Review Article
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The Bone Screw : An industrious implant

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Abstract

Objective: A bone screw is used for internal fixation more often any other implants. Thread of a screw is its most important part. It is akin to a long inclined plane or a wedge that gives it the power to convert an applied small torque to a large internal tensions along its axis to compress to surfaces together. Popular buttress thread has many drawbacks which are over come in a new design 'Bone-Screw-Fastener'. It is also superior to conventional locking screw as it offers comparable stability and also generates compression at plate bone interface. Lagging is a technique that can be applied to virtually all types of screws to produce compression across the bone surfaces; exact technique and positioning of the screw in the center of the fracture fragment and at right angles to the fracture plane is mandatory for optimum results. Both bolt and screw are threaded fasteners with similar functions but different in detail.

Keywords: Bone-screw-fastner, Simple machine, Screw thread, Lag screw, Bolt, bone screw.

Introduction

A screw is like a simple machine that converts a small applied torque into a large internal tension along its axis while producing compression between the two surfaces being held together.

A screw is a simple machine that converts a small applied torque into a large internal tension along its axis while producing compression between the two surfaces being held together. The simple machines as described by Renaissance scientists are simplest mechanisms that use leverage

or mechanical advantage to multiply force. These six simple machines are illustrated (Fig. 1).

The Thread

A screw thread can be visualized as a long inclined plane or a wedge encircling core (root) (Fig. 2). A standard orthopaedic screw has a single thread. A screw may, however, have two or more sets of threads; although a double-thread screw advances twice as fast as a single-thread screw, the former consumes more torsional energy than the latter to produce the same amount of compression and is deemed inefficient.

Thread Design

The screw thread may be of a “‘V”’ or a buttress profile (Fig. 2). A “‘V”’ thread has a slanted profile on both sides. A locking screw has a “‘V”’ design and is symmetrical, shallower, and coarser (wider base) than a conventional screw. The screw does not produce compression, mainly resists shear loads. Its symmetrical thread is best suited in both cortical and cancellous bones. A buttress thread widens at its base to form a buttress that resists bending of the thread under load. The rounded corners at the junction of the base of the thread and the screw shaft reduce the stress concentrators that are associated with sharp corners. A buttress thread is slanted 45° only on the leading edge; the trailing edge is perpendicular or inclined up to 5–7° and faces the screw head. This thread transfers forces between the bone and the screw at right angles to the direction of the applied force. In principle, “‘V”’ and buttress threads should have the same pull-out strength if each has identical outer diameter. This is disputed on the grounds that a “‘V”’ thread produces compression and shear forces at the bone–-thread junction, whereas a buttress thread mainly produces compressional forces. Shear forces promote bone resorption and result in lessened pull-out strength. It has been argued that a buttress thread is less likely to loosen because it produces very little shear component and offers greater pull-out strength in the long run. The buttress thread resists high axial thrust in one direction and has strong shear strength and powerful unidirectional

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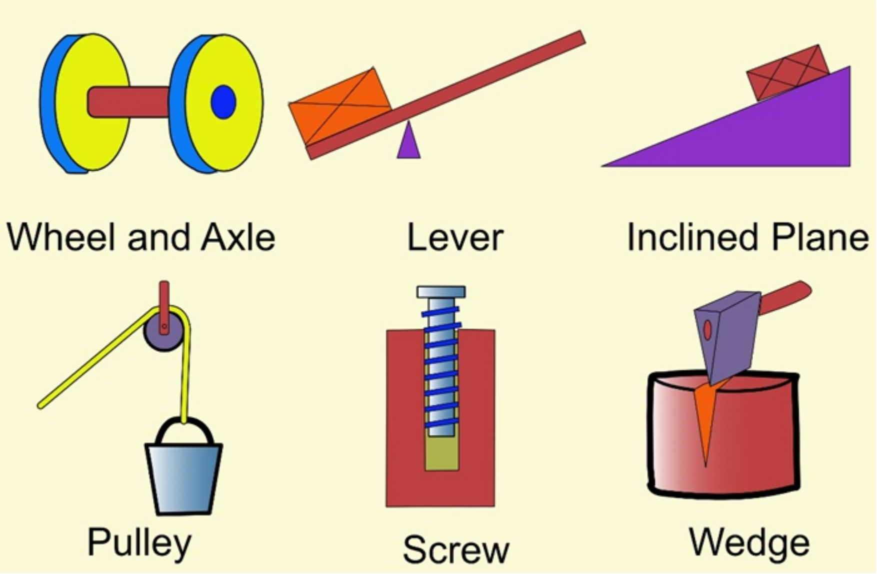

