Screw Fixation Review

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HISTORY

Historical reports show that screw design originates from as early as the 7th century BC. At that time, the original design was created to alleviate the process of watering the hanging gardens of Babylon. Since that era, further reports have surfaced, citing Archimedes of Syracuse as the "Father of the Screw." Using the design for removal of bilge water from large ships, and eventually used for the aqueduct system, he was the first individual credited with the creation in the 3rd century BC. Since that time, the screw has undergone a multitude of innovations and uses. In 1850, Drs. Cucel and Riguad, two French surgeons, were credited with the first performed case of internal screw fixation. Several decades later, Dr. Hansmann, a German surgeon, performed the first reported case of internal screw and plate fixation. Then, in 1912, an American surgeon by the name of Dr. Sherman published a series of recommendations on the most effective properties of screws. Dr. Danis, in 1949, furthered those principles, proposing 3 key screw design features specific to bone. He proposed altering the ratio from the exterior screw diameter to core diameter from 4:3 in industry metal screws to 3:2 in orthopedic screws. Additionally, he proposed a reduction of the thread surface area to 1/6 that of metal screws, based on the notion that bone strength is roughly 1/6 of the strength of metal. And lastly, he proposed a change from the classic industrial V-shaped thread design to buttress threads, based on the postulated increased pull-out resistance of buttress threads (1). From those initial innovations and guidelines, we have developed the multitude of screws in use today.

SOLID CORE VERSUS CANNULATED

Solid core screws, noted for their reduced costs and greater thread purchase, are often compared to their cannulated counterparts, which are well known for their ease of use and greater reproducibility. A multitude of studies have compared their key characteristics. When directly comparing their pullout strength, as done so by Leggon et al in 1993, the data suggested that there was no significant difference, and screw selection should not be based on the grounds of pull-out strength (2). Utilizing canine femurs, they compared 3.5 solid core and cannulated screws, as well as 6.5 solid core and 7.0 cannulated screws. Solid core screws were inserted into one limb, in both cortical bone and cancellous bone, while the comparative cannulated screw was placed in the contralateral limb. As one may expect, the study did demonstrate that in cancellous bone, large-fragment screws required more force to pullout than did small-fragment screws. Additionally, small-fragment screws did show a greater mean force to pull out in cortical bone than cancellous bone. Differences in screw design did demonstrate greater cross-sectional areas available for solid core screws as compared to cannulated screws, but that did not lead to significant differences in pull-out strength (2).

Furthering the comparison, Merk et al did a fatigue life analysis of small-fragment screws in 2001 (3). Comparing a variety of different fixation companies, screw sizes, and screw materials of small-fragment screws, they demonstrated no significant difference in fatigue between solid core and cannulated screws. Results indicated that among cortical screws, the cannulated and solid core Synthes screws did not statistically differ from the solid core Zimmer screws. Smith and Nephew cortical screws failed at statistically fewer cycles than the Synthes solid core and cannulated cortical screws, but did not differ from the Zimmer screws. The analysis supports the notion of core screw diameter as the principle factor determining fatigue life. Small increases in core diameter will lead to exponential increases in bending and fatigue strength. While the larger diameter improves bending and fatigue strength, it may decrease pull-out strength secondary to a decrease in purchase. Overall, cannulated screws performed well when compared with solid core screws, thereby supporting their use as a viable fixation option (3).

When Gardner et al recently compared the 2 varieties of screws, they selected 18 synthetic femur necks to allow them to compare the load to failure and displacement (4). They compared solid core and cannulated screw, utilizing 6.5 mm solid core and cancellous screws, as well as 7.3 mm cannulated screws. There was a statistically significant difference in load to failure, with the solid core screws demonstrating superiority to the cannulated screws. This was believed to be due to the greater cross-sectional area for bone purchase in non-cannulated screws and the self-drilling design of the cannulated screws. This difference was further exemplified with the higher compressive strength of the test models when a solid core screw was utilized over a cannulated screw (4).

