grinding wheel support elements.

FIGURE 3 is a pictorial view of the grinding wheel brackets.

FIGURE 4 is a diagrammatic view of the grinding wheels and feed wheels.

FIGURE 5 is a pictorial view of the feed wheel assembly.

FIGURE 6 is a top view of a portion of the feed wheel assembly.

FIGURE 7 is a front view of the portion of the feed wheel assembly shown in FIGURE 6.

FIGURE 8 is a pictorial view of the feed wheel assembly.

FIGURE 9 is a face view of the suture guides and safety frame.

FIGURE 10 is a sectional view of the suture feed block.

FIGURE 11 is a view of the grinding wheel dressing block.

FIGURE 12 is an enlarged view showing the action of the grinding wheels on the suture.

FIGURE 13 is a view in partial section of an alternative grinding wheel system.

FIGURE 14 is a face view of the suture guides and safety frame of an embodiment of the invention using a water jet as coolant.

FIGURE 15 is a section along line **15—15** of FIGURE 14, showing a transparent grinding shield and the water jet position.

FIGURE 16 is a sectional view of the air transport and drying system of the embodiment using water as a coolant.

FIGURE 17 is a diagrammatical view of a 125 diameter enlargement of a suture ground with water as the coolant.

FIGURE 18 is a diagrammatical view of a 125 diameter enlargement of a suture ground with kerosene as the coolant.

It is obvious that the size and relationship of the parts are related to the size of the suture or strand being ground. For the normal run of sizes used in surgical sutures, certain sizes are given by way of illustration. It is to be emphasized that the size may vary over a wide range without losing the advantage of the present invention.

Grinding Wheel Assembly

As shown in FIGURE 1 the precision suture grinder is shown as including a work bench **21** which is preferably of solid construction such as metal. Steel or aluminum alloys are both solid and easy to work. On the work bench is fastened a grinding wheel stand **22** with grinding wheel stand bolts **23**. As shown in FIGURE 2, on a working face of the grinding wheel stand are the dovetail guide ways **24**. In sliding relationship on the dovetail guide ways are a lower grinding wheel bracket **25** and an upper grinding wheel bracket **26**. In operating relationship in the dovetail are the dovetail gibs **27** and **28** which are adjusted by the gib screws **29**. It is preferred that, in accordance with good machine shop practice, the dovetail guide ways be accurately formed so that when the gibs are tightened with the gib screws the grinding wheel brackets slide smoothly on the grinding wheel stand dovetail guide ways with a minimum of shake or lost motion.

Each grinding wheel bracket is fastened with grinding wheel bracket cap screws **30** to a grinding wheel bracket positioning nut **31**. Interiorly of the grinding wheel stand **22** is mounted a grinding gap adjusting screw **32** which has right- and left-handed threads **33** operating the grinding wheel bracket positioning nuts. Conveniently the grinding gap adjusting screw has a square head **34** and a micrometer collar **35**.

Spring containing holes **36** are formed in the opposing faces of the grinding wheel brackets in which are placed biasing spring **37** which are sufficiently strong to overcome gravity and the effect of the spindle drive belt **47**, and firmly hold the grinding wheel brackets apart against the action of the grinding gap adjusting screw operating against the grinding wheel bracket positioning nuts; so as to eliminate all lost motion and insure that the upper and lower grinding wheel brackets move smoothly and symmetrically towards and away from each other as the grinding gap adjusting screw is rotated.

A lower and an upper grinding wheel spindle **38** and **39** are mounted in spindle plates **40** which are fastened with bolts **41** to the lower and upper grinding wheel brackets. Through grinding wheel shafts **42** are journaled in the spindles. On the front of the grinding wheel shafts, lower and upper grinding wheels 43 and 44 are fastened with retaining nuts and washers 45. On the back side of the grinding wheel spindles are spindle drive pulleys 46 which are driven by a spindle drive belt 47 from a grinding wheel motor 48.

A dressing tool support plate 49 is fastened to the grinding wheel brackets 25 and 26. In this dressing tool support plate is a dressing tool guide groove 50 which is in accurately parallel spaced relationship with each grinding wheel shaft. A separate dressing tool 51, as shown in FIGURE 11, has a dressing tool key 52 adapted to slide in the dressing tool guide groove. At the end of the dressing tool is a micrometrically adjustable dressing tool point 53. Preferably the dressing tool has a diamond point.