Figure 1: Simple machines. Six simple machines that form basics of more complex machines are wheel and axle, lever, inclined plane, pulley, screw, and wedge.

pull-out resistance; however, it is weak in resisting multidirectional forces and may come loose.

There are other issues with the buttress thread design: The cutting mechanism is imprecise, forms coarse threads, and causes microfractures. As a thread is cut, bone debris is pushed back along the pilot hole, collects along the thread teeth, creates friction, generates heat, and requires higher torque, making its insertion an arduous task (Fig. 3).

It is tough to initiate the insertion of such a screw; one may miss the far cortex hole; deviation from the track may damage the near cortex hole. Over-tightening may strip off the bone threads. Buttress threads also induce hoop stress that may create a stress riser and break the adjacent bone bridge.

“‘Standard buttress screws remain at a significant risk of failure when exposed to multidirectional loading forces”’ [2]. The thread on the locking screw is shallower than that on a conventional screw; unlike a conventional screw, it resists only pull-out forces and does not produce or maintain compression between the plate and the bone. In a conventional plate-screw construct, the force along the long axis of the screw is in the order of magnitude of several hundred kilograms. In a locking internal fixation plate (LIFP), the locked screws produce only a few kilograms of static pre-load; this is so because the steep conical connection of the screw-to-screw hole locks upon minimal axial tension. Besides, the core diameter of the screw is bigger to resist the increased bending moment and higher shear force.

Bone-screw-fastener (BSF) [4]. a new screw design is superior to the conventional buttress thread. BSF preserves bone. The details of the BSF thread are shown in Fig. 2 f and g. Its thread-cutting mechanism carves accurate “‘female thread”’ in the bone. The bone chips are pushed ahead of the advancing screw tip by the left-handed flutes on a right-handed screw, finally clearing out of the far cortex pilot hole (Fig. 3 b). The screw thread-bone interface is free of bone chips and the screw threads have a healthier grip on the bone face. The details of the BSF thread are shown in Fig. 3 d and e. The BSF thread retains greater bone and has larger tooth volume. The thread can be modified to suit differing bone quality, various anatomical sites, and diverse