STAINLESS STEEL VERSUS TITANIUM

Stainless steel screws have been around since the 1920s and are well known for their cost effectiveness and variety of strength levels, from plates and screws to Kirschner wires and cerclage wire. Historically, it is the most common material for orthopedic implants (5). Titanium, a relatively newer material, has been around since the 1960s, with titanium alloys being tested in the 1970s (1). It is known for its lower allergenicity and lower weight. To reach similar strength levels of stainless steel, commercially pure titanium is produced in 4 grades with differing chemical purities, as well as alpha-beta titanium alloys (5).

While relatively few articles directly compare the 2 varieties of screws, several comparisons can still be made to allow the surgeon further insight. With a direct comparison of stainless steel and commercially pure titanium screws of varying sizes, there is a similar maximum tensile load to failure. Of note however, there is an increase in the tensile load as core diameter increases, with a doubling of strength when increasing from a 1.9 core diameter to a 2.4 core diameter (5). This further supports the study previously published by Merk et al in 2001 (3).

When comparing the torque resistance of 4.5 mm cortical screws, the strength of titanium does lag behind that of stainless steel. The difference is noted for the torque angle at failure, and it has been shown to be a direct result of the limited ductility of titanium. Regardless of the difference, both do still perform above the minimum set industry standards for orthopedic implants (5).

Touching back upon the Merk et al study, commercially pure titanium and stainless steel cancellous screws produced by Synthes performed similarly in fatigue life analysis despite their difference in material properties. As a material, stainless steel is superior to grade IV commercially pure titanium in fatigue strength, but the titanium screw is aided by the 0.1 mm increase in core diameter and surface treatment (3).

In regard to local resistance to infection in vivo, a study by Arens et al compares the rate of infection in animal models after direct injection of *staphylococcus aureus*. Implants of titanium, in general, demonstrated a better resistance to local infection than those made of stainless steel. A common belief is that this may be associated with the degree of fretting and the difference in degradation products. The difference in degradation produced between the 2 materials may cause a difference in biological reaction, and therefore a different response to infection (6).

When selecting screw fixation, the surgeon must consider a multitude of different factors. It is not as simple as selecting a solid core screw versus a cannulated screw, or as simple as selecting a stainless steel screw versus a titanium screw. The surgeon must consider the placement of the screw and what the screw is attempting to achieve. Does one require greater pullout strength, fatigue strength, or torque resistance? A difference in material may be overcome by a difference in core diameter. The astute surgeon must familiarize themselves with all aspects of screw fixation and select the screw style and material that best suits their fixation needs.

REFERENCES

1. Roberts TT, Prummer BS, Papaliodis DN, Uhl RL, Wagner TA. History of the orthopedic screw. Orthopedics 2013;36:12-4.
2. Leggon R, Lindsey RW, Doherty BJ, Alexander J, Noble P. The holding strength of cannulated screws compared with solid core screws in cortical and cancellous bone. J Orthop Trauma 1993;7:450-7.
3. Merk BR, Stern SH, Cordes S, Lautenschlager EP. A fatigue life analysis of small fragment screws. J Orthop Trauma 2001;15:494-9.
4. Gardner AW, Toh MZ, Yew KSA, Lie DTT, Chou SM. Cannulated versus non-cannulated cancellous screw fixation for femoral neck fractures: a synthetic bone biomechanical study. J Orthop Trauma 2015;23:41-6.
5. Brunette DM, Tengvall P, Textor M, Thomsen P. Titanium as implant material for osteosynthesis applications. titanium in medicine: Material Science, Surface Science, Engineering, Biological Responses and Medical Applications, Springer; 2011, p. 804-7.
6. Arens S, Schlegel U, Printzen G, Ziegler WJ, Perren SM, Hansis M. Influence of the materials for fixation implants in local infection: an experimental study of steel versus titanium DC-Plates in rabbits. J Bone Joint Surg 1996;78:647-51.