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Original article

Effect of subcritical glenoid bone loss on activities of daily living in patients with anterior shoulder instability

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ABSTRACT

Background: It has been biomechanically demonstrated that 20% to 25% is a critical glenoid bone loss. Recently, there are several reports describing that a bone loss less than 20% to 25% needed to be treated because patients may have decreased quality of life without recurrent instability events. The purpose of this study was to clarify the presence of subcritical bone loss that would affect postoperative instability or quality of life.
Methods: Subjects were 43 patients aged ≤ 40 years with less than 25% glenoid bone loss who had undergone arthroscopic Bankart repair. These patients were assessed at a mean follow-up of 32 months. The Western Ontario Shoulder Instability (WOSI) and Rowe scores were used for the clinical evaluation. Patients were divided in 3 groups based on the percentage of bone loss: group 1: < 8%; group 2: 8% to 17%; and group 3: > 17%.
Results: The recurrence rate was 7% (3/43 shoulders). A weak negative correlation was seen between bone loss and sports/recreation/work domain of the WOSI score ($r = -0.304$, $p = 0.0191$). The WOSI for group 3 was significantly lower than that for group 1 and 2 ($p = 0.0009$). The male WOSI scores were significantly lower than the female ones ($p = 0.0471$). The WOSI scores of the contact athletes were significantly lower than those of non-contact athletes ($p = 0.0275$). All the patients in Group 3 were males and participated in contact sports.
Conclusion: Glenoid bone loss between 17% and 25% is considered to be a "subcritical bone loss" in our series, especially in male patients who are involved in sports or high-level activities.
Level of evidence: III, retrospective study.

1. Introduction

It is well known that a glenoid bone loss is a common injury in association with traumatic anterior shoulder instability. Several biomechanical studies [1–3] demonstrated that a glenoid bone loss greater than 25% of the glenoid width known as a critical bone loss needed to be treated by bone-grafting because arthroscopic Bankart repair alone was not enough. Clinically, it has been reported that shoulders with a glenoid bone loss of greater than 25% showed a high failure rate after arthroscopic stabilization [4–6]. There is still a controversy as to whether a glenoid bone loss less than 25% should be treated. A recent clinical report by Shaha et al. [7] showed that bone loss of 13.5% to 20% led to a clinically significant decrease in their quality of life consistent with an unacceptable outcome, even though the patients did not sustain a recurrent instability. They proposed that such a bone loss be treated as a "subcritical bone loss". After their report, several authors reported a "subcritical bone loss" [8–10]. Also, a most recent clinical study [11] indicated that a bone loss of 17.3% or more should be considered as the critical size that may result in recurrent instability after surgery. Thus, we need to re-consider the threshold of glenoid bone loss. The subcritical bone loss reported by Shaha et al. [7] was observed in military patients with high activity level. We hypothesized that the subcritical bone loss concept would be applicable only to those with high activity level. The purpose of this study was to determine the effect of glenoid bone less than 25% on the stability and quality of life based on patients' activity level.

2. Subjects and methods

Seventy-two consecutive patients with anterior dislocation of the shoulder underwent arthroscopic Bankart repair in our institution and affiliated hospitals between 2010 and 2015. Of these, 43

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Table 1
WOSI score before and after surgery.

	Before surgery	After surgery		p-value[a]
		1 year	2 years	
WOSI score (%)				
Total	49.9 ± 19.3	72.2 ± 17.9	78.3 ± 20.3	<0.001
Physical	65.9 ± 11.1	75.8 ± 8.1	80.7 ± 6.4	0.0341
Sports/recreation/work	50.5 ± 38.0	77.2 ± 19.5	79.0 ± 25.2	0.0272
Lifestyle	41.0 ± 22.2	68.0 ± 22.7	68.7 ± 25.0	0.0160
Emotion	47.7 ± 25.5	72.5 ± 22.2	77.2 ± 22.0	0.0047

WOSI: Western Ontario Shoulder Instability.
[a] Comparison of WOSI scores before surgery with those 2 years after surgery.

patients who met the following inclusion criteria were retrospectively reviewed:

- a Bankart lesion or its variants was confirmed during surgery;
- a minimum follow-up of 2 years.

Exclusion criteria were:

- patients with a glenoid bone loss of greater than 25% of the glenoid width;
- patients with an off-track Hill–Sachs lesion [12];
- patients with bilateral shoulder dislocation;
- revision Bankart repairs;
- patients older than 40 years.

