VOLUME - 10, ISSUE - 09, SEPTEMBER - 2021 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper | Radiology

ROLE OF 3D CT SCAN IN QUANTIFYING GLENOID BONE LOSS IN RECURRENT UNILATERAL SHOULDER DISLOCATION

Dr. Shivprasad Jaybhay* DMRD, DNB Radiodiagnosis. Assistant Professor, Department Of Radiodiagnosis, Government Medical College, Nagpur, India. *Corresponding Auhtor

Dr. Madhuri Misal BDS, MPH Resident, Government Medical College, Nagpur, India.

ABSTRACT

Purpose: Patients with recurrent shoulder instability often present with osseous injury to the glenoid and humeral head. Glenoid bone loss can easily be quantified on a three-dimensional computed tomography scan by modeling the inferior portion of the glenoid contour as a true circle on an en face view. This study investigated the accuracy of CT in determining the presence and severity of glenoid bone loss in patients with unilateral recurrent shoulder dislocation.

Methodology: This prospective cross-sectional study was done among patients with unilateral recurrent shoulder dislocation. Forty patients with anterior shoulder dislocation underwent shoulder CT examination before arthroscopy.

Results: Glenoid bone loss was evident in 38 (95%) of the 40 patients at arthroscopy. Compared with arthroscopy, CT had sensitivity in detecting glenoid bone loss of 92.1%; specificity, 100%; positive predictive value, 100%; and negative predictive value, 40.0%. Three false-negative CT assessments had 5%, 5%, and 20% glenoid bone loss, respectively, at arthroscopy. There was a strong correlation between CT and arthroscopy with respect to the severity of glenoid bone loss ($r = 0.73$).

Conclusion: CT has both a high sensitivity and a high specificity for detecting glenoid bone loss, and agreement with arthroscopy regarding the severity of glenoid bone loss is good. CT can be used to assess glenoid bone loss and the need for bone augmentation surgery.

KEYWORDS : Shoulder dislocation, MRI shoulder, Diagnostic arthroscopy

INTRODUCTION

Glenohumeral instability refers to symptomatic subluxation or dislocation of the humeral head in relation to the glenoid fossa. Anteroinferior instability is the most common type to involve the glenohumeral joint, occurring in 95% of all patients. [1].

Patients with recurrent shoulder instability often present with osseous injury to the glenoid and humeral head. After the initial traumatic shoulder dislocation, an associated glenoid rim fracture or attritional bone injury may compromise the static restraints of the glenohumeral joint, making further instability more likely. With recurrent instability, there can be further attritional glenoid bone loss. Glenoid bone deficiency with recurrent shoulder instability is an increasingly recognized cause of failed shoulder stabilization surgery.

Therefore, understanding and appropriately addressing irregularities in the osseous architecture of the glenohumeral joint are critical to the overall success of surgical repair for the treatment of glenohumeral instability. Appropriate preoperative imaging is essential for detection and quantification of osseous abnormalities in patients with recurrent shoulder instability. It is often difficult to visualize and quantify osseous glenoid lesions with radiographs even if specialized views that enhance the detection of osseous Bankart lesions are used. The commonest pre-operative investigation for anterior shoulder instability is often MRI which may fail to accurately assess the glenoid bone loss.

A good quality 3D MULTI SLICE CT with humeral head subtraction can evaluate this lesion overtly. Glenoid bone loss can easily be quantified on a three-dimensional computed tomography scan by modeling the inferior portion of the glenoid contour as a true circle on an en face view [2,3]. Different methods of quantification of glenoid bone loss using measurements obtained from this model have been widely published.

Arthroscopy, used for estimating glenoid bone loss is also based on the fact that the inferior two-thirds of the glenoid cavity is circularly shaped [2,4]. Arthroscopic methods of quantification utilize the glenoid bare spot as a geometrical reference point, the percentage of glenoid bone loss is calculated by measuring the anterior and posterior distances to the glenoid rim [4,5].

Considering this background, this study was done to estimate the accuracy of CT in determining the presence and severity of glenoid bone loss in patients with unilateral anterior shoulder dislocation. The specific objectives of the study were to quantify glenoid bone loss using various CT methods and compare these findings with arthroscopic estimation of glenoid bone loss.

MATERIAL AND METHODS

The institutional ethics committee approval was obtained before starting the study. It was a prospective cross-sectional study conducted among patients with unilateral recurrent anterior dislocation of the shoulder joint in a tertiary care teaching hospital from over a period of three years.

