

# Measurement of Glenoid Bone Loss

## A Comparison of Measurement Error Between 45° and 0° Bone Loss Models and With Different Posterior Arthroscopy Portal Locations

Matthew T. Provencher,<sup>\*†‡</sup> MD, LCDR, MC, USNR, Alvin J. Detterline,<sup>‡</sup> MD, Neil Ghodadra,<sup>‡</sup> MD, Anthony A. Romeo,<sup>‡</sup> MD, Bernard R. Bach Jr,<sup>‡</sup> MD, Brian J. Cole,<sup>‡</sup> MD, and Nikhil Verma,<sup>‡</sup> MD  
*From the <sup>†</sup>Naval Medical Center San Diego, San Diego, California, and <sup>‡</sup>Rush University, Division of Orthopaedic Sports Medicine, Department of Orthopaedic Surgery, Chicago, Illinois*

---

**Background:** Osteotomies at an angle of 45° to the long axis of the glenoid were originally used in a cadaveric model to simulate the bone loss that can occur clinically in anterior instability of the shoulder. However, this type of glenoid defect is not consistent with the usual clinical scenario, in which bone loss occurs parallel (at 0°) to the long axis of the glenoid.

**Purpose:** Our objectives were to compare the amount of glenoid bone loss measured after a 45° glenoid osteotomy compared with a 0° osteotomy and to determine differences in bone loss measurement from 2 different posterior shoulder portals.

**Study Design:** Controlled laboratory study.

**Methods:** Glenoids of 14 embalmed cadaveric shoulders (mean age, 81 years; range, 56-90) were mounted in a custom shoulder holder, and 2 posterior portals (2 and 3 o'clock) were fixed into place. The area of a best-fit circle of the inferior portion of the glenoid was digitally calculated, and 2 sequential osteotomies of 12.5% and 25% of anteroinferior glenoid bone loss area were created. Two different types of osteotomies were created: group 1, "inverted-pear" bone loss (45° to the long axis of the glenoid); and group 2, "clinical" bone loss osteotomy (0° to the long axis of the glenoid). Measurements of bone loss were performed based on the bare spot method from 2 simulated posterior portals at 2 and 3 o'clock using a calibrated probe and digital calipers. The osteotomy was measured in 3 different locations (upper, middle, and lower thirds).

**Results:** In the 12.5% bone loss model, bone loss measurements for both groups were significantly higher than expected (22.2%-23.1% in group 1, 17.4%-17.9% in group 2;  $P = .031-.049$ ). In the 25% bone loss model, the mean measured bone loss was 27.8% in group 1 and 27.5% in group 2; however, bone loss measurements varied significantly in group 1 based on measurement location along the osteotomy (upper third, 12.3%; middle third, 31.5%; lower third, 39.8% loss) ( $P = .01-.0001$ ). In group 2, the bone loss measurements were less varied (23.5%-30.3%). There were no differences between the location of the posterior portal (2 vs 3 o'clock) on determination of glenoid bone loss for both the 12.5% and 25% osteotomies.

**Conclusion:** Glenoid bone loss determination in a 45° osteotomy model significantly overestimates the amount of true glenoid bone loss. However, in a 0° clinical bone loss simulation model, the arthroscopic bare spot method of bone loss determination was sufficiently accurate at all 3 areas (upper, middle, and lower third) of bone loss. Both the 2-o'clock and 3-o'clock posterior portals were accurate to determine the amount of glenoid bone loss as referenced from the bare spot.

**Clinical Relevance:** Arthroscopic determination of glenoid bone loss is more accurate than what has been previously described with the 45° simulation model. Measurement of glenoid bone loss from either the 2-o'clock or 3-o'clock posterior portal is accurate in a clinical bone loss model.

**Keywords:** shoulder instability; glenoid bone loss; inverted-pear glenoid; glenoid bare spot; recurrent instability

---

\*Address correspondence to Matthew T. Provencher, MD, LCDR, MC, USNR, 34800 Bob Wilson Drive, Suite 112, San Diego, CA 92134-1112 (e-mail: mattprovencher@earthlink.net).

