CHAPTER **37**

HEADLESS SCREW FIXATION IN FOOT SURGERY

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INTRODUCTION

Headless screws are not a recent phenomena. Headless screws in one form or another have been in use for the past 30 years. Numerous variations of this theme have been proposed. As this author had been an initial advocate of the Herbert bone screw, his interest has swelled with the recent introduction of new designs. Headless screws are available in many sizes from numerous manufacturers. Their use is not a recent phenomena but there are certain unique features that merit consideration and will be discussed. Utilization of headless bone screws may provide for advantages in a variety of procedures performed by reconstructive foot surgeons. Useful applications will be detailed.

SCREW MECHANICS

The earliest use of headless screws in orthopedic surgery probably goes back to initial work by Timothy Herbert of Australia who developed a screw for repair of fractures and nonunion of the carpal navicular (1, 2). At this point, in the science of osteosynthesis, interfragmentary compression was considered the ideal form of fixation between bone fragments. This was initially accomplished with a lag screw wherein a non-threaded portion of the screw, the shaft, would not engage the near fragment. The head of the screw was rotated with a screwdriver and advanced the thread across the fracture or osteotomy until only the far fragment was engaged. As the threads advanced, the head of the screw pressed against the near cortex and compressed the near fragment against the far osseous segment.

The distance a screw advances with one revolution of the screw is referred to as the "lead." This concept was the working premise of the initial headless screws. The screw that Herbert developed worked with a rather new concept (Figure 1). The screw possesses threads at either end and each possesses a different "lead." The pitch of the leading thread was greater than that of the trailing thread and therefore advanced more within the bone segment with each revolution of the screw. This design of pitch differential allowed for interfragmental compression. The unique advantage of the headless screw was that it allowed a screw to be completely buried within the bone that it was implanted in. The head was no longer prominent above the bone surface. This was useful when little subcutaneous tissue was available to protect the skin from irritation such as the dorsum of the foot.

HISTORY OF HEADLESS SCREWS

The Herbert screw was initially designed for the navicular and only available in one size. The size of the screw was designated by the diameter of the trailing thread, which in the case of the Herbert screw was 4.0 mm. The success of the Herbert screw has led to numerous variations of this theme over the years. One of the earliest variations was that of William Reese in Arizona (3, 4). He developed a screw initially for digital interphalangeal joint fusion. The Reese screw was different in that the thread patterns involved a left-handed and a right-handed pitch although the thread diameter at either end was the same. This screw allowed a screw driver to be utilized from either end and advancement of the screw from either clockwise or counterclockwise rotation depending upon which end of the screw was within bone. The initial Reese screw was a 2.4 mm design and later other sizes were added.

The Herbert screw possessed a shaft or non-threaded central portion of the screw. The Reese screw possessed a longer thread pattern both proximal and distal but still possessed a non-threaded shaft area. The next screw that was

Trailing thread	
Thread diameter	4.0 mm
Core diameter	2.4 mm
Pitch	1.07 mm
Shaft diameter	1.85 mm
Leading thread	
Thread diameter	3.0 mm
Core diameter	1.9 mm
Pitch	1.22 mm
Pitch differential	0.12 mm

Figure 1. The Herbert bone screw initially was made in only one size. The screw requires that the bone fragments be brought in apposition and interfragmentery compression would be generated through the variable "lead" between the leading and trailing threads.

introduced was a fully threaded version of the Herbert type screw. The Acutrak (Acumed, Beaverton, OR) screw possessed thread along the entire length of the screw but the pitch varied from near to far with a wider pitch at the tip and a narrower pitch at the head end (5, 6). Subsequent designs were introduced with variable screw size and thread diameters available. Following the advent of cannulated screws, headless screws were also introduced in cannulated versions and the second generation of Acutrac was available in a more tapered version.

More recently, a new concept of obtaining interfragmentary compression with the headless screw was introduced. Several studies have shown that headless screws generally yield lower compressive forces then the more traditional screw with a head (7-12). The AO group designed a screw that on first appearance seemed very similar to that of a cannulated Herbert screw (13). This screw in point of fact actually possesses no variability in the pitch or "lead" between the leading and trailing thread. It provides for the same distance of advancement of the leading and trailing thread for turn or revolution of the screw. Interfragmentary compression is introduced through a lag effect typically achieved with a traditional screw with a head (Figure 2). This is accomplished through the use of "dual screwdrivers." An initial screwdriver or compression sleeve is attached to the trailing thread (head end) and eliminates exposure of the trailing thread portion of the screw. This compression sleeve acts much as the land of a typical screw and rotation of the compression sleeve with a screwdriver handle allows for not only insertion of the screw but also compression.