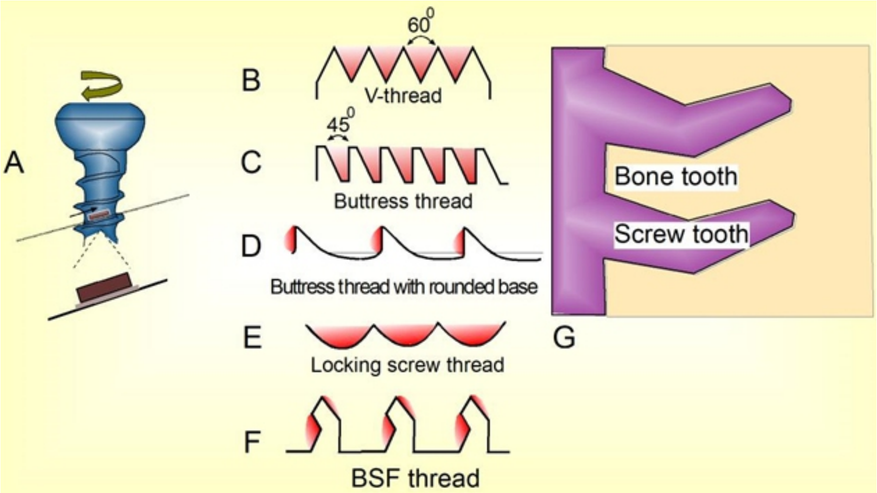

Figure 2: Variety of screw threads. (a) A screw thread may be compared to an inclined plane on which a block of material is moving along its surface. The inclined plane, being a simple machine, converts the torque to a force which moves the block upward and along the surface. This moving force generates tension in the screw and the consequent compression that the screw applies to the fracture surface [1]. (b) “V” thread. (c) Schematic buttress thread [2]. (d) Buttress thread with rounded base [2]. The form is superior to any other when the screw is expected to develop compression. (e) Thread profile of a locking screw that is symmetrical, shallower, and coarser (wider base) than that of a conventional screw. The screw does not produce compression and mainly resists shear loads. The symmetrical thread is best suited in both cortical and cancellous bones. Shaded areas represent the width of bone engaged in the screw threads. (f) Profile of bone-screw-fastener (BSF) screw. (g) Cross-section of BSF thread configuration. The screw tooth is angled for improved fixation and the bone tooth is larger and stronger than prevalent screws.

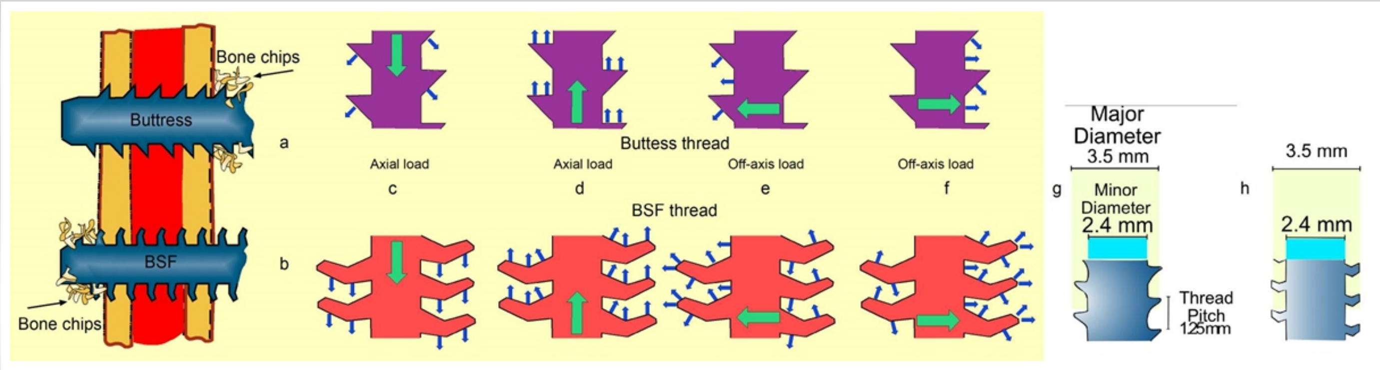

Figure 3: Bone-screw-fastener (a) in a conventional buttress thread screw, the bone chips are pushed back along the pilot hole and collected along the teeth. (b) The flute of a bone-screw-fastener (BSF) screw pushes the bone chips in its front and out of the far cortex. Cross-sections of the new BSF thread configuration and conventional buttress thread with comparable points of different load vectors on the threads resulting from an axial loading force (c and d) and from an off-axis loading force (e and f) [3]. Schema of conventional buttress thread and BSF. (g and h) Buttress thread has two thread faces while BSF has multiple faces. Buttress thread screw has three right-handed cutting flutes, whereas the BSF has two left-handed cutting flutes. Both screw types have a positive rake angle and right-handed threads.

physiological conditions. The BSF threads distribute axial loads to multiple thread faces and the multiaxial loads are disseminated more efficiently than the conventional buttress threads. In laboratory testing, the 3.5- mm BSF showed increased resistance to torque failure compared with the standard 3.5-mm AO buttress screw [5]. Biomechanical comparison of BSF and locked screw in plating a female geriatric bone shows that BSF offers similar stability as a conventional locking screw. However, BSF is superior to locking screw as it can generate compression at the plate bone interface. BSF may be use used in non-locking and locking mode in optimizing screw purchase in short fracture segments and poor-quality bone [6].

