History of the Orthopedic Screw

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Few inventions compare with the wheel—an elegant, simple device that has had a profound effect on human development. Perhaps worthy of comparison, the screw is a machine of simplicity and near-universal application; however, for all of its uses and ubiquity, few appreciate the story behind the screw’s evolution.

Considered the father of the screw, Archimedes of Syracuse is widely regarded as having invented the screw in the third century BCE. His published treatises on geometry were a mathematical milestone. However, beyond mathematical theory, Archimedes’ discovery had a remarkable application. His water screw consisted of a long wooden pole that was 2 to 3 meters in length; this core supported a continuous double or triple helical thread of wood strips that were sealed with pitch resin. Wooden planks placed lengthwise around its circumference completed the tubular construct, which could rotate as a single piece. With 1 end submerged in low-lying water reservoirs, water screws provided a pulsatile lift of water, a process famously responsible for providing irrigation to the Greek city of Alexandria. Some surviving representations of the water screw depict an individual treader balanced atop the cylinder and running in place to spin the massive helix.

Recently, similar designs of water screws have been proposed by archeologists to have existed in Mesopotamia as early as the seventh century BCE. These cast bronze water screws are thought to have had a rotating helix mechanism, which turned by hand crank within a stationary tube (Figure 1). Purportedly, they helped irrigate the Hanging Gardens of Babylon—one of the Seven Wonders of the Ancient World. Although the true origins of the water screw are disputed, it is clear that the first application of the screw was for irrigation. Amazingly, over a millennium would pass before the screw was used for its more familiar purpose: a fastener.

In the 15th century, shoulder-supported firearms such as Harquebuses were common among soldiers of Europe and Asia. These light, muzzle-loaded weapons contained matchlocks, which allowed for superior accuracy because operators no longer had to relinquish a hand to light the chamber. However,
repeated firing of the weapon would quickly loosen the small nails used to fasten matchlocks to the stocks. Small screws were substituted for their superior holding power. However, despite their clear advantages, the complexities and high costs associated with producing screws made them an impractical option for most types of fixation. It was not until the 19th century that screws would be manufactured in industrial quantities and made available for everyday purposes.

By the late 18th century, European and American craftsmen had developed and patented effective screw-cutting lathes (Figure 2). The inventions created a rapid increase in threaded fasteners, and with the introduction of standardized thread forms, a highly mechanized industry evolved in which millions of screws were produced per year by the mid-19th century. Accompanying the evolution of standardized forms, self-tapping screws with gimlet points were introduced in 1832, eliminating the need for pilot holes. Similar revolutions occurred with the development of new alloys and drives, and with the development of the turret lathe in 1840, diminishing production costs established the ubiquity of screws.

**History of the Orthopedic Screw**

The 19th century saw similar revolutions in the field of orthopedic surgery. In 1850, French surgeons Cucel and Rigaud performed the first internal fixation procedure by reducing an olecranon fracture with 2 transcutaneous screws fastened by string. Perhaps more famously, German surgeon Carl Hansmann performed the first internal plate fixation using a removable steel plate and nickel-plated screws in 1886. Hansmann’s screws were pre-welded to his screwdrivers, and the driver handles remained attached to the plate and protruded through the skin upon fixation. After 6 to 8 weeks, the entire construct was removed—often a necessary second procedure given the lack of aseptic technique and the impurities inherent to 19th century metallurgy.

By 1912, William O. Sherman, surgeon to the Carnegie Steel Company, published recommendations on the most effective properties of orthopedic screws. Among his many recommendations—which concerned everything from alloy composition to the width of drive heads—Sherman advocated self-tapping, fully threaded vanadium machine screws instead of the customary tapered soft-steel screws that were intended for use in carpentry. In addition, Sherman produced his own plate design, which remained the international gold standard for 50 years until the advent of the AO screw.

Despite significant advances in the principles of fixation and the development of devices such as Sherman’s plates, orthopedic screws remained relatively indistinct from their metal- and wood-working counterparts. However, by the 1940s, many surgeons were advocating for the development of screws adapted specifically to human bone. Most famously, Belgian surgeon Robert Danis proposed 3 key screw design features tailored specifically to bone: a ratio of exterior diameter to core diameter of 3:2, not 4:3 as is typical of metal screws; a reduction of thread surface area to one-sixth that of metal screws because bone is approximately one-sixth the strength of metal; and a buttress thread design to replace standard V-shaped threads because buttress threads had greater holding power.

With retooled screws and the addition of compression plates (another of his creations), Danis was able to achieve precise anatomical fracture reductions with rigid fixation. This allowed for both early mobilization of the patient and primary bone healing (Haversian remodeling) that characteristically lacked external callus formation. So impressive were the results that Swiss surgeon Maurice Müller, himself one of Danis’ students, assembled a team of fellow Swiss surgeons to study the process of bone healing and the influence of rigid fixation on fractures. Meeting first in Chur, Switzerland, in 1958, they called themselves Arbeitsgemeinschaft für Osteosynthesefragen (AO)—German for the Association for the Study of Internal Fixation. “The AO was soon joined by additional surgeons, manufacturers, and metallurgists. The influential group would subsequently develop the lag screw, tension band wires, articulated tensioning devices, powered equipment, and specialized instruments for implant insertion. In the same year as the AO’s founding, George Bagby and Joseph Janes, surgeons at the Mayo Clinic in Rochester, Minnesota, published their design of a new “impacting” bone plate. The American plate, which had a lower profile than many of its European counterparts, bore unique oval-shaped holes that allowed eccentrically placed screws to provide intrafragmentary compression upon tightening. Their design, with relatively little modification, remains in use today.

Subsequently, research and innovation continued to change the course of the orthopedic screw. From the introduction of stainless steel in 1926 to the testing of titanium alloys in the...
1970s, screw strength and biological inertness improved to a point at which metal composition was no longer a significant factor for potential screw pullout. Likewise, the introduction of Phillips and Woodrugg screw heads made slippage at the driver–head interface a rare event. Over the following decades, screw composition, thread count, shape, pitch, and diameter continually advanced with designs optimized for a variety of bone types, qualities, and pathologies.

**ROLE IN MODERN ORTHOPEDIC SURGERY**

Similarly to general orthopedics, research in spine surgery is currently exploring the biomechanics of screws. Central study questions concern the role of techniques, such as tapping vs non-tapping, and the biomechanical qualities of screw features, such as cannulation, thread depth, pitch, and single- vs double-lead threads.

In 1996, Chapman et al. explored how factors such as screw thread geometry, tapping, and cannulation affected the holding power of screws in cancellous bone. Using polyurethane models, they demonstrated that tapping a hole prior to screw insertion reduced the maximum pullout strength by 8%. Tapping of a porous material results in removal of excess supportive material, thus reducing the area of its interface with the screw threads. In addition, increasing the thread shape factor (the ratio of thread depth to pitch) increases the pullout strengths. Therefore, cannulated screws, which have a relatively low thread shape factor to accommodate the central bore, have weaker pullout strength than noncannulated screws.

In a similar study, the pullout strength of double-lead or fast drive screws was compared with that of single-lead screws. Using cadaveric thoracolumbar and lumbar vertebrae, Jacob et al. were unable to find a significant difference between the pullout strengths of either lead type, despite the double-lead screw having a faster insertion time.

As our understanding of biomechanics, medicine, and material science continues to evolve, so too will the role of the screw in orthopedics. From Archimedes’ water screw to matchlock fastening and from Hansmann’s fortuitous fixation to dual-lead titanium pedicle screws, innovation continues to drive the screw’s progression, one revolution after another.

**REFERENCES**