Influence of Screw Design, Sex, and Approach in Scaphoid Fracture Fixation

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Abstract

Background Screw fixation of scaphoid fractures has gained popularity. A long central screw has been shown to be biomechanically advantageous.

Questions/purposes We compared the ability of different screw designs to obtain this goal and determined the influence of sex and approach on screw length.

Methods We performed all measurements on three-dimensional reconstructions of 20 CT scans of normal scaphoids (10 men and 10 women) with the use of software. The three-dimensional computer models were

analyzed, the central axis was defined, and the screws were placed along this axis. We compared 15 different available screw designs and volar and dorsal screw placement.

Results The length of the scaphoid along its central axis was longer in men (mean, 27.14 mm; standard error of the mean, 0.97 mm) than in women (mean, 23.86 mm; standard error of the mean, 0.37 mm). The screw length that can be used was longer in the volar approach (mean, 23.72 mm; standard error of the mean, 0.19 mm) than in the dorsal approach (mean, 23.31 mm; standard error of the mean, 0.19 mm) regardless of the screw design. Screws with a trailing thread diameter greater than 3.9 mm and leading thread diameter greater than 3.0 mm were shorter.

Conclusions Scaphoids in women are smaller than in men. Theoretically, fixation of scaphoid fractures through a volar approach will allow the surgeon to use longer screws. The screw design has a significant influence on the screw length that can be used in scaphoid fracture fixation. We recommend using a differential pitch screw with a thread diameter of 3.9 mm or less.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Among all wrist injuries, the incidence of fractures of the scaphoid is second only to fractures of the distal radius. It is the most commonly fractured carpal bone, accounting for 60% of carpal fractures and 11% of all hand fractures [21]. The annual incidence has been estimated at eight in 100,000 in women and 38 in 100,000 in men [24]. Because scaphoid nonunion or malunion can lead to osteoarthritis, instability, chronic discomfort, and subsequent functional impairment [4, 15, 23, 28, 38, 40, 41], displaced waist fractures, proximal pole fractures, and fractures with loss of carpal alignment should be treated surgically unless

surgery is contradicted or the patient refuses it [18]. Internal fixation also has been advocated in young active individuals with nondisplaced scaphoid fractures or if there is a delay in diagnosis [13].

The goal of internal fixation of the scaphoid is to reduce the fracture and position a single screw as close to the central axis as possible. Technical difficulties include obtaining and maintaining proper reduction of the fracture [2, 16, 36], avoiding joint penetration [2, 16], avoiding prominent hardware [2, 16], and correct positioning of the screw [2, 9, 35]. Failure to accomplish this goal could lead to fracture nonunion, malunion, or displacement [2, 35, 36, 40]. Numerous studies have made recommendations for better screw placement in the scaphoid [11, 26, 27, 32–34, 42].

Percutaneous fixation has become popular, and with the introduction of a new headless compression screw [20], the technique has evolved such that the benefits outweigh the risks [3, 8, 17, 31]. Because of the complex anatomic shape of the scaphoid, internal fixation is technically demanding. Scaphoid fracture stabilization with a single screw has been promoted for several decades, but the past decade has seen the introduction of several different screw designs from various manufacturers whereby headless compression screws have replaced screws with a prominent head (Table 1).

McCallister et al. [30] reported an eccentrically placed screw offers less biomechanical stability than a screw placed centrally. The chosen implant should be buried

below the level of the cartilage on both ends of the scaphoid to prevent the development of radioscaphoid or scaphotrapezial arthritis. In the clinical setting, a shorter and centrally placed screw has the advantage of avoiding prominence at the chondral surface. However, a study by Dodds et al. [14] showed that compared with a long screw that ends just under the chondral surface, a short and centrally placed screw does not take advantage of the holding power of the cancellous bone throughout the scaphoid length. Therefore, a long centrally placed screw, with purchase of the screw threads in the subchondral bone, provides better fixation.