In operation the grinding wheels are maintained in precise adjustable relationship with each other and are accurately symmetrically positionable so that the grinding surfaces of the grinding wheels 43 and 44 are parallel to each other and positioned the same distance above and below a grinding line. The dressing tool is used to smooth the surface of each wheel, and because the dressing tool slides in parallel relationship with the grinding wheel shafts, the grinding surfaces of the grinding wheels may be kept accurately cylindrical and parallel to each other, and of the same size. Inasmuch as the dressing tool support plates rest on the grinding wheel brackets 25 and 26 any necessary adjustments are easily made by grinding the dressing tool supporting plate contacting face of the grinding wheel brackets to insure a parallel relationship.

As will be apparent the entire gap between the grinding wheel faces is the same height and accordingly no matter where a suture passes through the gap, the suture is ground to the same size.

Suture Feed System

The suture feed system is separately mounted as a unit and is positionable with respect to the grinding gap, so that the suture may be fed at any selected position across the grinding surfaces of the grinding wheels. A feed guide support 54, FIGURE 1, is mounted on the work bench 21 and held in position by feed guide support cap screws 55. The feed guide support includes a vertical plate 56. Adjacent and clamped to this vertical plate is a positionable feed frame 57. This feed frame is held to the vertical plate with C-clamps 58. The positionable feed frame has thereon trunnion blocks 59. Adjusting screws 60 screwed into tapped holes in the vertical plate 56 support the trunnion blocks and thus control the height of the positionable feed frame.

The feed wheels are mounted so that each wheel may be rotated about a common diameter including the point of tangency, and also adjusted horizontally along that diameter to set the gap between them through which the unground suture passes. The action of these feed wheels is diagrammatically illustrated in FIGURE 4. The actual mounting is shown in FIGURES 5, 6, 7, and 8.

The trunnion blocks 59 are mounted opposite each other. At the side away from the positionable feed frame 57, the trunnion blocks each have a round axle clamp hole through which passes a feed wheel support axle 61. The trunnion block has a trunnion block slit 62 which slit is compressed together with a trunnion block clamp screw 63. The feed wheel support axle rotates in the trunnion blocks and is clamped in position with the trunnion block clamp screw after being adjusted both angularly and axially to the proper suture feed position. On the other end of the feed wheel support axle is the off-set feed wheel support block 64. This off-set feed wheel support block is generally L-shaped with the short arm of the L integral with or attached to the feed wheel support axle. In the long arm of the L is journaled a feed wheel shaft 65. Ball bearings are preferred but not essential. The feed wheel shaft axis intersects the feed wheel support axle axis at 90. Mounted on the feed wheel shaft is a suture feed wheel 66. The suture feed wheel has a resilient rim 67. The rim may be of rubber, natural or synthetic, and preferably is of polyurethane. Two suture feed wheels are mounted on the feed wheel shafts so that the working diameter of each is on the common axis of the two feed wheel support axles. The wheels are spaced apart by a distance slightly less than the diameter of the suture to be ground 68 which is thus resiliently held between the rims of the suture feed wheels. The plane of each suture feed wheel is turned slightly from parallel with the positionable feed frame 57, and in opposite directions, so that the line of rolling contact between the resilient rim and the suture is a helix with a large helix angle. This helix angle is adjusted to give the desired rate of suture feed and may be from about 80° to 89°. The term "helix angle" is sometimes misused, but is defined as the constant angle between the tangent to a helix and the generator of the cylinder upon which the helix lies. By having the point of tangency of the feed wheels on the feed wheel working diameter, the helix angle can be changed without otherwise readjusting the feed wheel position. If constant feed rates are desired, the supports need not be adjustable.

The suture feed wheels are driven by feed wheel drive pulleys 69 mounted on the feed wheel shaft, conveniently on the opposite side of the off-set feed wheel support blocks from their respective suture feed wheels.

The feed wheel drive motor 70 may be mounted on the feed wheel guide support 54. On the shaft of this motor is feed wheel driving pulley 71. A feed wheel belt 72 passes around the feed wheel driving pulley and the two feed wheel drive pulleys thus causing the feed wheel drive motor to turn the suture feed wheels. Conveniently, this belt is a round elastic belt of a rubber-like material of sufficient elasticity that an adjustment for length is not necessary, and the pulleys are all designed for a round belt; all three pulleys turn in the same direction, such as to advance the suture.

Through the positionable feed frame towards the point of tangency of the suture feed wheels extends a suture transfer tube 73. This is conveniently a piece of hypodermic tubing which is just slightly larger than the largest suture to be ground. Other sources of tubing may be used but steel tubing used for the manufacture of hypodermic needles is tough and conveniently obtained in desired sizes. Mounted on the end of the suture feed tube away from the feed wheels is a suture feed block 74 as shown in cross-section in FIGURE 10. This block is conveniently of a transparent plastic (or of brass with a transparent insert) so that the passage of a suture may be observed.