BSF is available as self-tapping (ST) and non–-STself-tapping (NST) implant in sizes of 3.5-mm cortex screw and 4.0-mm cancellous screw to be used with stainless steel conventional and locking plates. It may be used as a lag screw, as a positioning screw, or with bone plates. Insertion and removal technique is similar to that of conventional screws. BSF has been approved for fixation of fractures, osteotomies and non-unions of the clavicle, scapula, olecranon, humerus, radius, ulna, pelvis, tibia, calcaneus, femur, and fibula in adults and in both children (2–12 years) and adolescents (12–21 years) in whom growth plates have fused or in whom growth plates will not be crossed by screw fixation.

Whatever type of screw is used, the first action in screw insertion is drilling a pilot hole. A special drill bit has been invented for use with BSF for higher efficiency. Helix angle of a drill bit controls the rate of advance of the drill through the bone. This special drill bit has a larger helix angle than commonly used drill bit. It also has more turns per unit length than the commonly used drill bit, a feature that helps in quick clearance of debris from the flutes and thus reduces axial

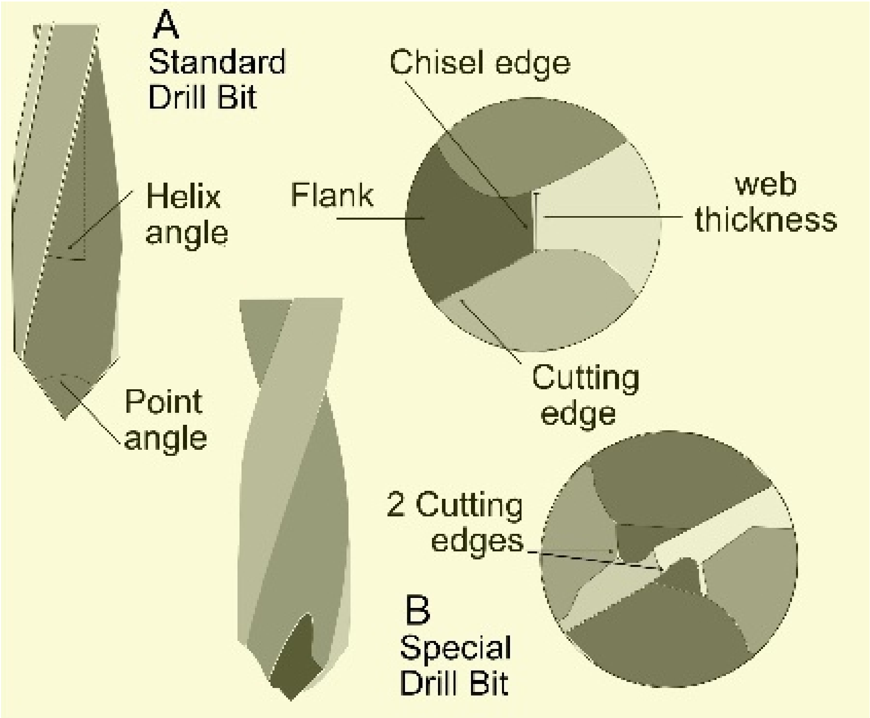

Figure 4: Drill bit tip. Simplified representation of features of (a) standard drill bit and (b) special drill bit. The special drill bit has a larger helix angle and point angle; its tip has a notched web thinning, a feature that reduces the length of chisel edge [7].

