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Morphological Variations in Columns of Scapula & Reverse Total Shoulder Arthroplasty

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Abstract: ***The three column concept for glenoid base - plate fixation in Reverse Total Shoulder Arthroplasty, which include the base of the Coracoid process, the scapular spine and the lateral border of scapula, provide good basis for screw fixation. However there exists a significant variability in the morphology of these three columns which can affect the outcome of the procedure and also the screw trajectory for each column, therefore knowledge of the shape is critically important for designing and fixation of prosthesis. For instance fractures of scapular spine after Reverse total Shoulder Arthroplasty is not uncommon. The purpose of this study was to classify scapular spine and coracoid process, and also morphometry of relevant geometrical parameters. A total of 100 dry scapulae, 46 left and 54 right, of unknown age and sex were obtained and classified based on morphological characteristics of scapular spine and coracoid process. Total of five morphometric parameters were chosen, three for scapular spine and two for coracoid process. As for scapular spine, total of five types were noted, type 1 (fusiform shape) was found to be 58%, type 2 (slender rod shape) 7%, type 3 (thick rod shape) 13%, type 4 (wooden club shape) 3% and type 5 (horizontal S - shape) 19%. Furthermore Type 2 and 5 of scapular spines were much thinner than the other types. As for coracoid process three morphological types were found. Type 1 (vertical '8' shaped) 45%, type 2 (long stick) 16% and type 3 (short stick) 39% with no significant statistical difference between the types 1, 2 and 3. The present study revealed anatomical variance of scapular spine and coracoid process and we presume that scapular spine types 2 and 5 may show poor surgical outcome.***

Keywords: Reverse Total Shoulder Arthroplasty, Three column concept, morphology of scapular spine, morphology of coracoid process.

1. Introduction

Aanatomical Total Soulder Arthroplasty (TSA) has been used to treat the shoulder joint with end - stage glenohumeral osteoarthritis but with an intact rotator cuff. However, loosening of the glenoid component remains a common cause of failure after TSA, leading to revision surgery in 0.8% of TSAs per year.[1 - 3] Alternatives to TSA are cup arthroplasty, hemi - arthroplasty and interpositional allografts with hemiarthroplasty. For patients with non - functional rotator cuff or with rotator cuff tear arthropathy, the traditional treatment was hemiarthroplasty. The problem with hemiarthroplasty is that the outcome is unpredictable in terms of pain relief. Secondly, with hemiarthroplasty there is little improvement in range of motions or functions.[4]

Reverse total shoulder arthroplasty (RTSA) is increasingly gaining popularity worldwide in treating various traumatic and degenerative glenohumeral diseases and irreparable rotator cuff arthropathies. The RTSA is a semi - constrained prosthesis and includes different components compared to the anatomical total shoulder arthroplasty prosthesis (ATSA). The anatomical shoulder arthroplasty consists of a concave glenoid socket and proximal humeral ball prosthesis. While in the reverse shoulder arthroplasty, the anatomy is reversed to a glenoid ball (glenosphere) and concave proximal humerus component.[5]

The scapular spine has been usually regarded as an optimal region to support screw pin because of the adequate bone stock and cortical thickness which increases screw pullout strength[6]. Incidence of scapular spine fractures as a result of the complications of the procedure is relatively high (0.9% - 10%). Scapular spine fracture are likely to propagate from a single traumatic event and often find their origin at the tip of metaglene screw, leading to inferior clinical outcomes and an increased risk of revision and dislocation.[6, 7, 8]

In 2008, Noris et al[9] popularized the three column concept for glenoid baseplate fixation in RTSA. The author conceptualized the scapula as 3 bony columns attached to the glenoid. The three columns include:
1) The Coracoid process base
2) The scapular spine
3) The lateral border of scapula

These three columns of the scapula forms the basis for screw fixation. However there exists a significant variability in the morphology of these three columns which can affect the outcome of procedure and also the screw trajectory for each column, therefore knowledge of the shape is critically important for designing and fixation of prosthesis. The present study is aimed to classify scapular spine and coracoid process in order to find out if morphology and morphometry of these columns could affect the clinical outcome and if the customization of prosthesis is required.