All patients with anterior shoulder dislocation with at least one previous radiographically documented dislocation visiting the orthopedics OPD during the study period were included. Whereas, patients with bilateral shoulder dislocations, patients with an interval of more than 60 days between CT and scheduled arthroscopy and patients who did not consent to participate in the study were excluded.

The patients fulfilling the inclusion and exclusion criteria were enrolled for the study. These patients underwent CT examination and arthroscopy to estimate the glenoid bone loss.

CT Assessment

Each patient underwent simultaneous CT examination of both shoulders with arms positioned by the chest wall on an MDCT scanner (Siemens SOMATOM Sensation 64 slice MDCT). The protocol included 64 x 0.6 mm acquisitions with 220 mAs, 120 kV, and a pitch of 1.2. The scanning plane extended from the acromion to just below the glenoid. Double oblique reconstruction of each glenoid was used to obtain oblique sagittal images en face to the glenoid articular surface

(Advantage Windows, SOMATOM version, Siemens). On this image, a line was drawn along the long axis of the glenoid (glenoid length). The width of the glenoid was measured at right angles to this long axis through the mid portion of the inferior glenoid. The intersecting point of long axis and the widest anteroposterior distance of the glenoid in its inferior two third region was identified as the Bare spot. The glenoid shape and the measurements of the glenoid bare spot from the anterior, posterior and inferior glenoid margins were determined. The surface area of the glenoid including the coracoid process is measured on both sides.

Glenoid bone loss was quantified using various methods The Pico method [6], Glenoid Bare Spot method [7] and Ratio method [8].

Two new methods were used in the quantification of glenoid bone loss using the glenoid width and surface area of the glenoid. In the new glenoid width method, the width was calculated at same height from inferior glenoid margin on both affected as well as contralateral normal side. The percentage of glenoid bone loss was calculated as the difference in glenoid width compared with the width of the normal non dislocating glenoid. In the other new method, the surface area of the glenoid along with adjacent contiguous coracoid process on the CT image was calculated. The percentage of glenoid bone loss was calculated as the difference in glenoid surface area compared with the surface area of the normal non dislocating glenoid with coracoid. [Figure 1A].

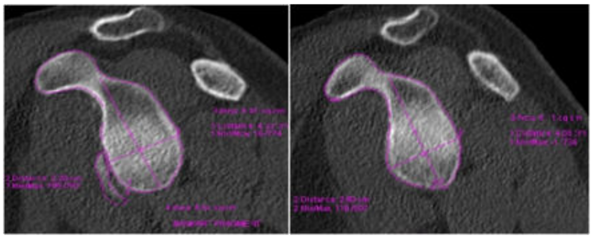


Figure 1A-E: Measurement of glenoid bone loss in 37 Y/ M with recurrent right shoulder dislocation (5 times) by various methods

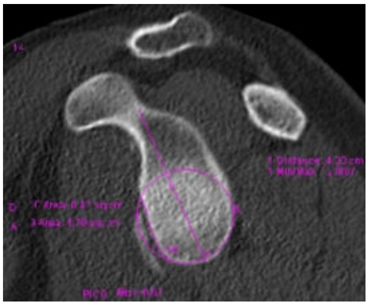
1A: Glenoid width (GW) method; 1B: Glenoid surface area (GSA) method

% Bone loss (GW) = Unaffected GW-Affected GW/Unaffected Gwx100;

% Bone loss (GSA) = Unaffected GSA-Affected GSA/ Unaffected GSAx100

1C: Glenoid bare spot method- % glenoid bone loss = B-A/2Bx100; Distance of bare spot from anterior (A) & posterior (B) glenoid margins.

1D: Ratio method- % Bone loss = 1/



1E: Pico Method-

% glenoid bone loss= D/Ax100;

D- Area of glenoid defect remaining from the best fit circle;

A- Area of true best fit circle superimposed on the affected glenoid

Arthroscopic Measurement

Diagnostic arthroscopy of the patients was performed using a 4-mm arthroscope. An arthroscopic calibrated probe was used to determine and quantify the degree of anterior glenoid bone loss with reference to the central bare spot of the glenoid. The tip of the probe was first placed against the posterior glenoid margin, then against the bare spot in the middle of the inferior glenoid, and finally against the anterior glenoid margin. Care was taken to pass the probe perpendicular to the long axis of the glenoid. Measurements of glenoid bone loss are reported in intervals of 5%.