There is a difference in scaphoid morphometry between the two sexes [19]. The smaller size of the female scaphoid must be taken into consideration when planning internal fixation. The scaphoid is narrowest at the proximal pole and contemporary screw designs have a trailing thread diameter that is greater than the leading thread diameter. Therefore, the approach could have an influence on the maximum screw length that can be used.

We determined the influence of sex and approach on maximum screw length and compared the maximum screw length of the different screw designs that can be used to fix scaphoid fractures. The aims of this study were to determine whether (1) there is a difference in morphologic features of the scaphoid between men and women; (2) whether there is a difference in maximum screw length among different screw designs; (3) whether there is a difference in maximum screw length along the longitudinal

Table 1. Screw dimensions from various manufacturers

Screw (manufacturer*)	Leading thread diameter (mm)	Trailing thread diameter (mm)	Length range (mm) (increments)	Guide pin size (mm)
3.0-mm Cannulated Short Thread (Synthes)	3.0	5.5	8–30 (1), 32–40 (2)	1.1
Acutrak® Standard (Acumed)	3.3	3.8–4.6	12.5–30 (2.5)	1.1
Acutrak® Mini (Acumed)	2.8	3.2–3.5	8–26 (2)	0.88
Acutrak 2® Standard (Acumed)	4.0	4.1	16–30 (2)	1.4
Acutrak 2® Mini (Acumed)	3.5	3.6	16–30 (2)	1.1
AutoFIX™ (SBI)	2.0	3.0	10–30 (1)	0.91
AutoFIX™ (SBI)	2.5	3.3	10–30 (1)	0.91
Headless Bone Screw (HBS) (KLS Martin)	3.0	3.9	10–30 (1)	1.0
Headless Bone Screw (HBS) Mini (KLS Martin)	2.5	3.2	10–28 (1)	0.8
Headless Compression Screw (HCS) (Synthes)	3.0	3.5	10–30 (1), 32–40 (2)	1.1
Herbert™ Mini (Zimmer)	2.5	3.2	10–24 (2)	NA
Herbert™ Scaphoid (Zimmer)	3.0	3.9	12–30 (2)	NA
Kompressor™ Standard (KMI)	4.0	5.0	14–34 (2)	1.1
Kompressor™ Mini (KMI)	2.8	3.6	10–26 (2)	0.9
TwinFix® (Stryker)	3.2	4.2	14–20 (2), 21–30 (1), 32–34 (2)	1.0

* Manufacturers include: Synthes Inc, West Chester, PA, USA; Acumed LLC, Hillsboro, OR, USA; Small Bone Innovations Inc (SBI), Morrisville, PA, USA; KLS Martin Group, Tuttlingen, Germany; Zimmer Inc, Warsaw, IN, USA; Kinetikos Medical Inc (KMI), Carlsbad, CA, USA; Stryker Orthopaedics, Mahwah, NJ, USA; NA = not available.

axis of the scaphoid between the volar and dorsal approaches; and (4) to validate the method for consistency and reliability

Materials and Methods

We performed measurements on the CT scans of 20 normal wrists (10 men and 10 women) with the wrist in neutral position. The CT scans were made for other reasons and used retrospectively for this study. The mean age was 39.5 years (range, 19–59 years) for the men and 31.9 years (range, 18–59 years) for the women. We excluded the CT scans of patients younger than 18 years and older than 60 years, patients with evidence of bony disorders, fracture of one or more of the carpal bones and/or distal radius or ulna, old carpal bone lesion, osteoarthritis, volar or dorsal intercalated segment instability, and avascular necrosis of the scaphoid or other carpal bones. The CT scans were obtained with a dual-source CT scanner (SOMATOM[®]; Siemens Medical Solutions, Erlangen, Germany). Images of 0.5-mm thickness with 0.5-mm spacing between images and without overlap were obtained. Bone surface models were created from the CT scans (3-matic[®]; Materialise, Leuven, Belgium) (Fig. 1). A coordinate system for each scaphoid was computed using its inertial properties [26]. The x-axis along the length of the scaphoid was used as the central axis. Analysis of the CT scans was performed using specialized software (Somaris 5 VA40C [Siemens Medical Solutions] and Mimics[®] 13 [Materialise]). The computer software performed all measurements with an accuracy of 0.01 mm.