As shown in FIGURE 10 the suture feed block 74 has a T-shaped passage 75. The stem of the T is connected to a vacuum line 76. One side of the head of the T slides over the suture transfer tube 73. The other side has attached thereto the suture conveying tube 77. Conveniently the suture conveying tube is a piece of hypodermic needle tubing sufficiently long to hold the longest suture to be ground. Preferably the suture conveying tube is slightly larger than the suture transfer tube. The entrances of all tubes are flared slightly so that the ends of the sutures may be more easily threaded thereinto. The stem of the T may match exactly the head passage of the T. It is usually more convenient from a machining operation viewpoint to have a slight enlargement forming a vacuum chest 78 at the intersection. The suture conveying tube is much longer and slightly larger than the suture transfer tube. Thus when vacuum is applied through the vacuum line 76, a suture is drawn by vacuum into the suture conveying tube and as the end passes the intersection of the T, is guided into the transfer tube and fed into the gap between the suture feed wheels. Because the conveying tube is much longer, the influence of air flowing through it is much greater than the effect of air flowing through the comparatively shorter and smaller suture transfer tube 73 and as a result draws the end of a suture through the T and feeds it into the feed wheels. It is very surprising that an unbalanced head T would have such a simple yet positive feeding effect.

Once the feed wheels contact the leading end of the suture, the suture is caused to rotate and advance by the action of the feed wheels, and vacuum no longer has any control on the feeding of the suture. The vacuum may be discontinued once the feed wheels have grasped the suture, but on the other hand the continuing application of vacuum does no harm so that by leaving the vacuum acting, a control valve is eliminated. The transfer tube and conveying tube permit the suture to float freely therein as it is rotated at high speeds by the feed wheel. The interior passages through the suture conveying tube, the suture feed block, and the suture transfer tube must be smooth and free from burrs which could damage the rapidly rotating sutures.

The feed wheels are preferably spaced close to the grinding wheels, so that the end of the suture is released close to the grinding gap. Momentum carries the suture on through the grinding gap, after the trailing end passes the feed wheels. The use of feed wheels on each side of the grinding gap is usually not necessary, although a dual set of feed wheels may be used. If dual feed wheels are used, one set may have an overrunning clutch to avoid undue torsion on the suture.

Surrounding the grinding wheels 43 and 44 is a safety guard frame to protect the operators, from flying particles of suture, and in case of wheel explosion. The safety guard frame consists of a main guard frame 79, which surrounds nearly three-quarters of the perimeter of each wheel and a small guard block 80. Between them is a gap for dressing the grinding wheels. The small guard block is supported by a support arm 81 attached to the positionable feed frame 57. A suture feed tube 83 passes through the small guard block and extends almost up to the bite of the grinding wheels. Conveniently the suture feed tube is firmly retained in the small guard block and is initially put into position extending further in towards the bite of the grinding wheels than is desired and is ground to size and fit by contact with the rotating grinding wheels.

On the opposite side of the grinding wheels is the suture receiving tube 82 which extends through and is supported by the main guard frame 79. This suture receiving tube 82 has a flared entrance, so as to pick up the suture as it comes from between the grinding wheels. The suture receiving tube should be long enough to keep the front end of the suture from unduly whipping until the entire length of the suture is ground and rotation of the suture ceases. If desired, an additional vacuum T may be used at the end of the receiving tube to discharge the sutures by pulling them out of the receiving tube. Such a vacuum T, which by analogy to radar practice might be called a "magic T," is particularly convenient if the sutures being ground are of varied length so that short sutures may readily be drawn from the receiving tube, and the suture receiving tube is to be long enough to hold the longer sutures.

The main guard frame may be attached to the positionable feed frame 57 but is more conveniently attached to the feed guide support 54. Shims may be used if necessary to adjust the height of the receiving tube so that it is exactly opposite the grinding gap between the grinding wheels.

The entire feed and receiving assembly is mounted on the feed guide support 54, which is mounted for movement parallel to the axis of the grinding wheels and held in position by the feed guide support cap screws.

