

# Classification and Morphological Parameters of the Scapular Spine

## *Implications for Surgery*

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**Abstract:** Incidence of scapular spine (SS) fractures as a result of complications of reverse total shoulder arthroplasty is relatively high leading to inferior clinical outcomes and an increased risk of revision and dislocation. Fractures of SS because of trauma, including the acromion, constitute 6% to 23% of scapula fractures. The purpose of this study was to classify the SS and present specific geometrical parameters according to osteologic features. A total of 319 intact dry scapulae were collected and classified based on morphological characteristics and shape of the SS. Nine bony landmarks were also chosen and described for their relevance to regions of interest for scapular fixation. Five specific types of SS were noted and the most prevalent groups were Type 1 (Fusiform shape) (47.17%) and Type 5 (Horizontal S-shape) (19.18%). Overall, Types 3, 4, and 1 showed thicker landmark values compared to Type 5, with Type 2 having smaller values. Our classification into 5 distinct types allowed appreciation of the anatomical variance of SSs. The contours of Types 5 and 1 presented a more complex morphology and may lead to a worse surgical approach due to a fracture. As Types 2 and 5 were much thinner than the other types, these may be more susceptible to fractures.

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**Abbreviations:** SD = standard deviation, SS = scapular spine.

## INTRODUCTION

The scapular spine (SS) is a prominent plate of bone and provides elegant reinforcement to the scapula. It originates from the vertical (scapular) plane of the fossa and attaches to the scapular neck. With the worldwide application of reverse total

shoulder arthroplasty, incidence of SS fractures as a result of complications of this procedure is relatively high (0.9%–10%).<sup>1–11</sup> SS fractures are likely to propagate from a single traumatic event and often find their origin at the tip of the metaglene screw, leading to inferior clinical outcomes and an increased risk of revision and dislocation.<sup>4,5,12,13</sup> In addition, the SS has been demonstrated to be the most useful region for screw fixation for reverse total shoulder arthroplasty prosthesis on account of more bone stock and cortical thickness which increase screw pullout strength.<sup>14–16</sup> However, there exists a significant variability in SS morphology, and knowledge of shape and dimension is critically important for these procedures.

Fractures of SS including the acromion constitute 6% to 23% of scapula fractures, approximately the same frequency as glenoid fractures.<sup>17–24</sup> Direct trauma is mostly seen in high-energy injuries and in combination with other fractures.<sup>17,18</sup> The cause of indirect trauma is the violent voluntary contraction of muscles and ligaments attached to the SS, often related to stress events with coughing, cuff-tear arthropathy, work-related activities, or sporting activities such as baseball, golf, or football.<sup>19–21</sup> SS mal-union has been shown to reduce subacromial space and alter normal kinematics of the acromioclavicular and scapulothoracic joints. However, these can be corrected with subacromial opening osteotomy of the SS.<sup>25</sup> Surgical management for SS fracture is recommended especially in young, fit, and active patients.<sup>17–21</sup> During these surgical procedures, detailed knowledge of SS is fundamentally important to minimize overlying tissue irritation, aid in fracture reduction, and improve the mechanics of the bone–plate construct.

The SS has been a popular topic involved in surgical management. Quantitative and detailed knowledge of this subject is needed to ensure the best functional outcome without increasing the risk of complications. Until now, the importance of the SS seemed to have been neglected, and few studies have reported quantitative and morphological characteristics of the SS.<sup>14,15,26–28</sup> Missing anatomical information might have increased hardware removal rate rise to as high as 7.1% because of either implant-related discomfort or failure.<sup>29,30</sup> In addition, the SS has been versatile used in many areas of the body due to the ease of harvesting, minimal donor site morbidity, as well as the reliable blood supply to this bone.<sup>31–40</sup> Thus, the purpose of the current study was to classify the SS according to osteologic features on the basis of a large number of Chinese scapulae. In addition, we present specific geometrical parameters and show a comparative analysis between different types and sides of the body which is rarely reported in previous literature and useful for surgical procedures.