Upon complete insertion of the screw, the inferior tip of the compression sleeve acts like the under surface of the screw and imparts an axial force within the proximal fragment compressing it against the distal fragment. Once the desired compression is achieved, the compression sleeve handle is removed and a screwdriver is inserted within the compression sleeve. At this point, advancement of the screw is achieved with screwdriver rotation but holding the compression sleeve stationary. Rotation of the screw then allows for complete insertion within the bone and in doing so exclusion from the compression sleeve. This screw is cannulated and placed over a central guide pin and is available in a wide range of sizes. It is this new generation of headless screw that is the subject of the current paper.

Figure 2A. The Synthes headless screw requires some unique instrumentation for insertion including compression sleeve that attaches to a handle. Figure 2B. The trailing thread, "head" end is threaded into the tip of the compression sleeve. The screw may now be inserted over the guide pin. Figure 2C. Illustrates the star tip screwdriver and insert of the screw head.

PROCEDURAL REPORTS

Distal First Metatarsal Osteotomy

This author has particular experience with the use of headless screws for Chevron type osteotomy bunion procedures. His initial experience was with the original Herbert screw at the time of its initial introduction in 1983. The screw was manufactured and distributed by Zimmer (Warsaw, Indiana) and his initial series of more than 100 patients was published as a white paper for Zimmer and Austin bunionectomy technique guide (14). This screw allowed for complete intraosseous placement of the screw on the oblique plane to the dorsal surface of the first metatarsal thus eliminating the subcutaneous prominence and potential irritation from the head of the screw. The initial screw was non-cannulated and possessed a very small screwdriver that was prone to failure upon insertion of the screw in a hard bone such as the dorsal cortex of the first metatarsal. Over the years, this was solved with the self-tapping nature of the screw and with the new generation of headless screw insertion is actually quite easy and requires less effort.

Currently, the headless screws are being utilized for a variety of osteotomy bunionectomies including the Chevron/Austin and the Hohmann/Wilson type procedure. The technique will be described and is illustrated (Figure 3).

Distal 5th Metatarsal Osteotomy

A tailor's bunion deformity is generally corrected by a fifth metatarsal osteotomy. One of the more common osteotomies has been an oblique through-and-through osteotomy from distal lateral to proximal medial. Following completion of the osteotomy, medial transposition of the capital fragment reduces the deformity but has been somewhat difficult to fixate with traditional fixation techniques. The small 2.4 mm headless compression screw has been found useful as a methodology of single point fixation for this osteotomy (Figure 4).

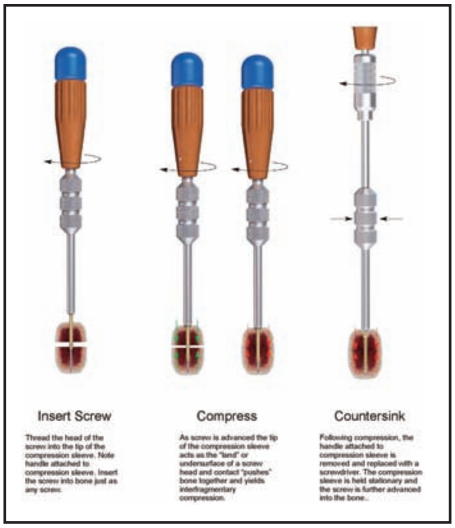

Figure 3. This illustration from the Synthes technique guide shows the technique of insertion of the headless screw. (Illustration courtesy of Synthes)

Figure 4A. AP radiograph demonstrating the use of the 3.0 mm Synthes headless compression screw for the chevron bunionectomy.

Figure 4B. Lateral radiograph demonstrating the use of the 3.0 mm Synthes headless compression screw.

Following completion of the osteotomy, temporary fixation is achieved with a small Kirschner wire (K-wire). The guide pin for the 2.4 mm headless screw is inserted in an oblique manner from proximal lateral and somewhat plantar to a distal end medial direction protruding in the distal metaphyseal portion of the fifth metatarsal. A drill is utilized to enlarge the proximal cortex and near fragment. The length of the inserted guide pain is measured and generally a screw 2 to 3 mm shorter than the measurement is selected. The screw was initially inserted attached to the compression sleeve and subsequently placed below the bone surface. This technique has proved useful with a relatively unstable osteotomy as a single point of fixation. It is the author's belief that catastrophic failure from loss of interfragmentary compression is less likely with headless screws as the screw threads purchase both the near and far fragment. So far this has been confirmed in clinical practice.