In grinding sutures, the catgut is rather soft and tends to load the grinding wheels. Also, the grinding wheels are slowly worn away by contact with the sutures being ground. By dressing the entire face of the wheels, the grinding gap is uniform and sutures can be fed at any point along the face. Grinding may be started adjacent one edge of the face, and the feed guide support and feed assembly moved by stages so that sutures are ground at various points across the entire face of the grinding wheels. By periodically moving the line of suture travel a small increment, for example, a thirty-second of an inch, new and sharp surfaces of the grinding wheels are brought into action and a single dressing of the grinding wheels suffices for a long period of operation, and the grinding of a large number of sutures. The safety guard frame should be thick enough to protect the operator from wheel breakage no matter where along the face of the wheel the sutures are being fed. Obviously the feed guide support can be mounted on ways for screw feeding, either manual or automatic, in relationship to the grinding wheels. The use of cap screws and manual adjustment in slots is sufficiently flexible for most operations.

Similarly, a transparent plastic plate can be placed across the face of the safety guard frame and a vacuum port placed opposite the grinding wheel gap to withdraw ground fragments and eliminate the release of dust in the vicinity of the grinder.

FIGURE 12 shows on an enlarged scale the action of the grinding wheels 43 and 44 on the suture 68. As is shown diagrammatically, the suture being fed is slightly larger than final size and has a rough surface. The suture emerging from the grinding gap is smooth and of uniform size.

Theoretically, points on the surface of the suture follow a helical path and the surface is ground with a thread. However, the pitch of the thread is so fine as compared with the curvature of the grinding wheels that such threads cannot be found even by microscopic examination, and the surface of the suture is smooth.

The surface speed of the grinding wheels is so much greater than the surface speed of the suture that any abrasions or work marks on the surface of the suture are nearly longitudinal.

Inasmuch as the grinding wheels are contacting the suture in opposite directions and the suture rotates, each wheel gives a grinding action with a very slight helix angle, in the order of magnitude of less than 1° to 2° or 3°, so that a slight criss-crossing effect occurs giving much greater surface smoothness than could possibly be obtained with a grinding surface acting in but a single direction with respect to the suture surface.

Furthermore, any irregularities are predominately longitudinal of the suture and permit the suture to be more smoothly drawn through tissue when in use.

Additionally any scratches or abrasions by being longitudinal of the suture are much less apt to cause weakness in the suture than would grinding marks at nearly right angles to the length of the suture. It is well known in the mechanical arts that when metals have fine fissures, there is a concentration of stress in the metal at the root of the fissures, causing work hardening and premature breaking through fatigue failure. The same type of action appears to give greater strength to the longitudinally ground sutures than to peripherally ground sutures.

Even though the sutures are selected for minimum size, and ground so that the minimum diameter of a suture before grinding is selected for the maximum diameter after grinding, it is possible for flaws or zones of weakness to pass almost undetected, particularly if the flaw is reentrant in character. Such flaws can be detected conveniently by coloring the surface of the suture with a dye or pigment before grinding and then after grinding the suture can be inspected for unground areas which might otherwise be zones of weakness. The use of fluorescent colors and inspection by ultraviolet light renders the detection of such flaws particularly convenient.

FIGURE 13 shows an alternative construction for the grinding wheels in which hollowed out grinding wheels are used. The hollowed out grinding wheels **84** have interior recess **85** with a slight flange **86**. A coolant can be supplied through coolant supply tubes **87**. The wheels are slightly porous which permits the coolant to flow through the wheels under the influence of centrifugal force. The coolant thus washes away any suture material which tends to load the surface of the wheel by washing such material out of crevasses by concurrent flow. Obviously, a jet of coolant driven against the surface of the wheel would not be as effective as it would tend to wash particles into the wheel. The use of a coolant such as kerosene or a halogenated hydrocarbon, which is fire resistant, permits grinding at somewhat higher feed speeds by keeping the surfaces of both the suture and the grinding wheels cool.

Highly suprisingly it has been found that sutures of catgut or regenerated collagen can be ground in the presence of water. Because collagen is swelled by water, it would be anticipated that the collagen would be swelled by water and hence become so soft that the suture could not be ground. This assumption is logical and correct if the suture remains in contact with water for very long. However, it has now been found that if a jet of water is used as a coolant and lubricant on the grinding wheel, and the suture is protected from contact with the water until just before grinding, a much smoother grind is obtained than when the suture is ground dry, or with kerosene as the coolant. It appears that the water actually wets the suture and hence any frizzles are either removed or drawn tighter against the suture by surface tension so that the surface is markedly smoother. The use of water as a lubricant is particularly effective in the grinding of chromic treated catgut sutures.

Additionally, any grinding dust is washed off. Water is cheap. Hence, after contacting the suture and grinding wheels, the water is discarded. There are no problems of recovery. There is no necessity for separating the ground suture fines. Any ground material is washed away by using an adequate supply of water. Cleanness is easier to maintain. Dust free grinding is obtained.