To compare scaphoids between the sexes, we determined the sagittal and coronal planes by creating planes with the x- and y-axes and x- and z-axes, respectively. The contours of the scaphoid in the sagittal and coronal planes were used to measure scaphoid length and width in both planes (Fig. 2). The dimensions of the scaphoids of the men and women were compared.

To compare screw designs, we obtained implant dimensions for screws currently available for clinical use from the manufacturers (Table 1). Two cylinders, representing the trailing and leading thread diameters of a screw, were placed along the longitudinal axis of the scaphoid (Fig. 1B–C). The cylinders were constructed using the sagittal and coronal plane two-dimensional model. This allowed placement of a rectangle with the short side as long as the trailing or leading thread diameter and perpendicular to the longitudinal axis of the scaphoid and dividing the short side in two equal segments. Based on this rectangle a cylinder was made and the three-dimensional model of the scaphoid was used to make sure the cylinder did not violate the cortex. By changing the diameter of both cylinders

Fig. 1A–D (A) Bone surface models of the scaphoid with a coordinate system according to its inertial properties are shown with two cylinders representing a (B) small and (C) broad double-threaded variable pitch screw and a frustum of a cone representing a (D) screw with a conical design inserted through a volar approach.

Fig. 2 A contour of the scaphoid in the coronal plane used to measure length and width is shown.

according to the properties of the different screws and measuring the distance between both ends, the maximum screw length for each screw was determined using the two-dimensional plane (Fig. 3A–B). For the screws with a conical design we used two lines perpendicular to the longitudinal axis in the two-dimensional sagittal and coronal plane model which were connected to form a trapezium. This was used to make a frustum of a cone representing a conical screw design in the three-dimensional model without violating the cortex (Fig. 1D). We determined the effect of the availability of different screw lengths and compared screws with 0.01-mm (the scale used with the software), 1-mm, 2-mm, and 2.5-mm increments.

The distances between the tip of the different screws and the proximal (pTAD) and distal poles (dTAD) were measured and compared (Fig. 3A).

To compare the volar and dorsal approaches, we simulated a volar approach using a smaller proximal cylinder to represent the leading head diameter and a broader distal cylinder to represent the trailing thread diameter and a dorsal approach using a broader proximal cylinder and a smaller distal cylinder (Fig. 3). The maximum length according to both approaches was calculated for the different screw designs. We measured the pTAD and dTAD for all screws and compared them according to the different approaches.

Fig. 3A–D (A) A contour of the scaphoid in the coronal plane used to measure pTAD, dTAD, and length of a screw inserted through a volar approach is shown. (B) The same measurements are performed with a screw with a different diameter of the leading and trailing threads inserted through a volar approach. The same measurements are performed with the screw in (C) Illustration A and in (D) Illustration B inserted through a dorsal approach.

To validate this method we analyzed the intraobserver and interobserver variability of the measurements of scaphoid dimensions and screw length. Measurements in 10 scaphoids were done by both authors in a random order and this was repeated at a 3-week interval to establish the intraobserver and interobserver reliability.