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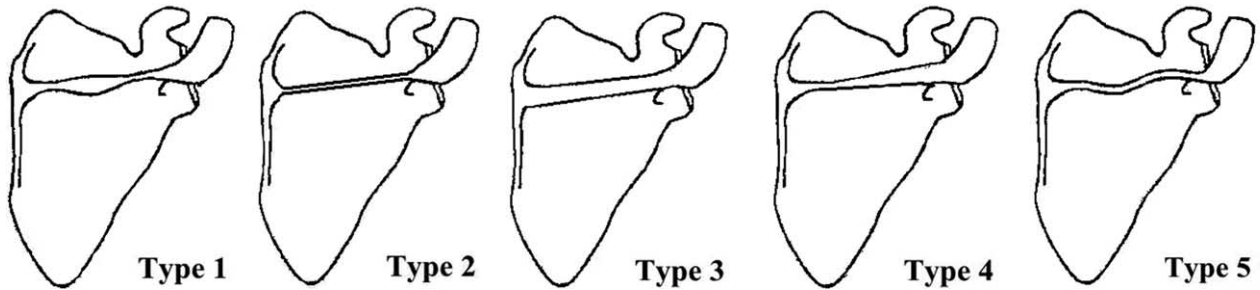
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**FIGURE 1.** Scapular spine classification schematic: Type 1-Fusiform shape (tapered at both ends and wide in the middle), Type 2-Slender rod shape (thin throughout), Type 3-Thick rod shape (thick throughout), Type 4-Wooden club shape (gradual thickening from medial to lateral edge), and Type 5-Horizontal S-shape (“S” shaped spine).

## MATERIALS AND METHODS

After ethical approval was obtained from the Human Research Ethics Committee at Southern Medical University, China, a total of 319 intact dry scapulae were obtained from adult specimens from the Department of Anatomy. These consisted on 213 left and 106 right scapulae preserved in hermetic boxes. Age and sex of donors were unknown.

### Classification of the Scapula Spine

Two investigators simultaneously classified the scapulae. Classification was based on morphological characteristics, shape, and the course of scapula spine (SS). When any disagreement arose during the observations, a 3rd investigator was consulted for a final determination. Five specific types of SS were noted: Type 1, Fusiform shape (tapered at both ends and wide in the middle); Type 2, Slender rod shape (thin throughout); Type 3, Thick rod shape (thick throughout); Type 4, Wooden club shape (gradual thickening from medial to lateral edge); and Type 5, Horizontal S-shape (“S” shaped spine). Figure 1 shows the different classifications.

### Morphometric Measurements

Morphological features of the SS were observed and measured in all scapulae. Nine bony landmarks/points were chosen for their relevance to regions of interest for scapular fixation and on their measurement reproducibility among specimens. Distances between the points were measured and compared on all left and right SS. Measurements were made using a digital Vernier caliper (Mitutoyo, Japan; accuracy up to 0.01 mm). Thickness at these locations of the spine was measured using a micrometer (Qinghai, China; accuracy up to 0.01 mm). The parameters were as follows:

AE (superior border of SS): length of SS measured from the medial edge of the scapula where it meets with the SS to the lateral edge of the acromion;

BC (lateral border of SS, spinoacromial notch): height of the spine at the lateral edge;

AC (base border of SS): distance from the medial edge of the scapula where it meets with the SS to the edge of the spinoacromial notch;

AB: length of SS measured from the medial edge of the scapula where it meets with the SS to point where BC meets with the spine;

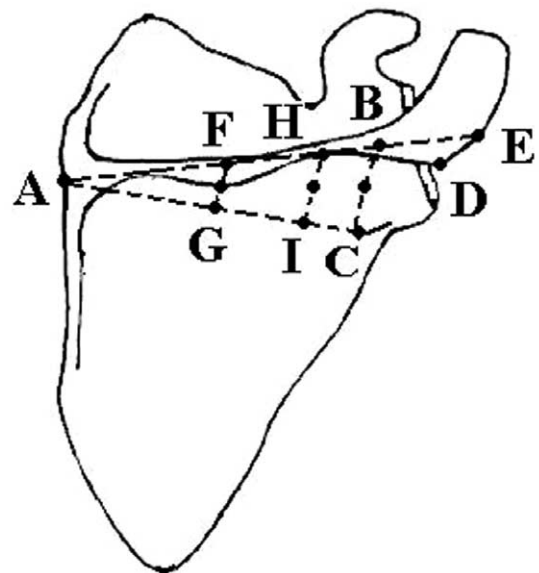
AD: length of SS measured from the medial edge of the scapula where it meets with the SS to the corner of the acromion;

FG and HI: height of the spine at point G and I; J, K, L, midpoints of FG, HI, and BC.