Surprisingly the water greatly lengthens the effective grinding life of the grinding wheel. When using a hydrocarbon lubricant and coolant, such as kerosene, grinding wheels have to be dressed once an eight-hour shift. With water as a lubricant and coolant, dressing of the wheels is required only about once every **10** days.

A modification of a machine using water as a coolant is shown in FIGURES 14 to 16.

As shown in FIGURES 14 and 15, the main guard frame **79** has a small hole drilled therein at the top above the center of the upper grinding wheel **44** for an upper water feed line **88**. This upper water feed line conveniently is a piece of hypodermic tubing which fits snugly in the hole in the main guard frame, and hence may be adjusted for wear of the grinding wheel. At the end of the upper water feed line is the upper water jet tip **89**. The main guard frame also has a drilled hole to the side of the lower grinding wheel **43**, for a lower water feed line **90**, which terminates in a lower water jet tip **91**. The water supply to these water feed lines is conveniently a piece of rubber tubing from a convenient source, not shown.

As shown in FIGURE 15, the water feed lines are positioned so that the tips supply water to the grinding wheels preferably in line with the suture feed tube **83** and the suture receiving tube **82**. Thus the suture receiving tube, the suture feed tube, the two water jet tips, and the grinding line on each grinding wheel, lie in a common plane.

As the main guard frame **79** is traversed with respect to the grinding wheels **43** and **44**, the water jet tips continue to supply water to that portion of the wheel surface which is grinding the suture at a particular time. Thus, the entire face of the grinding wheels may be used in a plurality of grinding positions and in each instance the water is fed to the line on the periphery of the grinding wheel which is doing the grinding at that particular time.

Conveniently a transparent grinding shield **92** is mounted on the open face of the main guard frame, and is also in contact with the small guard block **80**. This transparent grinding shield protects the operator from water spray and yet permits observation of the grinding operation. A plastic sheet such as polystyrene is easily cut to fit and is strong enough to protect the operator in case of wheel failure.

Conveniently, as shown in FIGURE 1, a water drain pan **93** surrounds the work bench **21** to receive the water as it drains from the grinding wheels. The water drain pan has a suitable connection to waste, frequently a sewer line.

Adjacent to the suture feed wheels **66** and directed towards the point of intersection of the resilient rims **67** and the suture to be ground **68** is an air jet **94**. As shown in FIGURE 14, this jet is connected to an air blowing line **95** which connects to a source of compressed air, not shown. This air jet blows off any water that may seep back through the suture feed tube **83** and keeps the suture being fed to the grinding wheels and resilient rims of the suture feed wheels dry.

Whereas the suture may be removed without drying through the suture receiving tube **82**, a more convenient system is shown in FIGURE 16 in which a suture receiving transfer block **96** fits over the receiving tube **82** adjacent to the main guard frame **79**. The suture receiving tube **82** is cut short. The suture receiving transfer block **96** has a T-passage **97** therein. The stem of the T is connected to an air pressure line **98**. One end of the head of the T slides over the suture receiving tube **82**. Either a friction fit or a suitable retainer may be used. The other end of the head of the T in this transfer block holds the suture discharge tube **99** which is of sufficient length to hold the entire ground suture. The suture discharge tube **99** is of smaller size than the suture receiving tube **82**, and is much longer, hence the air flowing therethrough is brought into greater frictional contact with the suture therein which therefore transports the suture. Preferably the entrance in the suture receiving feed block has a slight bevel **100** to facilitate the entry of the sutures. The head of the T adjacent to the suture receiving tube **82** conveniently has a funnel configuration **101** to cut down on the flow of air through the suture receiving tube **82** and to ensure the directing of the suture towards the center of the suture discharge tube **99**. Obviously, the size of these passages must be such as to receive the sutures being ground, but need not be much larger than the maximum diameter of the biggest suture passing through. A very free fit is of course required.

Air blowing back through the suture receiving tube blows back any water on the sutures, and dries the sutures promptly. Thus water on the sutures is rapidly blown off. The evaporation of water from the surface of the suture permits the surface tension of the water to be used as an effective force to lay any light frizzles on the surface of the suture against the suture itself. Centrifugal force from the rapid spinning of the suture also aids in throwing off water. The positive feed from the feed wheels forces the suture into the suture receiving tube against the air pressure. The high rotational speed aids in keeping the sutures centered and aids in preventing jams.