We performed statistical analysis using an unpaired Student's *t*-test for comparison of scaphoid length and width in the sagittal and coronal planes between men and women. A one-way ANOVA and a repeated-measures ANOVA with post hoc Bonferroni's multiple comparison test were used for comparison of the pTAD and dTAD in men and women and for comparison of the different screw designs, respectively. A paired Student's *t*-test was used for the comparison of screw length in the volar and dorsal approaches. A repeated-measures ANOVA with a post hoc Bonferroni's multiple comparison test was used for comparison of the screw design, approach, available screw lengths, pTAD and dTAD, and screw length according to approach. Intraclass correlation was measured using a Bland-Altman analysis for continuous data [7] and evaluated using the grouping recommended by Landis and Koch [24]. Scores between 0.61 and 0.8 represented substantial agreement and those greater than 0.81 almost perfect agreement. Significance was defined as *p* values less than 0.05. The statistical software used for analysis was GraphPad Prism[®] 5 (GraphPad Software, Inc, San Diego, CA, USA).

Results

The mean length of the scaphoid was longer ($p = 0.013$) in men (27.14 ± 0.97 mm; 95% CI, 24.58–29.92 mm) than in women (23.86 ± 0.37 mm; 95% CI, 22.88–25.00 mm). The mean width of the scaphoid at the midwaist in the coronal plane was wider ($p = 0.004$) in men (14.57 ± 0.65 mm; 95% CI, 12.76–16.38 mm) than in women (11.34 ± 0.49 mm; 95% CI, 9.96–12.72 mm). The mean width of the scaphoid at the midwaist in the sagittal plane was wider ($p = 0.014$) in men (10.91 ± 0.18 mm; 95% CI, 10.42–11.41 mm) than in women (9.88 ± 0.28 mm; 95% CI, 9.12–10.65 mm) (Fig. 4).

There were no differences in pTAD and dTAD in men and women when using the same screw. In men, the mean pTAD and dTAD were 2.64 ± 0.24 mm and 1.04 ± 0.10 mm for the broadest screw and 0.85 ± 0.07 mm and 0.31 ± 0.10 mm for the smallest screw, respectively. In women, the mean pTAD and dTAD were 2.58 ± 0.14 mm and 1.06 ± 0.15 mm for the broadest screw and 0.67 ± 0.06 mm and 0.33 ± 0.05 mm for the smallest screw, respectively (Table 2).

In screws with a conical design, screws with a relatively narrow leading thread diameter (Acutrak[®] Standard and

Mini) were longer ($p < 0.05$) than conical screws with a relatively parallel design (Acutrak 2[®] Standard and Mini). For screws with a double-threaded variable pitch or

Fig. 4 A bar chart shows the mean values for the different dimensions of the scaphoid in men and women. The mean scaphoid length, frontal width, and sagittal width are greater in men than in women. Whiskers indicate standard error of the mean.

Table 2. Tip-apex distance

Screw (manufacturer*)	pTAD (mm)		dTAD (mm)	
	Volar	Dorsal	Volar	Dorsal
3.0-mm Cannulated Short Thread (Synthes)	1.17	2.60	1.28	0.51
Acutrak [®] Standard (Acumed)	1.32	2.02	0.60	0.10
Acutrak [®] Mini (Acumed)	1.10	1.42	0.58	0.43
Acutrak 2 [®] Standard (Acumed)	1.68	1.73	0.57	0.57
Acutrak 2 [®] Mini (Acumed)	1.42	1.50	0.72	0.71
Autofix 2.0 [™] (SBI)	0.73	1.17	0.35	0.41
Autofix 2.5 [™] (SBI)	0.96	1.32	0.46	0.57
Headless Bone Screw (HBS) (KLS Martin)	1.17	1.63	0.67	0.68
Headless Bone Screw (HBS) Mini (KLS Martin)	0.96	1.26	0.38	0.54
Headless Compression Screw (HCS) (Synthes)	1.17	1.42	0.52	0.70
Herbert [™] Mini (Zimmer)	0.96	1.26	0.38	0.54
Herbert [™] Scaphoid (Zimmer)	1.17	1.63	0.67	0.68
Kompressor [™] Standard (KMI)	1.10	1.50	0.62	0.55
Kompressor [™] Mini (KMI)	1.68	2.30	1.06	0.82
TwinFix [®] (Stryker)	1.26	1.77	0.90	0.70

pTAD = distance between tip of screw and proximal pole; dTAD = distance between tip of screw and proximal pole; * Manufacturers include: Synthes Inc, West Chester, PA, USA; Acumed LLC, Hillsboro, OR, USA; Small Bone Innovations Inc (SBI), Morrisville, PA, USA; KLS Martin Group, Tuttlingen, Germany; Zimmer Inc, Warsaw, IN, USA; Kinetikos Medical Inc (KMI), Carlsbad, CA, USA; Stryker Orthopaedics, Mahwah, NJ, USA.