For this study, written informed consent was taken from the patients. The patients were free to leave the study at any point of time and their refusal to participate did not affect the treatment they received at the hospital.

STATISTICAL ANALYSIS

Data was analyzed using SPSS Statistics software version 21. T test was used to test the difference between means. Pearson's correlation coefficient was used to examine the correlation between CT and arthroscopy in quantifying the percentage of glenoid bone loss. The sensitivity, specificity, and positive and negative predictive values, false negative and false positive rate of CT in detecting glenoid bone loss were calculated considering arthroscopic findings as the gold standard.

RESULTS

Total 41 patients with anterior shoulder dislocation underwent CT examination before with measurement of glenoid loss. One patient did not undergo arthroscopy at this hospital, so data of 40 patients was analyzed for this study.

The mean age of study patients was 33.55 ± 11.92 years [Range 12 – 63 years]. Among the patients, 32 (80.0%) were male and 8 (20.0%) were female. Eleven (27.5%) patients had shoulder dislocation on the left side and 29 (72.5%) had it on the right side. The median number of shoulder dislocations the patients have had was 5 (IQR 3 - 9) with a minimum of 2 and maximum of 60.

The various glenoid measurements of the shoulder affected with recurrent dislocations and contralateral normal shoulder are given in Table 1. The mean glenoid width and distance between bare spot and anterior margin were significantly shorter in the affected shoulder ($p<0.001$). The glenoid width to length ratio was also lower in the affected shoulder ($p=0.002$).

Table 1: Comparison of glenoid measurements of normal and affected shoulders

	Normal shoulder	Affected shoulder	p value

Glenoid length (cm)	4.49 ± 0.50	4.40 ± 0.48	0.401
Glenoid Width (cm)	2.53 ± 0.23	2.31 ± 0.31	<0.001
Width to Length ratio	0.567 ± 0.05	0.527 ± 0.06	0.002
Bare spot to anterior margin (cm)	1.23 ± 0.13	1.01 ± 0.27	<0.001
Bare spot to posterior margin (cm)	1.31 ± 0.14	1.33 ± 0.16	0.566
Bare spot to inferior margin (cm)	1.40 ± 0.21	1.44 ± 0.23	0.402
Glenoid+ Coracoid Surface Area (cm^2)	9.97 ± 1.85	9.34 ± 1.73	0.264

Out of 40 patients, 38 (95.0%) had glenoid bone loss on arthroscopy and 2 (5.0%) did not. Glenoid bone loss on arthroscopy showed significant correlation with age of the patients (r = 0.386) and frequency of dislocation (r = 0.570).

On CT assessment, glenoid bone loss was seen in 33 (82.5%) patients by Pico method, 37 (92.5%) patients each by GBS and Ratio method and 35 (87.5%) cases on Glenoid Width method. In newer method, the actual glenoid bone loss was seen in 30 cases based on the surface area alone while the detection increased to 37 cases in combined method.

Various 3D CT methods of glenoid bone loss quantification were compared with arthroscopy. [Table 2]

Table 2: Comparison of glenoid bone loss measured using various CT methods and arthroscopy

Methods	**Glenoid bone loss on arthroscopy**		**Total**
	Present n = 38	Absent n = 2	
Pico method			
Bone loss present	33 (86.8%)	0 (0.0%)	33 (82.5%)
Bone loss absent	5 (13.2%)	2 (100%)	7 (17.5%)
Glenoid Bare Spot method			
Bone loss present	36 (94.7%)	1 (50.0%)	37 (92.5%)
Bone loss absent	2 (5.3%)	1 (50.0%)	3 (7.5%)
Ratio method			
Bone loss present	36 (94.7%)	1 (50.0%)	37 (92.5%)
Bone loss absent	2 (5.3%)	1 (50.0%)	3 (7.5%)
New methods			
Glenoid Width method			
Bone loss present	35 (92.1%)	0 (0.0%)	35 (87.5%)
Bone loss absent	3 (7.9%)	2 (100%)	5 (12.5%)
Surface area method			
Bone loss present	30 (78.9%)	1 (50.0%)	31 (77.5%)
Bone loss absent	8 (21.1%)	1 (50.0%)	9 (22.5%)

Using the Pico method for glenoid bone loss, 5 false-negative cases were seen. Bone loss on arthroscopy was 5% in 3 and 10%, and 20% in one patient each. No false-positive cases were shown by Pico method. There was a strong correlation between CT and arthroscopy with respect to the severity of glenoid bone loss (r = 0.75).