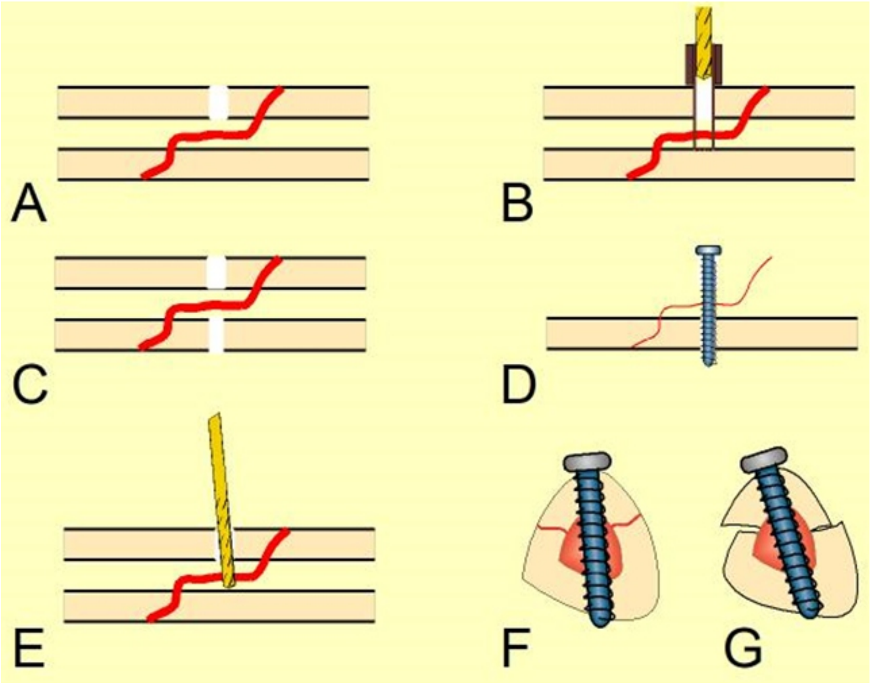

Figure 5: 32 steps of lag screw insertion (a) 4.5-mm drill hole is made in proximal cortex. (b). A sleeve of 3.2-mm inside diameter is inserted in the hole. A 3.2 mm drill bit is used to drill the distal cortex. (c) The two holes are coaxial. (d) A 4.5-mm screw is passed. It has no hold on the proximal cortex and optimum hold on the distal cortex. It draws the distal cortex toward the proximal one and compresses the fracture line. This is the correct technique for inserting a lag screw. (e) If the drill is passed without the centering sleeve, there is a possibility of oblique drilling. (f) Fracture accurately compressed when coaxial drilling was achieved. (g) Fracture displaced when eccentric drilling happened.

force, torque, and heat production during drilling. This special drill bit also has a larger point angle, which is the angle between the two cutting lips in the sagittal plane. Large point angle ensures better contact between the bone and cutting edges. The drill tip has been modified; it has a notch in the web thickness that reduces the chisel edge of the tip. This modification decreases the axial force needed during drilling and ensures the precision of hole diameter. (Fig. 4).

The Lag Screw

The lag screw is a technique of insertion and not a screw. It is the most effective way to achieve compression between two bone fragments; it pulls the fragments together producing friction across the fracture lines. It achieves this by gaining purchase on the distal fragment while being able to turn freely in the proximal. If the screw threads engage both cortices, the fragments remain apart like two nuts on the same bolt; no compression is generated and the fracture gap remains open and uncompressed.

Lag screw practice
A lag screw must glide freely through the near fragment and engage only the far fragment.
■ Whenever a screw crosses a fracture line, it should be inserted as a lag screw
■ Two small screws produce a more stable fixation than one large screw.

Lagging is an excellent technique with any screw because the threads in the proximal cortex do little to improve the purchase and tend to hold fracture fragments apart. Compression between fragments increases the friction force so that interfragmentary motion is less likely and therefore strengthens the structure. Additional stability between the two bone fragments is created by interlocking of the bone surfaces, hence the need for accurate reduction.

The lagging technique can be applied to virtually all types of screws. In diaphyseal fractures, a cortical screw is applied as a lag screw. As the screw is threaded over its entire length, it can act as a lag screw only if it passes freely through the near cortex. A “‘gliding hole”’ is drilled through the near cortex with a drill bit equal to or larger than the outside diameter of the screw thread. The distal hole is precisely tapped. The screw thus has no hold on the near cortex but has a firm purchase on the far cortex. Alternatively, a cortical shaft screw may be used.

Insertion of a lag screw starts with drilling gliding hole, e.g., 4.5 mm in the near cortex (Fig. 5). Next, a sleeve with inner diameter of 3.2 mm is inserted in the gliding hole. Then, a 3.2- mm drill bit is used to drill a pilot hole in the far cortex; the hole made in this manner will always be coaxial, correctly aligned, and in the centre center of the larger hole. When lag screw is passed, the fracture will not displace.