2. Materials and Methods

After approval from the department of Anatomy Government Medical college, Srinagar. A total of 100 dry scapulae were obtained from the department of Anatomy, GMC Srinagar. Out of 100 scapulae, 46 left and 54 right, of unknown age and sex.

Classification of scapula spine
The scapulae were classified based on their morphology and course of scapular spine. Five types of scapular spine were observed: Type - 1 (fusiform), Type - 2 (thin throughout), Type - 3 (thick throughout), Type - 4 (gradual thickening from medial to lateral edge) and type - 5 ("S" shaped spine). Hua - jun Wang et al[10] also used the same method of classification and noted the above mentioned five variants.

Morphometric measurements
Total of three morphometric parameters were used. Measurements were done using digital Vernier caliper.
1) Length of scapular spine (measured from the medial edge of the scapula where it meets with the SS to the corner of the acromion) AB.
2) Height of the spine at the lateral edge (lateral border of scapular spine) CD.
3) Thickness of lateral border of spine (Thickness of the lateral border of spine measured at midpoint) ST.

Classification of Coracoid process:
Based upon the classification of **Lei Zhang et al**[11], scapulae were classified into following five types five types. Type1 (vertical 8 - shape blunt at top and bottom), type 2 (long stick shape, the length is three times longer than the width, blunt at top and bottom, and the sunken in the middle not obvious), type 3 (short stick shape, length is less), type 4 (water drop shape, sharp at the top, blunt at the bottom and not sunken in the middle) and type 5 (wedge shape blunt at the top, sharp at the bottom and not sunken in the middle). Lei Zhang et al has also reported the above mentioned five types.

Two morphometric parameters were chosen:
1) Base length of coracoid process (PQ)
2) Base thickness of coracoid process (RS)

3. Results

Scapular spine
Five types of scapular spine were noted in the following frequency.

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) as shown in **Fig.1, 2, 3, 4 & 5** respectively**.** Type - 1 was found 58%, type - 2 was 7%, type - 3 was 13%, type - 4 was 3% and type - 5 was 19% as shown in **chart 1**.

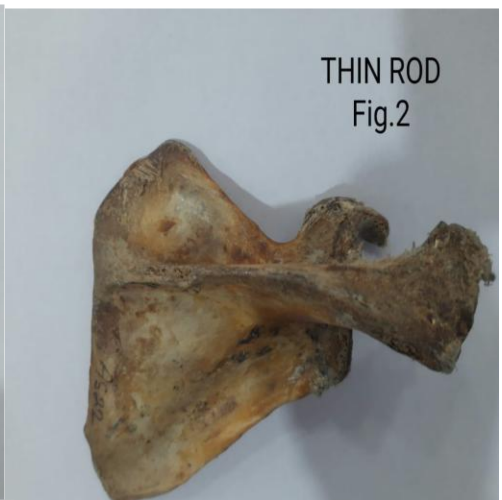
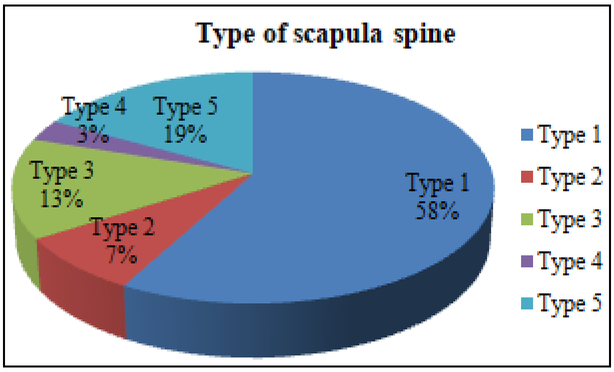