Patients older than 40 years were excluded because their postoperative outcomes were likely to be affected by other factors such as rotator cuff lesions. The mean follow-up was 32 months (range: 24–60 months). This study was approved by our institutional review board.

2.1. Measurement of glenoid bone loss

Bone loss was measured on three-dimensional-computed tomography (3D-CT) images using the contralateral comparison method. The width of both the injured and uninjured glenoid was measured with use of the scale available on the CT monitor screen. Then, the injured glenoid width (d) was subtracted from the uninjured contralateral glenoid width (D), which was the width of glenoid bone loss. The percent of bone loss was calculated as $(D - d)/D \times 100$ [13]. To clarify the threshold of the subcritical bone loss, patients were divided in 3 groups based on the percentage of bone loss: group 1: <8%; group 2: 8% to 17%; and group 3: >17%. These values were chosen from the previous biomechanical studies [1–3], which showed that more than 25% was unstable, and less than 17% was stable in a cadaveric model after Bankart repair.

2.2. Arthroscopic Bankart repair and postoperative management

Arthroscopic Bankart repair was performed by two senior surgeons with the patient in a beach chair position. Bioabsorbable suture anchors (Gryphon anchor, DePuy Mitek, Norwood, MA and Osteoraptor HA curved, Smith & Nephew, Andover, MA) were used. The arthroscopic technique included a minimum of 3 anchors (mean: 4.1) and a routine incorporation of capsular plication as previously reported [14,15]. When there was greater anterior laxity of the glenohumeral joint (11 shoulders) under anesthesia compared with the contralateral side, the rotator interval closure was added. SLAP repair was performed in 5 shoulders. Remplissage procedure was not performed. The same rehabilitation protocol was used including 3 weeks of sling immobilization. The arm was free to move for activities of daily living, and active-assisted shoulder range of motion exercises were initiated. Full participation in sports was permitted after 6 months.

2.3. Clinical evaluation

At one- and two-year follow-up, patients underwent physical examination of the shoulder to complete the Rowe score. To evaluate patient's symptoms and their effects on physical activity and quality of life, we used the Western Ontario Shoulder Instability Index (WOSI), which was a questionnaire as a disease-specific quality-of-life scoring system for shoulder instability [16]. The WOSI contains 21 questions in 4 domains: physical symptoms, sports/recreation/work, lifestyle, and emotions. Scores for each domain were expressed on a scale of 0% to 100%, with higher scores being more favorable.

2.4. Statistical analyses

The paired *t*-test was used to compare the differences between the preoperative and final follow-up scores of the Rowe and WOSI. Comparison of the WOSI with the bone loss was performed by calculating the Pearson's correlation coefficient. Differences of the WOSI scores and recurrence rate among groups were assessed using the one-way analysis of variance (ANOVA) followed by a Tukey–Kramer HSD test. To identify the factors affecting the WOSI scores, a logistic regression analysis was performed using the following factors as explaining variables: age, gender, hand dominance, type of sports (contact or non-contact), and bone loss size. JMP statistical software (SAS Institute, Cary, NC) was used for all statistical analyses, with the α level set at 0.05.

3. Results

The mean age at the time of surgery was 26 years (range: 16–38). There were 30 males and 13 females. Twenty-eight patients (65%) were involved in sports activities. Twenty-five had dominant side involved and 18 non-dominant side. The mean (±SD) bone loss of the glenoid was 7.7% ± 5.3% (range: 0.4%–19.5%). The recurrence rate after surgery was 7% (3/43 shoulders). All three patients had injury during sports activity. The bone losses of these recurrent cases were 3.1%, 10%, and 18.6%, respectively and their WOSI scores were 46.5%, 66.2%, and 32.2%, respectively. The Rowe score significantly improved from 44.1 ± 5.3 preoperatively to 91.8 ± 6.8 at the final follow-up ($p < 0.05$). The WOSI score significantly increased from 49.9% ± 19.3% preoperatively to 78.3% ± 20.3% at the final follow-up ($p < 0.001$) (Table 1). There was no significant difference between WOSI score at one- and two-year follow-up. A significant correlation between glenoid bone loss and total WOSI score was not found but the subdomain analysis revealed that there was a weak negative correlation between the size of bone loss and sports/recreation/work domain of the WOSI score ($r = -0.304$, $p = 0.0191$) (Table 2). Group 1 ($n = 26$) had

Table 2
Relationship between bone loss and WOSI score.