For extremely small frizzles, such as the frizzles on the surface of the ground sutures, surface tension of water is a force of sufficient magnitude to hold the frizzles against the suture, and as both are very slightly surface softened by the water, these frizzles are caused to adhere to the surface of the suture, giving a remarkably smooth polished suture.

The water jets spraying the grinding wheels need not be of great pressure. Just enough to direct the flow is required. Depending upon the size of the jets, a pressure of ½ pound to 10 pounds per square inch gives good results. Even a mere drip of water on to the wheel from the upper jet is sufficient. The speed of the wheel causes centrifugal action sufficient to spread the water over the surface of the wheel, and wash off any ground fragments.

The improved surface smoothness obtained by grinding in the presence of water is very difficult to describe. The surface roughness of a ground suture consists largely of small frizzles, that are so flexible that ordinary surface contacting devices are not effective in measuring surface roughness. One method of determining surface roughness is to mount the sutures under a microscope and observe the number of frizzles which are visible. With a magnification of 125 diameter, a typical suture ground in the presence of kerosene as a coolant showed about 12 frizzles per linear inch of magnified suture diameter. This is conveniently measured by taking a picture at 125 diameters and counting the frizzles on both sides per inch of picture. A pictorial representation is shown in FIGURE 18.

FIGURE 17 shows a similar suture ground in the presence of water which is found to have 3.8 frizzles per inch of picture shadow length.

Greater enlargement shows the improved surface characteristics of the water ground sutures, but a graphical representation or description is not practical.

Obviously the cant of the feed wheels, the speed of the feed wheels, and the rates of grind can vary over wide limits. Conveniently, the grinder can be adjusted to feed a 5 foot length in about 15 seconds as a maximum rate at which an operator can conveniently supply sutures to the machine.

Two or more grinders may be used in tandem if desired but usually a single grind is adequate to achieve the desired surface smoothness.

Other variations are obvious to those skilled in the art which modifications are within the scope of the present invention as defined in the following claims.

Having described certain embodiments thereof as our invention, we claim:

1. A method of grinding sutures which comprises: positively rapidly rotating a suture about its longitudinal axis and simultaneously positively advancing the suture along its longitudinal axis, passing the suture through a feed tube into a grinding zone, contacting diametrically opposed portions of the suture with two grinding wheels, the grinding surface of one of which is moving in the direction of advance along the longitudinal axis of the suture, and the grinding surface of the second of which is moving in the reverse direction, whereby the suture is ground by each in a slight spiral, predominately in the longitudinal direction of the suture, one grind being a right-hand helix, and the other a left-hand helix, whereby the criss-crossing of the grinding paths minimizes surface roughness.

2. A method of grinding sutures which comprises: positively rotating a suture about its longitudinal axis relative to grinding surfaces, and simultaneously positively advancing the suture along its longitudinal axis, passing the suture through a feed tube into a grinding zone, contacting diametrically opposed portions of the suture with two grinding surfaces, one of which is moving in the direction of advance along the longitudinal axis of the suture, and the second of which is moving in the reverse direction, whereby the suture is ground by each in a slight spiral, predominately in the longitudinal direction of the suture, one grind being a right-hand helix, and the other a left-hand helix, whereby the criss-crossing of the grinding paths minimizes surface roughness.

3. Apparatus for grinding sutures comprising: two opposed grinding wheels, the axes of rotation of which are parallel, and in a plane perpendicular to the longitudinal path of the suture being ground, means for rotating said grinding wheels, a suture feed tube, two suture contacting opposed canted feed wheels, means for rotating said feed wheels in the same direction, means for feeding a suture between said feed wheels, and in frictional contact with each, and means for positioning said feed wheels such that the points of suture contact are opposed and the direction of rolling along the suture describes a helical path with a large helix angle, giving a rapid rotation and a slow longitudinal feed to the suture.

4. Apparatus for grinding sutures comprising: two opposed grinding wheels, the axes of rotation of which are parallel, and in a plane perpendicular to the longitudinal path of the suture being ground, means for rotating said grinding wheels, means to micrometrically adjust the grinding gap between said grinding wheels, a suture feed tube, two suture contacting opposed canted feed wheels, means for rotating said feed wheels in the same direction, means for feeding a suture between said feed wheels, and in frictional contact with each, means for positioning said feed wheels such that the points of suture contact are opposed and the direction of rolling along the suture describes a helical path with a large helix angle, giving a rapid rotation and a slow longitudinal feed to the suture, and a ground suture receiving tube.