Chart 1



The average length of AB (Length of scapular spine measured from the medial edge of the scapula where it meets with the SS to the corner of the acromion), was 119.344. Average length AB was shortest in type 2 and no significant statistical difference between types 1, 3, 4 and 5, **table 1.**

Table 1

Type of Scapular Spine	AB (Average Length in mm.)
Type 1	118.32
Type 2	113.14
Type 3	119.11
Type 4	122.88
Type 5	123.36

Eight of the spine at the lateral edge (CD) (lateral border of scapular spine). Average height of the spine at the lateral edge was 46.36. CD was shortest in type 4 and no significant statistical difference between types 1, 2, 3 and 5, **table 2.**

Table 2

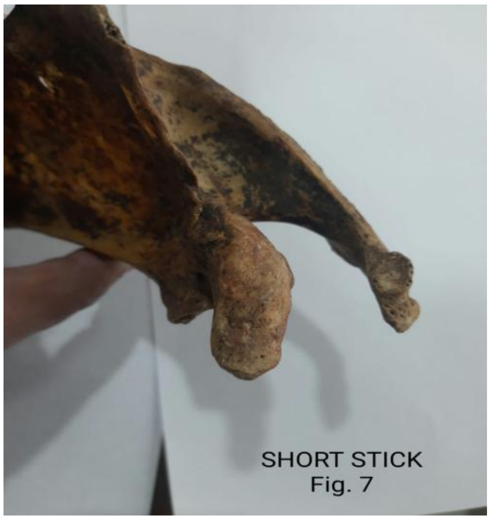
Type of scapular spine	CD (Average height of spine at the lateral edge in mm.)
Type 1	47.34
Type 2	46.85
Type 3	48.36
Type 4	42.77
Type 5	46.48

Thickness at mid point (h) of CD.
Average thickness (h) at the midpoint CD was 7.116mm. Types 3, 4 and 1 thicker than type 5 and 2, type 2 being the thinnest, **table 3**.

Table 3

Type of Scapular Spine	h (Thickness at midpoint of CD)
Type 1	7.88
Type 2	4.76
Type 3	8.12
Type 4	8.32
Type 5	6.50

Coracoid Process
Based on morphological classifications, only three morphological types were found. Type 1 (vertical '8' shaped), type 2 (long stick) and type 3 (short stick) as shown in **figs.6, 7 and 8**. Type 1 was 45%. Type 2 was 16% and type 3 was 39% as shown in **chart 2**.



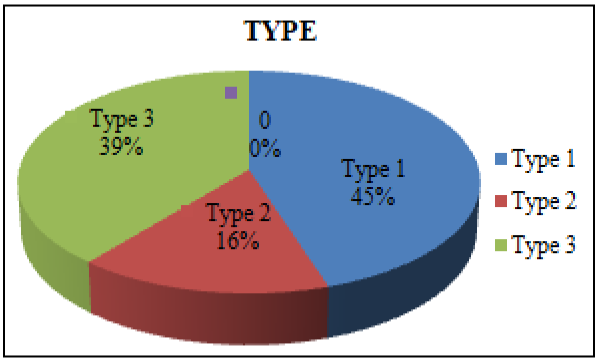


Chart 2

The average base length of coracoid process (PQ)
The average base length of coracoid process (PQ) was 26.06mm and no significant statistical difference between types 1, 2 and 3 as shown in **table 4**.

Table 4

Type of coracoid process	PQ (Average base length of coracoid process)
Type 1	25.96 mm
Type 2	25.78 mm
Type 3	26.42mm

Base Thickness of Coracoid Process (RS)
The average base thickness RS was 10.83mm, highest in type 2 followed by type 3 with an average thickness of 11.47 and 10.82 respectively, and was least in type 1 with an average thickness of 10.22, **Table 5.**

Table 5

Type of Coracoid process	RS (Base thickness of Coracoid process)
Type 1	10.22 mm.
Type 2	11.47 mm.
Type 3	10.82 mm.