WOSI score	Coefficient correlation	*p*-value
Total	−0.175	0.41
Physical	−0.244	0.21
Sports/recreation/work	−0.389	0.045[a]
Lifestyle	−0.124	0.53
Emotion	−0.137	0.48

WOSI: Western Ontario Shoulder Instability.
[a] Significant correlation between bone loss and WOSI score.

a WOSI score of 96.5% ± 17.0%, group 2 (n = 12) had 80.9% ± 25.5%, and group 3 (n = 5) 45.3% ± 9.3%. The WOSI score analyzed by groups were significantly lower for group 3 than other groups (p = 0.0009) (Fig. 1). The WOSI score in males (70.9% ± 18.5%) was significantly lower than that in females (81.0% ± 20.4%) (p = 0.0471). There was no significant difference of the recurrence rate among the groups. There were 10 contact athletes and 18 non-contact athletes. The WOSI score of the contact athletes (58.7% ± 22.0%) was significantly lower than that of the non-contact athletes (75.5% ± 21.5%) (p = 0.0275), although there were no significant differences in the Rowe score and in the recurrence rate between them (Table 3). All the patients in group 3 were males and 4 out of 5 participated in contact sports (rugby: 2 patients; judo: 1 patient; karate: 1 patient). According to the logistic regression analysis, bone loss size and type of sports were significantly correlated with the WOSI scores (p = 0.03174, p = 0.0413, respectively). On the other hand, there was no relationship between age, gender, and hand dominance and the WOSI scores.

4. Discussion

A negative correlation was observed between the glenoid bone loss and sports/recreation/work domain of the WOSI score: the greater the bone loss, the lower the WOSI score. This indicates that within the range of 0.4%–19.5% of the glenoid bone loss, patients with greater bone loss are likely to have their activities affected by their glenoid bone loss compared to those with less degrees of bone loss. When patients were divided in 3 groups, the WOSI score of group 3 (> 17% bone loss) was significantly lower than the other groups. Therefore, the bone loss of 17% to 25% in our series was considered to be the "subcritical bone loss". The WOSI score in males was lower than the one in females. The WOSI scores of the contact athletes were worse than those of the non-contact athletes. This means that with the same amount of glenoid bone loss, male athletes are more likely to be affected than female non-athletes. Thus, the subcritical bone loss concept proposed by Shaha et al. [7] could be applicable to males contact athletes in our series.

The threshold of 25% glenoid bone loss has been widely accepted. However, in practice, surgical decision making is sometimes difficult if a patient has a bone loss a little less the critical size such as 24%. Our data indicate that when a patient has a subcritical bone loss, we need to consider the background of the patient such as age, sex, activity level, and the type of sports (contact or non-contact sports). For example, when the size of glenoid bone

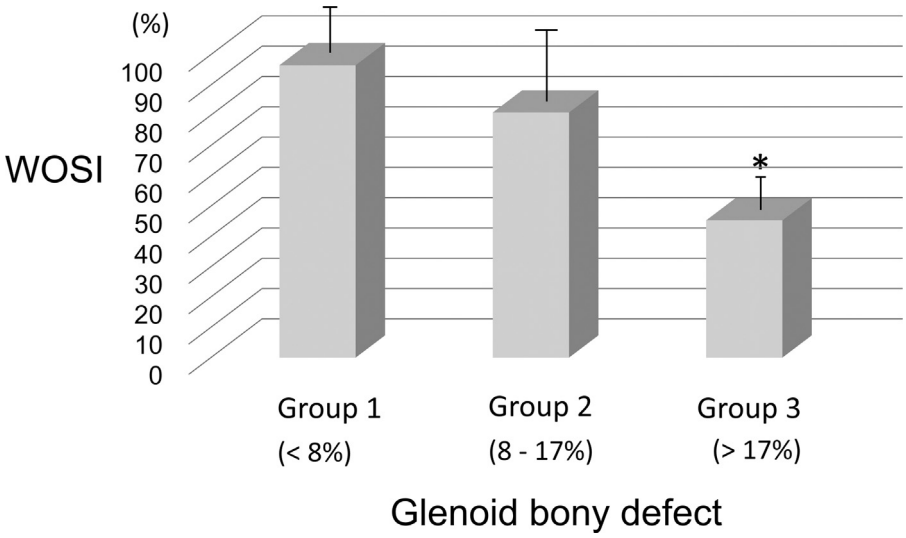

Fig. 1. The WOSI score of each group. The WOSI score analyzed by groups was significantly lower for group 3 than the other groups. WOSI: Western Ontario Shoulder Instability. *Significantly lower for group 3 than groups 1 and 2.