Two false-negative CT assessments identified with the Glenoid bare spot [GBS] method had 5%, and 10% glenoid bone loss, respectively, at arthroscopy. There was 1 false-positive CT assessment with this method with 3.4% bone loss by GBS method and none on arthroscopy. Glenoid bone loss showed a strong correlation between measurement by GBS method and arthroscopy (r = 0.86).

Similarly, the Ratio method also showed 2 false-negative and 1 false-positive CT assessment. One patient had 1.2% glenoid bone loss on CT by Ratio method, although no bone loss was apparent on arthroscopy. There was a strong correlation between CT and arthroscopy with respect to the severity of glenoid bone loss (r = 0.85).

Using the new glenoid width method, 2 false-negative patients had 5% and 1 false negative patient had 20% glenoid bone loss on arthroscopy. No false-positive cases were identified on CT. Glenoid bone loss quantification using this method was strongly correlated with arthroscopy findings (r = 0.73).

The new surface area method of glenoid bone loss quantification on 3D CT showed 8 false-negative assessments with bone loss of 5% (4 patients), 10% (2 patients), and 20% (2 patients) on arthroscopy. One false-positive CT assessments had 2.6% glenoid bone loss on CT, although no bone loss was apparent at arthroscopy. There was a moderate correlation between CT & arthroscopy with respect to the severity of glenoid bone loss (r = 0.51).

The correlation plots for all these CT assessment methods are given in Figure 2.

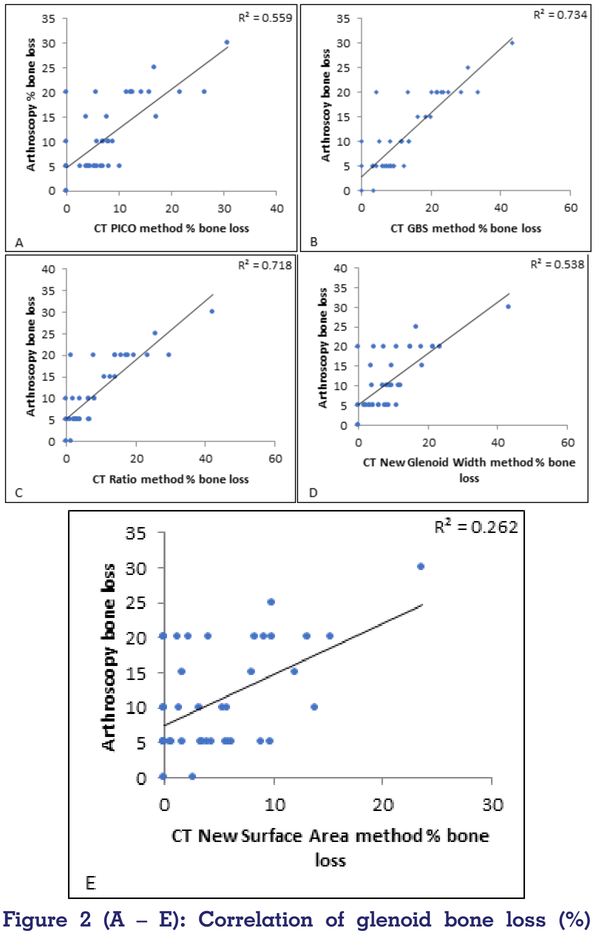


Figure 2 (A – E): Correlation of glenoid bone loss (%) measured by Various CT assessment methods and by arthroscopy

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), false positive rate and false negative rate of CT methods is given in Table 3.

Table 3: Measures of diagnostic accuracy of various CT methods compared with arthroscopy

	Sensitivity	**Specificity**	**Positive predictive value**	**Negative predictive value**	**False negative rate**	**False positive rate**
PICO method	86.8%	100%	100%	28.6%	13.2%	0.0%
Glenoid Bare Spot method	94.7%	50.0%	97.3%	66.7%	5.3%	50.0%
Ratio method	94.7%	50.0%	97.3%	66.7%	5.3%	50.0%

New methods						
Glenoid width method	92.1%	100%	100%	40%	7.9%	0.0%
Surface area method	78.9%	50.0%	96.8%	11.1%	21.1%	50.0%

DISCUSSION

Identification and quantification of glenoid bone loss are useful because that information helps to predict the likelihood of further dislocation and to determine the need for bone augmentation surgery to restore shoulder stability [3, 9]. Several recent studies deal with the quantification of glenoid rim defects show that CT is a reliable means of quantifying glenoid bone loss [3, 9, 10].