Figure 2 describes the location of the bony landmarks. To avoid interobserver variation, all measurements were performed twice by the same author.

### Data Analysis and Statistics

All data are presented as mean and standard deviation (SD). Descriptive statistics was used to describe demographics and measurement variables of all scapulae. Categorical variables are expressed as frequencies and percentages. ANOVA



**FIGURE 2.** Morphometric measurements: AE (superior border of scapular spine): length of scapular spine measured from the medial edge of the scapula where it meets with the scapular spine to the lateral edge of the acromion; BC (lateral border of scapular spine, spinoacromial notch): height of the spine at the lateral edge; AC (base border of scapular spine): distance from the medial edge of the scapula where it meets with the scapular spine to the edge of the spinoacromial notch; AB: length of scapular spine measured from the medial edge of the scapula where it meets with the scapular spine to point where BC meets with the spine; AD: length of scapular spine measured from the medial edge of the scapula where it meets with the scapular spine to the corner of the acromion; FG and HI: height of the spine at point G and I; J, K, L, midpoints of FG, HI, and BC.

and Student Newman–Keuls were used to compare types considering a *P*-value < 0.05 as statistically significant. The Statistical Package for Social Sciences (SPSS, Chicago, IL; version 13.0) was used for the analysis of the data.

**RESULTS**

Based on morphological classifications, Type 1-Fusiform shape (47.17%) and Type 5-Horizontal S-shape (19.18%) were the most common, followed Type 4-Wooden club shape (13.21%) and Type 3-Thick rod shape (12.58%). Type 2-Slender rod shape (7.86%) was the least common (Table 1). Figure 3 shows the different scapulae types. A unique case presenting a rough surface and abnormal ossification on the crest of the SS was found. This may be due to stress and ossification of the tendon and tendinous fibers of the trapezius muscles. The average length of AE, AC, and BC were 135.83 ± 10.33 mm, 83.27 ± 6.22 mm, and 45.60 ± 5.45 mm, respectively. AD was the shortest and significantly different in Type 2 compared to other types. AB was the shortest for the Type 1 scapulae and significantly different from other types. A complete description and summary of the results can be observed in Table 1. No difference was found between left and right scapulae (Table 2). A summary of the thickness for the bony landmarks on the SS is shown on Table 3. Landmarks B, L, C, H, K, J, and G were thicker in Types 3, 4, and 1 compared to Type 5, with Type 2 being the thinnest. Table 3 shows a complete summary of the measured data. Overall, Types 3, 4, and 1 showed thicker values than Type 5, and Type 2 the thinnest of all cases. No statistical difference was found between left and right sides of the body (Table 4).

**DISCUSSION**

In this study, we successfully classified 318 SSs into 5 types based on their morphological features. Few studies have reported morphological anatomy of SSs, and only 1 of these had a specimen population of 48.<sup>14,15,26,27</sup> Our results demonstrate that the variation of SS is not a rare occurrence. Spines were classified into Type 1-Fusiform shape, Type 2-Slender rod shape, Type 3-Thick rod shape, Type 4-Wooden club shape, and Type 5-Horizontal S-shape. Among the classified SS, Types 1 (47.17%) and 5 (19.18%) were the most common, followed Type 4 (13.21%) and 3 (12.58%), with Type 2 (7.86%) being the least common. The average length of landmarks AE, AC, and BC of the SS were 135.83 ± 10.33 mm, 83.27 ± 6.22 mm, and

45.60 ± 5.45 mm, respectively, which resemble previous published literature (133.6 ± 11.8 mm, 85.5 ± 8.7 mm, and 46.1 ± 6.3 mm, respectively).<sup>14,15,26,27</sup>

Type 5 SS classification obliquely crosses the dorsal surface of the scapula like a horizontal “S,” with a half forward cranial and the other half forward caudal. Although the other 4 types cross in a line from the vertical border to the scapular neck, the contour of Type 1 tappers at both ends with a wide middle region. Therefore, the contours of Types 5 and 1 reflect a more complex morphology than the other 4 types, eventually presenting a worse scenario with the presence of a fracture. It is an enormous challenge for the surgeon to bend and rotate the plate to fit the contour of these 2 types. Surgical time is delayed, there exists an increase in overlying tissue irritation, and it ends up aggravating the mechanics of the bone–plate construct.<sup>30</sup> Furthermore, hardware removal rate is approximately 7.1% due to either implant-related discomfort or failure.<sup>29,30</sup> Familiarizing with the morphological features may offer substantial benefits for the orthopedist in preoperative planning, and using precontoured locking plates may be an additional aid during surgery.