Fig. 5 A bar chart shows the mean values of the tip apex distance for the different screw designs. The Kompressor™ Standard, 3.0 Cannulated Short Thread, Acutrak 2® Standard, TwinFix®, and Acutrak 2® Mini screws were shorter than the other screws. The Acutrak® Standard, Headless Bone Screw (HBS), Acutrak® Mini,

Herbert™ Scaphoid, Kompressor™ Mini, and Headless Compression Screws (HCS) were shorter than the AutoFIX™ 2.5, HBS Mini, Herbert™ Mini, and AutoFIX™ 2.0 screws. Std = standard; 3.0 Screw = 3.0 Cannulated Short Thread; whiskers indicate standard error of the mean.

Herbert-type design, screws with a leading thread diameter greater than 3.0 mm and a trailing thread diameter greater than 3.9 mm were shorter ($p < 0.0001$). Screws with a leading thread diameter of 2.5 mm or less and a trailing thread diameter of 3.3 mm or less were the longest ($p < 0.05$) (Fig. 5).

There was no difference between the theoretically maximum screw length (up to 0.01 mm available) and the length of the actual screw when using screws with 1-mm increments. Screws with increments of 2 or 2.5 mm were significantly shorter ($p < 0.01$ and $p < 0.0001$, respectively) than the theoretically maximum screw or screws with only 1-mm increments (Fig. 6). The maximum screw length in this study ranged from 20 to 30 mm. Therefore, for the Acutrak® Mini, Headless Bone Screw (HBS) Mini, Herbert™ Mini, and Kompressor™ Mini, the maximum screw length could not always be used because these screws were not provided in lengths up to 30 mm.

The mean maximum screw length was longer ($p < 0.0001$) when using a volar approach (23.72 ± 0.19 mm; 95% CI, 23.34–24.09 mm) than when using a dorsal approach (23.31 ± 0.19 mm; 95% CI, 22.94–23.67 mm) regardless of the screw design (Fig. 7). In screws with a conical design there was no difference in screw length with a volar or dorsal approach. There was a significant difference in all screws with a double-threaded variable pitch design (Table 3).

Screws with a diameter of 4.0 mm or larger (3.0 Cannulated Short Thread, TwinFix®, and Acutrak® Standard screw through a dorsal approach and Kompressor™ Standard, and Acutrak 2® Standard screw through dorsal and volar approaches) could not always be buried 2 mm or

Fig. 6 A bar chart shows the mean values of the scaphoid length and maximum screw length for screws with different increments. There was no difference between the theoretically maximum screw length and the length of the actual screw when using screws with 1-mm increments. Screws with increments of 2 or 2.5 mm were shorter than the theoretically maximum screw or screws with only 1-mm increments. Whiskers indicate standard error of the mean; §not significant; * $p < 0.01$; ** $p < 0.0001$.

less beneath the articular surface of the proximal pole. The pTAD is smaller ($p < 0.05$) for each screw that is 0.2 mm smaller in diameter. There was no difference in mean dTAD between the volar and dorsal approaches for the same screw design. All screws could be placed 2 mm or less beneath the articular surface of the distal pole (Table 2).

Fig. 7 A bar chart shows the mean values of the maximum screw length for the different approaches. The mean maximum screw length was greater when using a volar approach than when using a dorsal approach regardless of the screw design. Whiskers indicate standard error of the mean.