In our study, we did quantitative comparison of the glenoid bone loss using various methods which were independent of the opposite shoulder and that were dependent on contralateral normal shoulder as well as other methods with arthroscopy as the gold standard.

We found that, the Pico method had lower sensitivity in detecting bone loss even when bone loss as high as 10% or 20% was present. The GBS method overestimates the glenoid bone loss due to slightly off-center and anterior position of the bare spot when compared with distance from the anterior and posterior glenoid margins, although it was closest and on a higher side of the bone loss calculated by arthroscopy due to same parameter (bare spot in both methods). Similar is the case with Ratio method.

We introduced newer methods comprising of calculating glenoid widths on both dislocated shoulder and contralateral normal shoulder as well as the surface areas of the glenoid along with the coracoid process visible on the sagittal en face image contiguous with the glenoid. This was based on assumptions that adequate quantification of the bone loss using CT scans of the affected shoulder only is difficult because it is not known how much bone was present before trauma [11-13] and that two scapulae are comparable with each other for side-to-side variability with no significant difference between the two. [9,14].

Griffith et al. [5, 9] developed an adequate method for quantification of bony Bankart lesions using CT of both shoulders with direct comparison of a variety of measuring parameters. They reported decreased maximum glenoid width and decreased maximum width-to-length ratio to be the most useful parameters of bone loss [5]. In 2007, Griffith's study referred to true glenoid bone loss only after fulfillment of two criteria on CT examination [5] presence of an anterior straight line and, a relative reduction in glenoid width compared with the normal contralateral side. Griffith et al., however, considered the cross-sectional area to be a less useful parameter, although this parameter differed significantly between normal and dislocated shoulders. An approach for imaging bone loss similar to the one used in Griffith's study was used in a recent article by Scalise et al. [15] where the whole scapula was superimposed to the contralateral side.

In our study, the comparison of the glenoid width was measured at same height from inferior glenoid margin on both affected as well as contralateral normal side. We found that the glenoid width at same height was the best method of accurate glenoid bone loss quantification with a high sensitivity and specificity. Glenoid bare spot was not in the centre and/ or equidistant from the anterior and posterior as well as inferior glenoid margins. The best fit circle approximating bare spot as a center wasn't always possible attributable to bare spot not being equidistant from the posterior and inferior glenoid margins & the variable shape of glenoid on either side precluding its superimposition in pico method.

The newer glenoid width as well as the glenoid surface area method did not take into consideration the bare spot and its position from the posterior and anterior glenoid margins. However, the affected shoulder glenoid including the visible coracoid surface area was larger than the normal uninvolved glenoid in 8 cases. The widest antero-posterior dimensions of glenoid on en face oblique sagittal reformatted image with subtraction of the humeral head of the affected shoulder was larger even when significant bone loss was present on arthroscopy in 1 case. Similarly, Griffith et al., using the maximum glenoid width method, showed that CT has a high sensitivity and specificity for detecting the presence of glenoid bone loss evident at arthroscopy and a strong correlation (r=0.79) between CT and arthroscopy findings. [5].

The new method of quantifying bone loss utilizing glenoid surface area including the coracoid process on the sagittal image contiguous with the glenoid and compared with the opposite side showed moderate correlation with the severity of the bone loss but with lower sensitivity and specificity. This was based on assumption to make an attempt to reduce the error occurring due to inherent asymmetry in the size of the glenoid when calculations were made based on the difference between the glenoid widths alone.

The main limitations in using CT for assessment of glenoid bone loss are additional radiation exposure which could be minimized by limiting the scanning plane to include both glenoid only, inherent error caused by known side-to-side variation in normal glenoid which, however, has been shown to be small [3], and the extra time, cost, and effort are needed to include a CT examination in the imaging algorithm for shoulder instability [9]. Further study may enable selection of patients most likely to benefit from the additional CT examination based on appearances at MR examination. Glenoid bone loss is normally characterized by a relatively smooth anterior straight edge or smooth anterior concavity to the glenoid. As with any other quantitative approach, it is likely that measuring more difficult and inaccurate when the method is applied to small glenoid rim defects.