The SS has been usually regarded as an optimal region to support screw, pin, or wire purchase for fracture fixation stabilization because of the adequate bone stock.<sup>14,17</sup> However, our study showed that the thickness of the landmarks of Types 2 and 5 were much thinner than those of types of Types 1, 3, and 4. Similarly, besides violent voluntary contraction of muscles, it has been believed that the fragility associated to the SS was one of the main reasons of avulsion fractures.<sup>19–21</sup> Sanjay et al demonstrated high tensile and compressive stresses on the cranial and caudal sides of SSs, indicating high bending loads.<sup>41</sup> This suggests that Types 2 and 5 might be more prone to fracture than other types. Furthermore, there exists a direct relationship between an increased screw pullout strength and the stability of the implant fixture with increased cortical thickness.<sup>42,43</sup> As a result, it might be difficult to assess the fracture of the SS with internal fixation to a direct or indirect trauma associated to these 2 types.

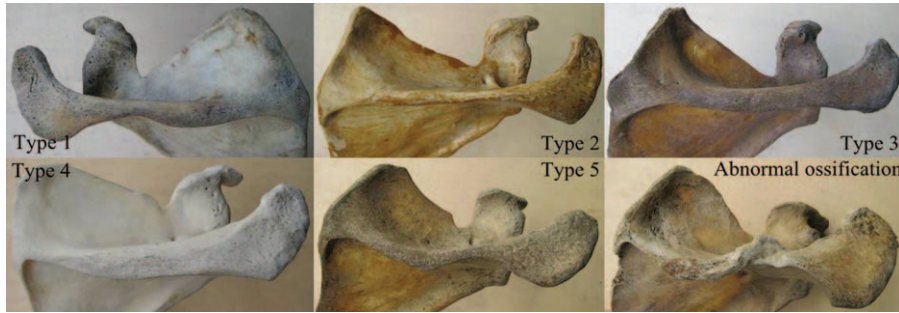
Osteoporosis has been the only clinical factor to significantly increase the risk of scapular fractures after reverse shoulder arthroplasty.<sup>11–13</sup> Although there are advantages with operative treatment, more recent research has recommended conservative management for the elderly patient with potentially osteopenic bone.<sup>5,11</sup> Recently, it has been shown that the stability of the glenoid construct would be further enhanced by placing a longer posterior glenoid screw through the

**TABLE 1.** Height, Length Distribution, and Measurements of the Scapular Spine Based on Classification

	N, %	AE, mm	AD, mm	AB, mm	AC, mm	FG, mm	HI, mm	BC, mm
Type 1	150 (47.17)	135.61 (10.35)	117.66 (9.60)	102.94 (10.69)	83.58 (6.06)	11.58 (3.21)	32.97 (5.71)	46.04 (5.16)
Type 2	25 (7.86)	134.59 (9.83)	112.40 (10.83) <sup>a</sup>	107.97 (9.44) <sup>a</sup>	85.11 (6.79)	13.11 (4.62)	34.29 (5.23)	45.85 (4.85)
Type 3	40 (12.58)	137.54 (9.71)	118.83 (10.95) <sup>b</sup>	108.43 (9.40) <sup>a</sup>	82.60 (5.39)	15.23 (4.30) <sup>a,b</sup>	35.18 (4.01)	47.96 (5.21)
Type 4	42 (13.21)	138.83 (11.28)	121.98 (10.76) <sup>b</sup>	111.45 (9.83) <sup>a</sup>	83.79 (6.26)	13.46 (4.00) <sup>c</sup>	34.12 (4.76)	41.97 (5.94) <sup>a,b,c</sup>
Type 5	61 (19.18)	133.71 (9.88)	123.16 (10.79) <sup>b</sup>	109.11 (9.87) <sup>a</sup>	81.85 (6.68)	11.65 (3.83) <sup>c</sup>	32.36 (4.90)	45.38 (5.13) <sup>d</sup>
Average	N/A	135.83 (10.33)	119.02 (10.62)	106.33 (10.65)	83.27 (6.22)	12.42 (3.90)	33.39 (5.26)	45.60 (5.45)

No statistical difference between types for AE (*P* = 0.130), AC (*P* = 0.096), and HI (*P* = 0.082). AD: Type 2 is shortest and there is no statistical difference between other types. AB: Type 1 is shortest and there is no statistical difference between other types. FG: Type 3 is largest and there is no statistical difference between other types. BC: Type 4 is shortest and there is no statistical difference between other types.