Table 3. Screw length and approach

Screw (manufacturer*)	Mean screw length (mm)		p value
	Volar	Dorsal	
3.0-mm Cannulated ShortThread (Synthes)	23.15	22.41	< 0.0001
Acutrak [®] Standard (Acumed)	23.65	23.57	0.55
Acutrak [®] Mini (Acumed)	23.84	23.72	0.38
Acutrak 2 [®] Standard (Acumed)	23.28	23.18	0.48
Acutrak 2 [®] Mini (Acumed)	23.49	23.36	0.31
Autofix [™] 2.0 (SBI)	24.49	24.00	0.0008
Autofix [™] 2.5 (SBI)	24.15	23.67	0.001
Headless Bone Screw (HBS) (KLS Martin)	23.74	23.28	0.002
Headless Bone Screw (HBS) Mini (KLS Martin)	24.23	23.75	0.001
Headless Compression Screw (HCS) (Synthes)	23.90	23.45	0.002
Herbert [™] Mini (Zimmer)	24.22	23.75	0.001
Herbert [™] Scaphoid (Zimmer)	23.82	23.31	0.0006
Kompressor [™] Standard (KMI)	22.82	22.41	0.003
Kompressor [™] Mini (KMI)	24.18	23.73	0.002
TwinFix [®] (Stryker)	23.40	23.08	0.02

* Manufacturers include: Synthes Inc, West Chester, PA, USA; Acumed LLC, Hillsboro, OR, USA; Small Bone Innovations Inc (SBI), Morrisville, PA, USA; KLS Martin Group, Tuttlingen, Germany; Zimmer Inc, Warsaw, IN, USA; Kinetikos Medical Inc (KMI), Carlsbad, CA, USA; Stryker Orthopaedics, Mahwah, NJ, USA.

There was nearly perfect agreement for all intraobserver and interobserver measurements regarding scaphoid length ($\kappa = 0.92$ – 0.96), width ($\kappa = 0.89$ – 0.94), and screw length ($\kappa = 0.87$ – 0.93).

Discussion

The goal of this study was to determine the influence of gender and approach on maximum screw length and to compare the maximum screw length of the different screw designs that can be used to fix scaphoid fractures. The scaphoid is significantly smaller in women, but the ability to place a screw less than 2 mm beneath the chondral surface depends on the design of the screw and is not related to the gender of the patient. Screws with a leading thread diameter greater than 3.0 mm and a trailing thread diameter greater than 3.9 mm are significantly shorter. Screws with increments of 2 or 2.5 mm were significantly shorter than those with 1-mm increments. Screws with a double-threaded variable pitch design placed through a volar approach are significantly longer compared with the dorsal approach. Screws with a diameter of 4.0 mm or greater cannot always be buried 2 mm or less beneath the articular surface of the proximal pole.

There are several limitations to our study. In this study, three-dimensional reconstructions of the scaphoid were used where the central axis was determined by the computer software. Placement of a screw along this axis can be technically demanding. In vitro or in vivo direction of the guide wire may vary from the long axis resulting in different screw length if directed obliquely away from the axis [26]. The approach can influence positioning of the screw and previous studies have shown that screws are placed more parallel to the long axis when using a dorsal approach [11, 22]. When using a dorsal approach, the wrist must be placed in maximum flexion and the screw inserted between the extensor tendons with several anatomic structures at risk [1]. The main difficulty when using a volar approach is hindrance of the trapezium [27]. This can be overcome by manipulation of the scaphoid, resection of part of the trapezium, or using a transtrapezial approach [27, 32]. A screw placed central in the distal pole allows the screw to be placed closely to the center of the scaphoid throughout its full length [11, 33]. Additionally, all patients in this study were Caucasian. We have not been able to evaluate possible differences in scaphoid size among different races. Information regarding length of the patients was not available. Some authors have used morphologic properties of the scaphoid to classify them into different types [12, 19]. We did not study the influence of morphologic features of the scaphoid on screw length.