Table 3
Comparison of WOSI score between contact and non-contact athletes.

	Contact athletes	Non-contact athletes	*p*-value
Number of the subjects	10	18	
Mean bone loss (± SD)(%)	9.1 ± 7.8	7.9 ± 5.1	0.61
Recurrence	1 (10%)	2 (11%)	0.88
Rowe score after surgery	90.1 ± 9.5	92.5 ± 8.9	0.93
WOSI scores			
Total	58.7 ± 22.0	75.7 ± 21.5	0.0275[a]
Physical	65.3 ± 12.0	80.6 ± 24.8	0.0343[a]
Sports/recreation/work	57.2 ± 30.5	83.7 ± 11.0	0.0111[a]
Lifestyle	56.0 ± 31.0	66.5 ± 24.5	0.19
Emotion	82.6 ± 6.3	94.0 ± 2.3	0.11

WOSI: Western Ontario Shoulder Instability.
[a] Significant difference between contact and non-contact athletes.

loss is 24% of the glenoid width, we can still perform arthroscopic Bankart repair alone if a patient is a female non-athlete. On the other hand, we should consider a bone block procedure if a patient is a male contact athlete. If the bone loss is less than the subcritical size (17%), we can safely select the Bankart repair regardless of other factors. Thus, surgical decision making depends not only on the size of bone loss but also on the risk factors of the patient. It is known that male [17], contact athlete [18,19], and hyperlaxity [20,21] are the risk factors for recurrent instability. Any patient with one or more of these risk factors should be considered a good candidate for bony procedures such as Latarjet procedure.

Shaha et al. [7] proposed that bone loss 13.5% to 20% should be treated as a "subcritical bone loss" because such a bone loss led to a significant decrease in their quality of life. In the present study, we found that a bone loss between 17% and 25% was a "subcritical bone loss", which was larger than that in Shaha et al.'s study [7]. There are several potential reasons. First, all the subjects in Shaha et al.'s study [7] were military patients with high-level of activities required, whereas our patients were all civilians (65% were involved in athletics). Second, measurement method of bone loss was slightly different. Patients with a bony Bankart lesion were included in our study but were excluded in their study. In our study, the width of the bony fragment was subtracted from the width of the bone loss because it was expected that a bony fragment would heal after surgery according to the recent report [22]. This might have affected on the mean value of the glenoid bone loss. Third, the mean bone loss was different: the mean bone loss was 13.4% in their study [7], which was much greater than 7.7% in our study. In our study, patients with greater than 25% were excluded because we performed the Latarjet procedure for such patients, whereas those patients were included in Shaha et al.'s study [7]. This may have affected the amount of subcritical bone loss.

There are several limitations in this study. First, the number of the subjects was small in the present study. We need more subjects, especially those with a relatively large glenoid bone loss but below the critical size or with a various activity or sports level to make a final conclusion. Second, although sex, activity level and the type of sports were demonstrated to be affected by the subcritical bone loss in the present study, the other factors such as joint laxity or concomitant lesions (SLAP lesion, rotator cuff tear, or etc.) were not clarified yet. We need further studies to clarify it.

5. Conclusions

We confirmed the existence of subcritical bone loss in our series, which was between 17% and 25% of the glenoid width. The effect of subcritical bone loss was most obvious in male contact athletes.

Disclosure of interest

The authors declare that they have no competing interest.

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None.

Authors' contribution

Yamamoto: data analysis and writing, Kawakami: data collection, Hatta: data analysis, Itoi: writing and edit paper.