<sup>a,b,c,d</sup>Indicate significant differences (*P* < 0.05) between: <sup>a</sup>Type 1, <sup>b</sup>Type 2, <sup>c</sup>Type 3, and <sup>d</sup>Type 4.



**FIGURE 3.** Cadaveric scapular spine classification: Cadaveric scapulae based on their classification are shown together with a scapula presenting a rough surface and abnormal ossification on the crest of the scapular spine. A total of 319 scapulae were obtained and 318 were used to classify into the different types.

spinoglenoid notch and into the spine of the scapula.<sup>44–46</sup> However, the study was limited by a significant variability in bone quality and size. Our study supplements this research by not recommending the addition of a longer posterior glenoid screw for Types 2 and 5, especially Type 2, because of the preexisting thinning spine. On the other hand, the bone stock

and the thickness of the SS also have a substantial influence on the application of the osteomyocutaneous flap. Previous studies had demonstrated cortical thickness of donor bone to significantly affect stability of the fixture, known to be an important factor for osseointegration of the implant. Cancellous bone density is also an important factor related to a donor/recipient,

**TABLE 2.** Height and Length Distribution and Measurements of the Scapular Spine Based on Body Side

	N, %	AE, mm	AD, mm	AB, mm	AC, mm	FG, mm	HI, mm	BC, mm
Left	106 (33.33)	137.40 (10.14)	119.32 (10.74)	105.92 (9.63)	83.01 (5.99)	12.09 (4.20)	32.79 (5.18)	45.53 (5.79)
Right	212 (66.67)	135.05 (10.36)	118.87 (10.58)	106.54 (11.14)	83.41 (6.34)	12.59 (3.74)	33.69 (5.29)	45.64 (5.29)
Total	318 (100.00)	135.83 (10.33)	119.02 (10.62)	106.33 (10.65)	83.27 (6.22)	12.42 (3.90)	33.39 (5.26)	45.60 (5.45)

There is no statistical difference between sides of body.

**TABLE 3.** Thickness Distribution and Measurements of the Scapular Spine Based on Classification

	B, mm	L, mm	C, mm	H, mm	K, mm	I, mm	F, mm	J, mm	G, mm
Type 1	14.58 (2.12)	8.49(0.94)	14.85(2.04)	11.55(1.18)	4.68(0.88)	11.31(1.24)	6.97(2.07)	3.92(1.16)	8.31(2.10)
Type 2	6.55 (1.15) <sup>a</sup>	4.12(0.98) <sup>a</sup>	6.82(1.00) <sup>a</sup>	4.29(1.02) <sup>a</sup>	2.34(0.99) <sup>a</sup>	4.73(0.87) <sup>a</sup>	3.96(1.13) <sup>a</sup>	2.10(1.07) <sup>a</sup>	4.32(1.16) <sup>a</sup>
Type 3	13.93 (2.33) <sup>b</sup>	8.45(0.97) <sup>b</sup>	14.54(1.21) <sup>b</sup>	12.00(1.24) <sup>b</sup>	5.00(0.93) <sup>b</sup>	12.12(1.13) <sup>a,b</sup>	8.38(2.09) <sup>a,b</sup>	4.24(1.28) <sup>b</sup>	8.64(2.13) <sup>b</sup>
Type 4	15.00 (2.14) <sup>b</sup>	8.89 (1.03) <sup>b</sup>	15.08(1.30) <sup>b</sup>	12.14(1.18) <sup>b</sup>	4.66(1.02) <sup>b</sup>	11.54(1.42) <sup>b,c</sup>	6.36(2.05) <sup>b,c</sup>	4.44(1.40) <sup>b</sup>	8.56(2.06) <sup>b</sup>
Type 5	9.53 (1.10) <sup>a,b,c,d</sup>	6.61(1.20) <sup>a,b,c,d</sup>	10.10(1.16) <sup>a,b,c,d</sup>	7.19(1.29) <sup>a,b,c,d</sup>	3.05(0.99) <sup>a,b,c,d</sup>	7.20(0.97) <sup>a,b,c,d</sup>	4.52(1.52) <sup>a,b,c,d</sup>	3.11(1.11) <sup>a,b,c,d</sup>	6.15(1.54) <sup>a,b,c,d</sup>
Total	12.95(3.33)	7.83(1.67)	13.30(3.12)	10.28(2.77)	4.22(1.27)	10.14(2.60)	6.36(2.33)	3.73(1.34)	7.66(2.34)