Arthroscopic assessment, used as the gold standard in this study, is not the ideal gold standard for reasons such as possibility of bare spot being an area rather than a spot, calibrated probe being inserted via the posterior portal may not always be aligned at right angles to the long axis of the glenoid and difficulty in counting the finely spaced lines on the calibrated probe resulting in approximations. [16]

CONCLUSION

The diagnosis and management of glenoid bone loss in patients with recurrent shoulder instability continue to evolve. The finding of glenoid bone loss should be suspected in a patient with a prolonged history of instability, multiple dislocations, a progressive ease of dislocation, and symptoms of humeral head engagement. Multiple radiographic studies for evaluation of glenoid bone loss are available; however, the three-dimensional reformatted computed tomography scan provides the most accurate assessment of bone deficiency or combined glenoid and humeral head defects. CT has both a high sensitivity and a high specificity for detecting glenoid bone loss. CT can be used to assess glenoid bone loss and the need for bone augmentation surgery.

REFERENCES

1. Ly JQ, Beall DP, Sanders TG. MR imaging of Glenohumeral instability. AJR Am J Roentgenol 2003;181:203–13.

2. Huysmans PE, Haen PS, Kidd M, Dhert WJ, Willems JW. The shape of the inferior part of the glenoid: a cadaveric study. J Shoulder Elbow Surg. 2006;15:759-63.
3. Sugaya H, Moriishi J, Dohi M, Kon Y, Tsuchiya A. Glenoid rim morphology in recurrent anterior glenohumeral instability. J Bone Joint Surg Am. 2003;85:878-84.
4. Barchilon VS, Kotz E, Barchilon Ben-Av M, Glazer E, Nyska M. A simple method for quantitative evaluation of the missing area of the anterior glenoid in anterior instability of the glenohumeral joint. Skeletal Radiol. 2008;37:731-6.
5. Griffith, J.F., Yung, P.S., Antonio, G.E., et al. (2007). CT compared with arthroscopy in quantifying glenoid bone loss. American Journal of Roentgenology, 189, 1490-1493.
6. Baudi P, Righi P, Bolognesi D, Rivetta S, Rossi Urtoler E, Guicciardi N, Carrara M. How to identify and calculate glenoid bone deficit. Chir Organi Mov. 2005;90: 145-52.
7. Sugaya H, Moriishi J, Kanisawa I, Tsuchiya A. Arthroscopic osseous Bankart repair for chronic recurrent traumatic anterior glenohumeral instability. J Bone Joint Surg Am. 2005;87:1752-60.
8. Barchilon VS, Kotz E, Barchilon Ben-Av M, Glazer E, Nyska M. A simple method for quantitative evaluation of the missing area of the anterior glenoid in anterior instability of the glenohumeral joint. Skeletal Radiol. 2008;37:731-6.
9. Griffith JF, Antonio GE, Tong CWC, Ming CK. Anterior shoulder dislocation: quantification of glenoid bone loss with CT. AJR 2003; 180:1423–1430.
10. Saito H, Itoi E, Sugaya H, Minagawa H, Yamamoto N, Tuoheti Y. Location of the glenoid defect in shoulders with recurrent anterior dislocation. Am J Sports Med. 2005 Jun;33(6):889-93. Epub 2005 Apr 12.
11. Warner JJ, Gill TJ, O'hollerhan JD, Pathare N, Millett PJ. Anatomical glenoid reconstruction for recurrent anterior glenohumeral instability with glenoid deficiency using an autogenous tricortical iliac crest bone graft. Am J Sports Med. 2006;34: 205-12.
12. Chen AL, Hunt SA, Hawkins RJ, Zuckerman JD. Management of bone loss associated with recurrent anterior glenohumeral instability. Am J Sports Med 2005; 33:912–925.
13. Churchill RS, Brems JJ, Kotschi H. Glenoid size, inclination, and version: an anatomic study. J Shoulder Elbow Surg 2001; 10:327–332.
14. Von schroeder hp, kuiper sd, botte mj. Osseous anatomy of the scapula. Clin orthop relat res 2001; 383:131–139.
15. Scalise JJ, Bryan J, polster j, Brems JJ, Iannotti JP. Quantitative analysis of glenoid bone loss in osteoarthritis using 3d ct scans. J shoulder elbow surg 2008; 17:328–335.
16. Tena-Arregui J, Barrio-Asensio C, Puerta-Fonolla J, et al. Arthroscopic study of the shoulder joint in fetuses. Arthroscopy 2005;21(9):1114.