Hallux Interphalangeal Joint Fusion

Hallux interphalangeal joint fusion is traditionally the first technique taught to foot surgeons in training. On first view, that technique appears to be quite simple but as most experienced surgeons can verify, complications can occur with this procedure. One of the difficulties, is whether or not to countersink ahead of the screw within the terminal phalanx distal tuft. Lack of countersinking combined with any loosening of the screw generally yields subcutaneous irritation with the potential for ulceration and infection. Application of the headless screw was felt to be advantageous to this procedure due to the ability to not only completely countersink the trailing thread within the distal phalanx but also thread purchase would mitigate against loosening and any retrograding of the screw.

Following resection of the articular surfaces, an axial guide pin is retrograded across the arthrodesis site and verify radiographically. A 3.0 or 4.5 mm screw may be selected depending upon the size of the individual. The length of the screw may vary according to the desires of the surgeon. A screw may be selected in order to cross the IPJ arthrodesis site and purchase the bone mainly within the head and neck area of the proximal phalanx (Figure 6). Alternatively, a longer screw may be selected if it is desirable to achieve purchase of more proximal bone within the phalanx.

Figure 5A. Preoperative radiograph of a patient who underwent an oblique fifth metatarsal osteotomy for repair of a tailor's bunion as well as a Hohman bunionectomy.

Figure 5B. Postoperative radiograph of a patient who underwent an oblique fifth metatarsal osteotomy for repair of a tailor's bunion as well as a Hohman bunionectomy. Each osteotomy was fixated with a headless compression screw; the Hohmann with a 3.0 mm and the fifth metatarsal osteotomy with a 2.4 mm screw.

Figure 6A. Preoperative AP radiograph of patient with painful deformity at hallux IPJ and bunion deformity.

Figure 6B. Postoperative AP view shows hallux IPJ fusion with a 4.5mm headless screw sized to purchase the proximal phalangeal head area. Note, also use of 3.0 mm headless screw for Hohmann osteotomy bunionectomy.

Figure 6C. Postoperative lateral view of hallux IPJ fusion with a 4.5 mm headless screw.

First Metatarsophalangeal Joint Fusion

This author has certainly been an advocate of staple fixation of the first metatarsophalangeal joint fusion with a dorsally placed compression staple. Most surgeons would generally agree that a second point of fixation is desirable and would add significant stability to the osteosynthesis construct. Generally this is accomplished with a second staple placed in a more medial to lateral direction. Alternatively, the headless compression screw has been shown to be a useful device as a second point fixation. This screw may be placed either prior or subsequent to the insertion of the dorsal staple. Intraoperative C-arm control has proven valuable with placement of the guide pin in a very exact manner from proximal medial and plantar to a lateral and distal direction attempting to perforate the lateral cortex of the hallucal proximal phalanx (Figure 7). Generally a 3.0 mm headless screw has been utilized as this provides adequate fixation and yet the screw is small enough for placement of the staple or second point of fixation. This screw purchases quite securely with the trailing thread within the first metatarsal head and the leading thread perforating the lateral cortex. The self tapping/self-drilling nature of the screw perform this with relative ease.

Hallux Osteotomy

Hallux osteotomy is the technique performed by most foot surgeons and is often a component of a bunionectomy procedure. The initial reports with the Regnauld-type procedure revealed a large number of complications including displacement, non-union, and avascular necrosis of the proximal phalangeal base. Utilization of this procedure seemed to lack the AO tenets of rigid internal fixation leading to primary vascular bone healing. In an effort to accomplish bone healing and avoid avascular necrosis of the phalangeal base, this author advocated rigid internal fixation. A large case series was performed showing the advantages of rigid internal fixation with headless screw fixation. Variations included the original Herbert bone screw, the Herbert-Whipple cannulated screw as well as the Bold screw. Each of these are actually very similar and allowed interfragmentary compression through the variable pitch design of the screw threads.

The author also recommends to treat the resected base of the proximal phalanx as a bone graft. The extripated portion of bone was fenestrated to allow vascular ingrowth as well as rigidly fixated. The osteosynthesis construct consisted of a headless bone screw placed from proximal and medial to distal and lateral across the osteotomy. Use of cannulated version allowed very accurate placement from the plantar and medial condylar area of the proximal phalanx extending distal and allowing for purchase of the leading thread within the head of the proximal phalanx or lateral metaphyseal wall.