Lateral border of Scapula
No obvious morphological variations were noted. The average thickness of lateral border of scapula was found to be 10.02mm.

4. Discussion

In the present study, we classified 100 scapulae on the basis of morphological features of scapular spine, into 5 types. In this study we found that Type 1 - Fusiform shape (58%), Type 2 - Slender rod shape (7%), Type 3 - Thick rod shape (13%), Type 4 - Wooden club shape (3%), and Type 5 - Horizontal S - shape (19%). **Hua - jun Wang et al**[9] aslo successfully classified 318 SSs into 5 types based on their morphological features but the frequency of the types was different. . 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. However in the present study the least common type was Type 4 - Wooden club shape. The average 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 (AB), was 119.344. Average length AB was shortest in type 2 and no significant statistical difference between types 1, 3, 4 and 5. The average height of the spine at the lateral edge (CD) was 46.36. CD was shortest in type 4 and no significant statistical difference between types 1, 2, 3 and 5. The average thickness (h) at the mid point CD was 7.116mm. Types 3, 4 and 1were thicker than type 5 and 2. Type 2 was the thinnest. It has been shown that the stability of the glenoid construct is enhanced by placing a longer posterior glenoid screw through the spinoglenoid notch and into the spine of the scapula.[12 - 14]. It is therefore assumed that Type 2 and Type 5, especially type 2 may show some disadvantages as far as the stability of the glenoid component is concerned due to their thin scapular spines. Secondly Types 2 and 5 might be more prone to fracture than other types because the fragility associated to the SS was one of the main reasons of avulsion fractures.[15 - 17] Furthermore, there exists a direct relationship between an increased screw pullout strength and the stability of the implant fixture with increased cortical thickness.[18, 19]

For base of coracoid process, only three morphological types were found in the present study. Type 1 - vertical '8' shaped (45%), type 2 - long stick (16%) and type 3 - short stick (39%). **Lei Zhang et al** [11] classified 377 scapulae (chinese population) and reported following five types. Type1 (vertical 8 - shape blunt at top and bottom), type 2 (long stick shape, the length is three times longer than the width, blunt at top and bottom, and the sunken in the middle not obvious), type 3 (short stick shape, length is less), type 4 (water drop shape, sharp at the top, blunt at the bottom and not sunken in the middle) and type 5 (wedge shape blunt at the top, sharp at the bottom and not sunken in the middle). Type I (30%) and Type III (29%) were more prevalent in China. However in present study Type 1 - vertical '8' was most prevalent (45%) while as type 2 - long stick was least prevalent (16%). *The average base length of coracoid process (PQ) was 26.06mm*andno significant statistical difference among types *1, 2 and 3.* The average base thickness RS was 10.83mm, highest in type 2 followed by type 3 with an average thickness of 11.47 and 10.82 respectively, and was least in type 1 with an average thickness of 10.22. Since no significant statistical difference was found among types 1, 2 and 3, therefore it is presumed that the type of coracoid process (type 1, 2 and 3) may not affect the surgical outcome considering three column approach in reverse total shoulder arthroplasy. For the lateral border of scapula o obvious morphological variations were noted. The average thickness of lateral border of scapula was found to be 10.02mm. Therefore lateral border of scapula may serve as reliable and more or less constant parameter as far three column approach is concerned.

5. Conclusion

In conclusion, the present study classified scapulae based upon the morphology of scapular spine and coracoid process. Types 2 and 5 of scapular spines were much thinner than the other types while as for coracoid process no significant statistical difference was found between the types 1, 2 and 3. Therefore, we presume that types 2 and 5, especially type 2 of scapular spine to be more prone to fracture in three column approach for reverse total shoulder Arthroplasty.

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