B, L, C, H, K, J, and G: Types 3, 4, and 1 are thicker than Type 5, with Type 2 being the thinnest. F: Type 3 is thicker than Types 1 and 4, with Types 5 and 2 being the thinnest. I: Type 3 is thicker than Types 4 and 1, followed by Type 5, with Type 2 being the thinnest.  
<sup>a,b,c,d</sup>Indicate significant differences ( $P < 0.05$ ) between: <sup>a</sup>Type 1, <sup>b</sup>Type 2, <sup>c</sup>Type 3, and <sup>d</sup>Type 4.

**TABLE 4.** Thickness Distribution and Measurements of the Scapular Spine Based on Body Side

	B, mm	L, mm	C, mm	H, mm	K, mm	I, mm	F, mm	J, mm	G, mm
Left	12.78(3.26)	7.77(1.65)	13.25(3.20)	10.27(2.73)	4.18(1.29)	10.04(2.62)	6.23(2.26)	3.61(1.39)	7.44(2.33)
Right	13.03(3.37)	7.86(1.68)	13.32(3.09)	10.28(2.80)	4.24(1.26)	10.18(2.59)	6.43(2.37)	3.79(1.32)	7.77(2.35)
Total	12.95(3.33)	7.83(1.67)	13.30(3.12)	10.28(2.77)	4.22(1.27)	10.14(2.60)	6.36(2.33)	3.73(1.34)	7.66(2.34)

There is no statistical difference between sides of body.

biological response, but more importantly, to the mechanical support of the implant fixture.<sup>42,43</sup> Although the average length and height of Types 2 and 5 were similar to other types, the preexisting thinning spine and limited bone stock including cortical and cancellous bone would be limiting factors in the osseointegration and with a subsequent reduction in support force.

The SS, as an osteomyocutaneous flap, has been previously used in the reconstruction of composite defects in the mandible.<sup>31</sup> Studies have also expanded this method of reconstruction to other complex and variable defects, such as maxilla, pharyngeal, face, head, neck, humerus, and femur defects as well as trauma and congenital deformities.<sup>32–36</sup> A study by Tubbs et al<sup>38</sup> found the SS to be well-suited for posterior spinal fusion graft and successfully utilized it in posterior lumbar interbody fusion surgery. The SS has been versatile used in many areas of the body due to the ease of harvesting, minimal donor site morbidity as well as the reliable blood supply to this bone.<sup>39,40</sup> An optimal osteomyocutaneous flap needs to be long and strong for bony union, and contoured to be able to reconstruct complex 3-dimensional skeletal defects.<sup>32,33</sup> More importantly, estimating bone availability as well as familiarizing with the morphological features of the spine is essential for an appropriate contouring and fitting of the bone graft to the defects to ensure the best functional outcome.

There are several limitations to this study. First, although the SS has a very complex structure, the classification and measurements were carried out on dry specimens using a micrometer and caliper. More precise measurements could be obtained by analyzing a patient CT scan with possible 3D reconstruction models. However, these are costly and involve a significant amount of image analysis. Second, we report morphological measurements of 318 specimens of unknown sex and age that were collected from 1 university, preventing a comparison between genders and age differences. Third, as this is the first classification available on the SS according to morphological features on a Chinese population, we were unable to check the reliability and reproducibility of the classification types with other ethnic groups.

In conclusion, the present study classified and measured SS morphology on a large number Chinese specimens. Type 1 was the most common, while Type 2 was the least common. The contours of Types 5 and 1 were more complex than the other 3 types. Types 2 and 5 were much thinner than the other types; therefore, we believe these types to be more prone to fracture. The presented data provides precise and well-sorted information about SS variation and localization in a Chinese population. This supplements existing reports which contribute to a thorough understanding of the human SS.

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