OTHER APPLICATIONS

Almost anywhere a surgeon desires to completely bury a screw head should be a consideration for use of a headless screw. These screws are available in variable sizes that have shown promise in a variety of osteotomies and fusions. Utilization of larger size screws, 6.5 mm diameter, have show usefulness in procedures such as triple arthrodesis, subtalar fusion, and talonavicular fusion. The foot possesses many subcutaneous areas wherein the presence of any fixation implant prominences may cause difficulties postoperatively.

DISCUSSION

Literature reports have questioned the compressive forces of the variable pitch headless screws. A new type of headless screw has been introduced that allows the surgeons to generate compressive forces much like any typical screw with a “head.” The technique is straightforward and screws are available in a large variety of sizes, from both the standpoint of screw diameter and lengths. In many of the smaller sizes, screws are available in 1 mm increments, which may be helpful in the smaller bones. This screw seems to offer little difficulty with insertion as encountered with the original headless screws, which were not self-tapping in design. This paper presents utilization of multiple procedures of reconstructive foot surgery.

Foot and ankle surgeons perform a large number of osteotomies and fusion procedures. A new version of the headless bone screw is available and shown to be useful in a new variety of the headless screw and offers it as an alternative to the traditional “headed” bone screw.

Figure 7A. Intraoperative C-arm images to demonstrate the technique of first metatarsophalangeal joint fusion. A guide pin is placed from the medial aspect of the 1st metatarsal head into the proximal phalanx distal and lateral.

Figure 7B. Following verification of position, the appropriate length 3.0 mm headless screw is inserted over the guide wire, note presence of compression sleeve.

Figure 7C. Shows placement of screw with retained guide pin still in place.

Figure 7D. Final position of screw/staple osteosynthesis.

REFERENCES

1. Herbert TJ, Fisher WE. Management of the fractured scaphoid using a new bone screw. J Bone Joint Surg Br 1984;66:114-23.
2. Herbert TJ. Use of the Herbert bone screw in surgery of the wrist. Clin Orthop Relat Res 1986;79-92.
3. Reese HW. Arthrodesis screw. J Am Podiatr Med Assoc 1987;77:622-3.
4. Reese HW. Reese arthrodesis screw. Osteosynthesis of the interphalangeal joint. J Am Podiatr Med Assoc 1987;77:490-4.
5. Galuppo LD, Stover SM, Jensen DG, Willits NH. A biomechanical comparison of headless tapered variable pitch and AO cortical bone screws for fixation of a simulated lateral condylar fracture in equine third metacarpal bones.Vet Surg 2001;30:332-40.
6. Wheeler DL, McLoughlin SW. Biomechanical assessment of compression screws. Clin Orthop Relat Res 1998;237-45.
7. Ramaswamy R, Evans S, Kosashvili Y. Holding power of variable pitch screws in osteoporotic, osteopenic and normal bone: are all screws created equal? Injury 1996;41:179-83.
8. Nguyen C, Singh D, Harrison M, Blunn G, Herman A, Dudkiewicz I. Biomechanical properties of new mini compression screws. Foot Ankle Int 2009;30:545-50.
9. Magee W, Hettwer W, Badra M, Bay B, Hart R. Biomechanical comparison of a fully threaded, variable pitch screw and a partially threaded lag screw for internal fixation of Type II dens fractures. Spine 2007;32:E475-9.
10. Bueno AC, Galuppo LD, Taylor KT, Jensen DG, Stover SM. A biomechanical comparison of headless tapered variable pitch and AO cortical bone screws for fixation of a simulated slab fracture in equine third carpal bones. Vet Surg 2003;32:167-77.
11. Lo IK, King GJ, Milne AD, Johnson JA, Chess DC. A biomechanical analysis of intrascaphoid compression using the Herbert scaphoid screw system. An in vitro cadaveric study. J Hand Surg Br 1998;23:209-13.
12. Murray RC, Gaughan EM, Debowes RM, Hoskinson JJ. Biomechanical comparison of the Herbert and AO cortical bone screws for compression of an equine third carpal bone dorsal plane slab osteotomy. Vet Surg 1998;27:49-55.
13. Technique Guide. 2.4mm and 3.0mm Headless compression screws. Synthes 2006: West Chester, PA.
14. Vanore JV. Austin Bunionectomy with Herbert Bone Screw Fixation. 1987: Warsaw, IN.