Although screws with a smaller diameter are longer, a smaller diameter can have an adverse effect on fixation strength. Biomechanical studies have shown wider screws provide better resistance to lateral displacement forces, as their resistance is proportional to the radius of the screw to the fourth power [39]. This also should be taken into account when selecting a screw for scaphoid fracture fixation. In this study, the central axis computed by the

software was used to determine the long axis of the scaphoid and standardize screw placement. There is no evidence that a screw placed central in the proximal pole but eccentric in the distal pole is biomechanically inferior to a screw placed centrally throughout the scaphoid. A finite element analysis showed that a screw placed perpendicular to the fracture has higher fixation stability than a screw placed along the long axis of the scaphoid [28]. In our model we only used the central axis as a reference for screw placement.

In a previous study [19], the mean scaphoid length was 31.3 mm in men and 27.3 in women, which is markedly higher than the mean length we found (27.15 mm in men and 23.86 mm in women). In that cadaver study [19], measurements were taken using a caliper from the most prominent point of the proximal pole and the distal articular surface. In our study, the central long axis was accurately determined for each scaphoid by the software. This leads to the elimination of human error in determining this axis. When the length of the scaphoid is not measured along the central axis, this can result in a 10% longer result [26].

In the same study [19], a difference ($p = 0.01$) in width at the proximal pole was found between men and women (4.5 ± 1.4 mm in men versus 3.7 ± 0.5 mm in women). This was measured at 2 mm distal to the tip of the proximal pole perpendicular to the long axis. We did not measure the width of the proximal pole in one plane but used a three-dimensional reconstruction to precisely measure maximum screw length and pTAD. In our study, there was no difference in pTAD between men and women when using the same screw. This distance is clinically more important for correct screw placement than the scaphoid width as such. Our data show the screws in women were shorter owing to the length of the scaphoid. In men and women, screws with a good design can be buried 2 mm or less under the surface proximally without compromising biomechanical strength.

The volar and dorsal approaches are being used for fixation of scaphoid fractures. The location and type of fracture determine which approach allows the best screw placement [18, 37]. In nondisplaced waist fractures perpendicular to the long axis of the scaphoid, the approach depends on the surgeon's preference. Complications have been reported for both methods [1, 3, 5, 6, 10]. Using the same central long axis of the scaphoid, our data showed screws placed through a volar approach were longer because of the smaller leading thread diameter and proximal pole. This leads to better purchase of the screw in the densest cancellous bone, which is located at the poles. It has been reported that a screw buried 2 mm under the chondral surface of the proximal and distal poles of the scaphoid offers more biomechanical stability [14]. This cannot always be achieved when using screws with a diameter of 4.0 mm or greater at the proximal pole (pTAD upper 95% CI, 2.01 mm). However, screws

with a diameter of 3.9 mm or less did not violate the cortex when placed 2 mm from the proximal pole (pTAD upper 95% CI, 1.94 mm).

Some screws are longer depending on the design. For our comparison, maximum screw length was used. Some surgeons do not use the maximum screw length but subtract 4 mm of the measured scaphoid length to avoid prominence of the screw at the articular surface, which could lead to chondral wear [14]. The ability of the screw to be placed 2 mm under the surface at the proximal and distal poles (pTAD and dTAD) is therefore clinically more important.

Our data showed a difference in scaphoid length between men and women, but screws with a good design can be placed 2 mm or less under the articular surface. The maximum screw length is different when comparing different screw designs. The surgeon must be aware of the screw properties to optimize scaphoid fracture fixation. We recommend using a screw with a diameter of 3.9 mm or less with 1-mm increments and available in lengths up to 30 mm to minimize the risk of screw prominence without compromising screw length and fixation strength. Theoretically, screws placed through a dorsal approach are shorter, but when the screw complies with the aforementioned criteria, screw prominence will be avoided, and the approach depends only on the surgeon's preference.

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