The compression produced by a lag screw is not consistent across the fracture line; it is greatest near the screw and reduces over a distance. The holding strength of a lag screw increases as the distance from the fracture line at far cortex to the screw shaft increases; lag screw grip is strongest

when the distance from the fracture line at far cortex to the screw is longest. Thus, in the position shown in Fig. 6 a and b, it is the weakest, and, in the position, shown in Fig. 6 c and d, it is the strongest [1].

To effect maximal interfragmental compression, lag screws must be inserted into the centre center of the fragment and at right angles to the fracture plane (Fig. 7). A single lag screw is insufficient to achieve stable fixation of diaphyseal fragments. Two screws distribute the interfragmental compression uniformly over the fracture interface and restrain rotation of the fragments around the screw axis (Fig. 7). At least two, and preferably three, screws are required.

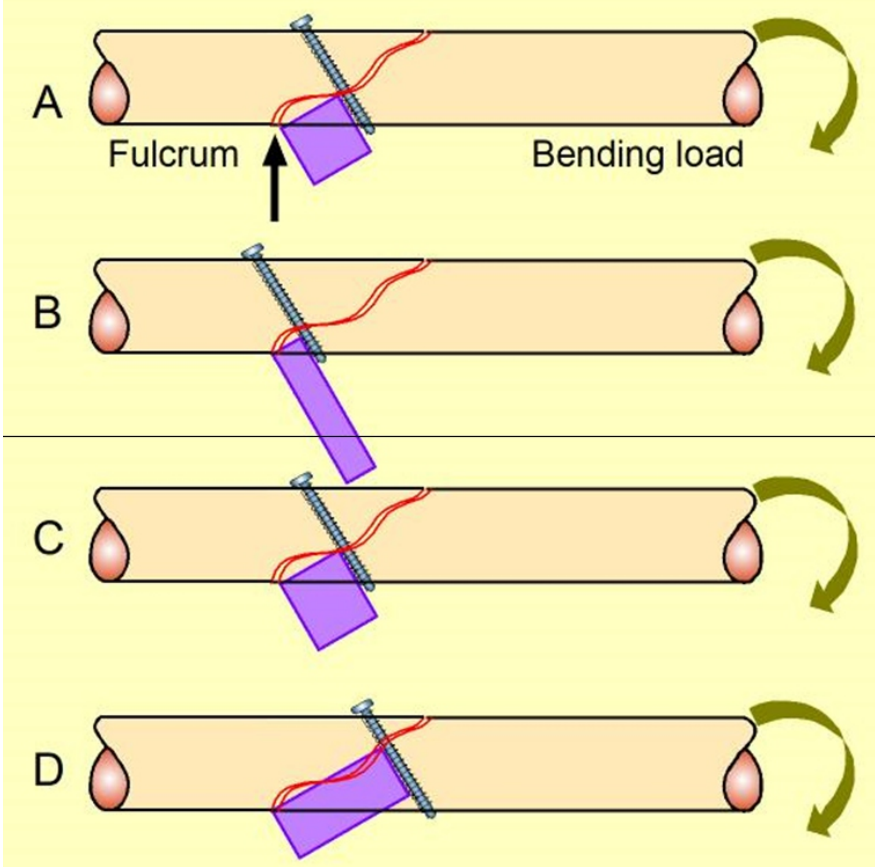

Figure 6: Effect of screw position on the holding strength of a lag screw [1]. (a) The fulcrum, the point around which the bone may rotate when bending load is applied, is at the junction of fracture line and far cortex. The width of the violet box represents the degree of holding power of the lag screw. (b) The lag screw is very close to fulcrum and width of the violet box is reduced. In this position, the lag screw's holding power is minimum. (c) The screw is in mid-cortex location. The holding power represented by the violet box is more than that in the previous position. (d) The screw is placed close to fracture line at near cortex. The violet box is now at its widest; lag screw placed in this location will have the strongest holding power.