5. Apparatus for grinding sutures comprising: two opposed grinding wheels, the axes of rotation of which are parallel, and in a plane perpendicular to the longitudinal path of the suture, means for rotating said grinding wheels, means to micrometrically adjust the grinding gap between said grinding wheels, a suture feed tube to control the path of the suture between feed wheels and said grinding wheels, two suture-contacting, opposed, canted feed wheels, means for rotating said feed wheels in the same direction, means for feeding a suture between said feed wheels, and in frictional contact with each, means for positioning said feed wheels such that the points of suture contact are opposed and the direction of rolling along the suture describes a helical path with a large helix angle, giving a rapid rotation and a slow longitudinal feed to the suture, a ground suture receiving tube to conduct the suture away from the grinding wheels, and means for moving the feed tube, feed wheels and receiving tube together laterally relative to the grinding face of the grinding wheels.

6. Apparatus for grinding sutures comprising: a grinding stand, guide ways in said stand, two grinding wheel supports slidably mounted on said ways, an adjusting screw in said stand, the axis of which is parallel to said ways, right-hand and left-hand threads on opposite ends of said screw, cooperating threaded nut means engaging said threads controlling the position of said grinding wheel supports along said ways, spring loaded biasing means pressing against each of said grinding wheel supports whereby all lost motion is eliminated, a grinding wheel spindle mounted on each grinding wheel support, parallel to each other, and in a plane perpendicular to the longitudinal path of the suture, a grinding wheel mounted on each spindle, and means for rotating said grinding wheels in the same direction, said right-hand and left-hand threads having the effect of moving the grinding wheels equally with respect to a suture path therebetween; a suture feed tube to control the path of the suture between feed wheels and said grinding wheels; a support, a positionable frame on said support, two coaxial trunnion blocks on said frame, an axially and rotatably adjustable feed wheel support axle in each trunnion block, clamp means to lock the position of each said axle in each block, a feed wheel support block on each of said axles, a feed wheel shaft journaled in each of said blocks, a feed wheel for sutures mounted on each said shaft, a resilient rim on each said feed wheel, each said feed wheel having its suture contacting diameter in line with the axis of said trunnion blocks, a pulley on each feed wheel shaft, a driving pulley, means to rotate said driving pulley, a drive belt over said

driving pulley and each driven pulley, and a suture transfer tube the axis of which intersects the axis of said trunnion blocks midway between said feed wheels; said feed wheels being canted to a slight angle with the line of the suture supply, whereby the suture is rotated rapidly and advanced axially slowly by the action of said feed wheels; a suture conveying system for supplying sutures to said feed wheels comprising an unsymmetrical T of small diameter tubing, in which the stem joins the cross-tube close to one end of the cross-tube through which the suture passes, the internal diameter of said tubing being larger than the largest suture to be fed, and suction means connected to the stem of the T, whereby air drawn through the longer part of the cross-tube has more frictional area and effect on the suture therein than air drawn through the shorter part of the cross-tube, thereby conveying the suture in the direction of the longer to the shorter part of said cross-tube, and simultaneously freely supporting the suture so that it may be readily rotated; a ground suture receiving tube to conduct the suture away from the grinding wheels, and means for moving the feed tube, feed wheels and receiving tube as a unit laterally relative to the grinding face of the grinding wheels.

7. The apparatus of claim 6 in which: each grinding wheel support has dressing tool guide means parallel to the axis of the spindle therein, a dressing tool detachably slidable in said means comprising a grinding wheel dressing element, and means for adjusting the radial position of said dressing element with respect to the grinding wheel when said dressing tool is positioned in said dressing tool guide means.

8. Apparatus for grinding sutures comprising: a grinding stand, guide ways in said stand, two grinding wheel supports slidably mounted on said ways, an adjusting screw in said stand, the axis of which is parallel to said ways, right-hand and left-hand threads on opposite ends of said screw, cooperating threaded nut means engaging said threads controlling the position of said grinding wheel supports along said ways, spring loaded biasing means pressing against each of said grinding wheel supports whereby all lost motion is eliminated, a grinding wheel spindle mounted on each grinding wheel support, parallel to each other, a grinding wheel mounted on each spindle, and means for rotating said grinding wheels in the same direction; said right-hand and left-hand threads having the effect of moving the grinding wheels equally with respect to a suture path therebetween.

9. The apparatus of claim 8 in which each grinding wheel support has dressing tool guide means parallel to the axis of the spindle therein, a dressing tool detachably slidable in said means comprising a grinding wheel dressing element, and means for adjusting the radial position of said dressing element with respect to the grinding wheel when said dressing tool is positioned in said dressing tool guide means.