References

[1] Itoi E, Lee SB, Berglund LJ, Berge LL, An KN. The effect of a glenoid defect on anteroinferior stability of the shoulder after Bankart repair: a cadaveric study. J Bone Joint Surg Am 2000;82:35–46.
[2] Yamamoto N, Itoi E, Abe H, Kikuchi K, Seki N, Minagawa H, et al. Effect of an anterior glenoid defect on anterior shoulder stability: a cadaveric study. Am J Sports Med 2009;37:949–54.
[3] Yamamoto N, Muraki T, Sperling JW, Steinmann SP, Cofield RH, Itoi E, et al. Stabilizing mechanism in bone-grafting of a large glenoid defect. J Bone Joint Surg Am 2010;92:2059–66.
[4] Boileau P, Villalba M, Héry JY, Balg F, Ahrens P, Neyton L. Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. J Bone Joint Surg Am 2006;88:1755–63.
[5] Burkhart SS, De Beer JF. Traumatic glenohumeral bone defects and their relationship to failure of arthroscopic Bankart repairs: significance of the inverted-pear glenoid and the humeral engaging Hill–Sachs lesion. Arthroscopy 2000;16:677–94.
[6] Lo IK, Parten PM, Burkhart SS. The inverted pear glenoid: an indicator of significant glenoid bone loss. Arthroscopy 2004;20:169–74.
[7] Shaha JS, Cook JB, Song DJ, Rowles DJ, Bottoni CR, Shaha SH, et al. Redefining "critical" bone loss in shoulder instability: functional outcomes worsen with "subcritical" bone loss. Am J Sports Med 2015;43:1719–25.
[8] Dickens JF, Owens BD, Cameron KL, DeBerardino TM, Masini BD, Peck KY, et al. The effect of subcritical bone loss and exposure on recurrent instability after arthroscopic Bankart repair in intercollegiate American football. Am J Sports Med 2017;45:1769–75.
[9] Lansdown DA, Wang K, Yanke AB, Nicholson GP, Cole BJ, Verma NN. A flat anterior glenoid corresponds to subcritical glenoid bone loss. Arthroscopy 2019;35:1788–93.
[10] Liu JN, Gowd AK, Garcia GH, Cvetanovich GL, Cabarcas BC, Verma NN. Recurrence rate of instability after remplissage for treatment of traumatic anterior shoulder instability: a systematic review in treatment of subcritical glenoid bone loss. Arthroscopy 2018;34:2894–907.
[11] Shin SJ, Kim RG, Jeon YS, Kwon TH. Critical value of anterior glenoid bone loss that leads to recurrent glenohumeral instability after arthroscopic bankart repair. Am J Sports Med 2017;45:1975–81.
[12] Di Giacomo G, Itoi E, Burkhart SS. Evolving concept of bipolar bone loss and the Hill–Sachs lesion: from "engaging/non-engaging" lesion to "on-track/off-track" lesion. Arthroscopy 2014;30:90–8.
[13] Griffith JF, Antonio GE, Yung PS, Wong EM, Yu AB, Ahuja AT, et al. Prevalence, pattern, and spectrum of glenoid bone loss in anterior shoulder dislocation: CT analysis of 218 patients. AJR Am J Roentgenol 2008;190:1247–54.
[14] Carreira DS, Mazzocca AD, Oryhon J, Brown FM, Hayden JK, Romeo AA. A prospective outcome evaluation of arthroscopic Bankart repairs: minimum 2-year follow-up. Am J Sports Med 2006;34:771–7.
[15] Cho NS, Hwang JC, Rhee YG. Arthroscopic stabilization in anterior shoulder instability: collision athletes versus noncollision athletes. Arthroscopy 2006;22:947–53.
[16] Kirkley A, Griffin S, McLintock H, Ng L. The development and evaluation of a disease-specific quality of life measurement tool for shoulder instability. The Western Ontario Shoulder Instability Index (WOSI). Am J Sports Med 1998;26:764–72.
[17] Deitch J, Mehlman C, Foad S, et al. Traumatic anterior shoulder dislocation in adolescents. Am J Sports Med 2003;31:758–63.
[18] Kawasaki T, Ota C, Urayama S, Maki N, Nagayama M, Kaketa T, et al. Incidence of and risk factors for traumatic anterior shoulder dislocation: an epidemiologic study in high-school rugby players. J Shoulder Elbow Surg 2014;23:1624–30.
[19] Yamamoto N, Kijima H, Nagamoto H, Kurokawa D, Takahashi H, Sano H, et al. Outcome of Bankart repair in contact versus non-contact athletes. Orthop Traumatol Surg Res 2015;101:415–9.
[20] Balg F, Boileau P. The instability severity index score. A simple pre-operative score to select patients for arthroscopic or open shoulder stabilisation. J Bone Joint Surg Br 2007;89:1470–7.
[21] Voos JE, Livermore RW, Feeley BT, Altchek DW, Williams RJ, Warren RF, et al. Prospective evaluation of arthroscopic Bankart repairs for anterior instability. Am J Sports Med 2010;38:302–7.
[22] Kitayama S, Sugaya H, Takahashi N, Matsuki K, Kawai N, Tokai M, et al. Clinical outcome and glenoid morphology after arthroscopic repair of chronic osseous Bankart lesions: a five to eight-year follow-up study. J Bone Joint Surg Am 2015;97:1833–43.