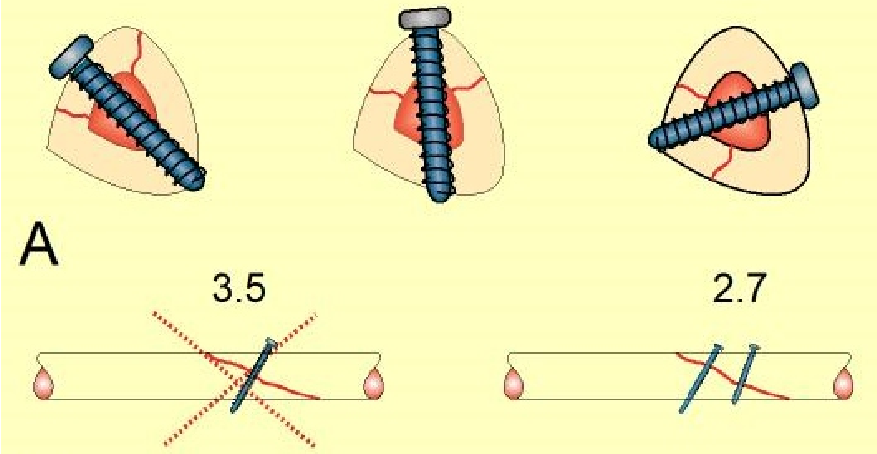

Figure 7: (a) A lag screw should be inserted into the center of the fragment and at right angles to the fracture plane. (b) Two small screws produce more stable fixation than one large screw [8].

Screw Versus Bolt

A screw is an externally threaded headed fastener which is tightened by applying torque to the head, causing it to be threaded into the material it will hold. A bolt is also an externally threaded headed fastener, which is used in conjunction with an internally threaded nut and is tightened or released only by twisting the nut (Fig. 8).

A further clarification aimed at disambiguation is as follows: A bolt is the male part of fastener system designed to be accepted by a pre-equipped nut of exactly the same thread design; it needs access from or exposure to the far side of the bone being fixed; occasionally, a washer is used to evenly distribute the compression load [9]. To obtain reliable and repeatable fastener torque, the bolt/nut combination should always be tightened by holding the bolt head stationary and turning the nut [10]. Cancellous and cortical screws are unsuitable to be used as bolts; a specific implant is mandatory.

Screws are headed, externally threaded fasteners that do not meet the above-stated definition of bolts. Only one instrument, a screw driver is required to insert / remove it. A screw is designed to cut its own thread; it has no need for access from or exposure to the opposite side of the component being fastened to. In simplest terms, a screw is “‘screwed into’ into” a bone, while a bolt “‘bolts bone fragments”’ together. A screw fastens directly in to the bone surface while a bolt requires a nut (and often a washer) on the far cortex to fasten the bone fragments.

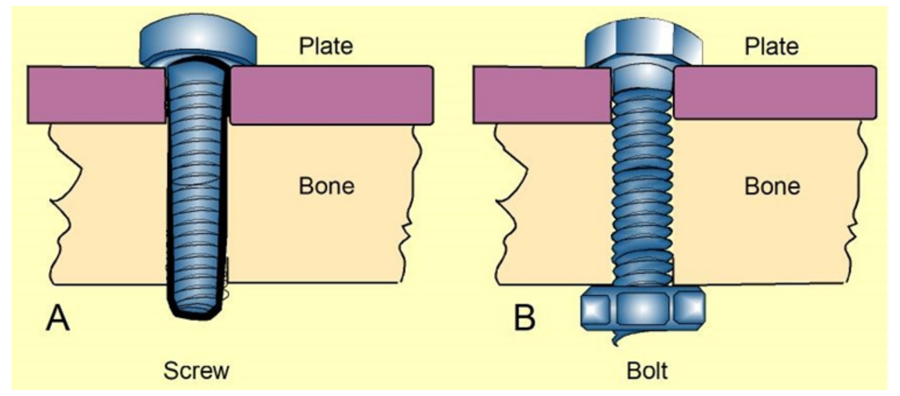

Figure 8: Both bolt and screw are threaded fasteners with similar functions but different in detail: (a) screw; (b) bolt.

Conclusion

Bone screw is a simple machine that has components with intricate design and function. Its best functional output is achieved only by following exact application technique.

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