10. A suture feed apparatus comprising: a support, a positionable frame on said support, two coaxial trunnion blocks on said frame, an axially and rotatably adjustable feed wheel support axle in each trunnion block, clamp means to lock the position of each said axle in each said block, a feed wheel support block on each of said axles, a feed wheel shaft journaled in each said block, a feed wheel for sutures mounted on each said shaft, said feed wheel having its suture contacting diameter in line with the axis of said trunnion blocks, a drive pulley on each feed wheel shaft, a driving pulley, means to rotate said driving pulley, a drive belt over said driving pulley and each drive pulley, and a suture transfer tube the axis of which intersects the axis of said trunnion blocks midway between said feed wheels; said feed wheels being canted to a slight angle with the line of the suture supply, whereby the suture is rotated rapidly and advanced axially slowly by the action of said feed wheels.

11. A suture feed apparatus comprising: two feed wheels, power drive means to rotate said two feed wheels at the same speed in the same direction, a resilient rim on each wheel, means to support said feed wheels, each in contact with a suture, on opposite sides of the suture at the point of contact, so that a point on the axis of each feed wheel, a point on the axis of the suture, and the point of contact between the suture and each feed wheel are on a common straight line, each wheel slightly canted, in opposite directions, so that the direction of rolling along the suture describes a helical path with a large helix angle, giving a rapid rotation and a slow longitudinal feed to said suture, and a suture transfer tube the axis of which directs a suture towards the points of contact with said feed wheels, and a suture supply means to feed a suture through the suture transfer tube to the feed wheels.

12. The apparatus of claim 8 in which: the grinding wheels are porous and have an interior recess with a flange on each side thereof forming a channel in which a coolant is held by centrifugal force and which coolant flows through the porous wheels under the influence of centrifugal force to concurrently wash away ground material from the surface of the wheel.

13. A method of grinding sutures which comprises: positively rapidly rotating a suture about its longitudinal axis, and simultaneously positively advancing the suture along its longitudinal axis, passing the suture through a feed tube into a grinding zone, contacting diametrically opposed portions of the suture with two grinding wheels, the grinding surface of one of which is moving in the direction of advance along the longitudinal axis of the suture, and the grinding surface of the second of which is moving in the reverse direction, whereby the suture is ground by each in a slight spiral, predominately in the longitudinal direction of the suture, one grind being a right-hand helix, and the other a left-hand helix, whereby the criss-crossing of the grinding paths minimizes surface roughness; and spraying water against the grinding surface of the grinding wheels, while blowing water off of the suture adjacent to the grinding zone.

14. The apparatus of claim 3, comprising means to spray water on the grinding surfaces of the grinding wheels, and means to blow water off of the suture being ground both before and after the grinding zone.

15. A suture conveyor tube for a suture grinding machine comprising: an unsymmetrical T of small diameter tubing, in which the tube which is the stem of the T joins a long cross-tube which is the head of the T close to one end of the cross-tube through which the suture passes, thus dividing the cross-tube into a longer part and a shorter part, the internal diameter of said tubing being larger than the largest suture to be fed, and suction means connected to the stem of the T; whereby air drawn through the longer part of the cross-tube has more frictional area and effect on the suture therein than air drawn through the shorter part of the cross-tube, thereby conveying the suture in the direction of the longer to the shorter part of said cross-tube, and simultaneously freely supporting the suture so that it may be readily rotated.

16. A method of grinding sutures which comprises: positively rapidly rotating a suture about its longitudinal axis, and simultaneously positively advancing the suture along its longitudinal axis, passing the suture through a feed tube into a grinding zone, contacting diametrically opposed portions of the suture with two grinding surfaces, whereby the suture is ground to size as the contacts of the diametrically opposed portions of the suture with the two grinding surfaces follow a controlled spiral, and spraying water against the grinding surfaces while blowing water off of the suture adjacent to the grinding zone.

17. A method of grinding sutures which comprises: coloring the surface of the suture with a fluorescent color, positively rapidly rotating the suture about its longitudinal

axis and simultaneously positively advancing the suture along its longitudinal axis, passing the suture through a feed tube into a grinding zone, contacting diametrically opposed portions of the suture with two grinding surfaces, whereby the suture is ground to size as the contacts of the diametrically opposed portions of the suture with the two grinding surfaces follow a controlled spiral, and after grinding inspecting for fluorescent areas indicative of unground areas, which might otherwise be a zone of weakness.

References Cited in the file of this patent

UNITED STATES PATENTS

223,722	Erk	Jan. 20, 1880
2,355,907	Cox	Aug. 15, 1944
2,794,304	Frankiewicz et al.	June 4, 1957