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or the United States Government.

One or more of the authors has declared a potential conflict of interest: Dr Romeo is a consultant for Arthrex, but no industry funds were used in this study.

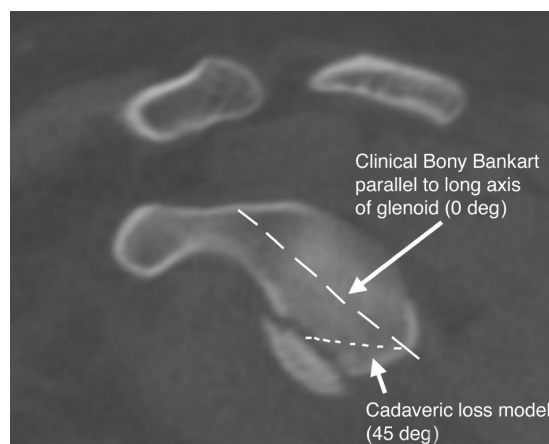
The successful arthroscopic treatment of recurrent anterior shoulder instability is predicated on optimal patient selection, as postoperative failure is higher in patients with soft tissue incompetence,<sup>13</sup> humeral head deficiency, and glenoid bone loss.<sup>2,16,19,21,22,24</sup> Considerable attention has been directed to the preoperative evaluation and optimal treatment of patients with bone loss, especially of the glenoid.<sup>2,6,19,21</sup> Glenoid bone loss remains a challenging issue with increased failure rates, ever since Burkhart and DeBeer<sup>4</sup> highlighted the dramatic increase in surgical failure (up to 61%) after arthroscopic stabilization of rugby players with anteroinferior glenoid bone loss. Thus, it is important to determine the extent of glenoid bone with radiographic studies<sup>6,8,10,15,21,23-25,27</sup> or via intraoperative measurement during arthroscopy.

The measurement of the amount of anteroinferior glenoid bone loss has been described with both arthroscopic methods<sup>5,14</sup> and radiographic methods, such as the apical oblique<sup>9</sup> and West Point<sup>18</sup> radiographs. The arthroscopic technique is performed with the arthroscope in the anterosuperior portal while several measurements of the glenoid are taken with a graduated probe. The measurements are referenced off the bare spot and are converted into a percentage anteroinferior bone loss based on the differential loss of bone from the bare spot anteriorly versus the bare spot posteriorly and presented as a ratio or overall percentage bone loss.<sup>5,14</sup> If the bone loss is significant (>20%), then the term “inverted-pear” glenoid has been applied,<sup>14</sup> which describes the altered shape of the anteroinferior glenoid in the setting of bone loss.

Although the intra-articular measurement of anteroinferior glenoid bone loss is commonly performed, the original work<sup>14</sup> that documented the measurements and mathematics in a bone loss setting used a simulated cadaveric osteotomy that was 45° relative to the long axis of the glenoid. The osteotomy essentially connected the 3-o'clock and 6-o'clock points on the glenoid, and bone loss measurements were validated with this type of simulated bone osteotomy. However, we now know from 3-dimensional CT studies<sup>19,21,22</sup> in the setting of anterior shoulder instability that glenoid bone loss occurs nearly parallel to the long axis of the glenoid, that is, parallel to the 12-o'clock and 6-o'clock line (Figure 1). Furthermore, the accuracy of glenoid bone loss measurements based on the bare spot as a reference point has been questioned.<sup>1,3,12</sup>

The intra-articular measurement of bone loss was originally determined based on 1 posterior portal position.<sup>14</sup> If the trajectory or initial starting position of the posterior arthroscopic portal is altered (for example, from 2 to 3 o'clock), this could potentially result in differing and erroneous determinations of the amount of glenoid bone loss. As such, little is known regarding the initial posterior arthroscopic portal starting position on determination of glenoid bone loss.

Because the original measurements of glenoid bone loss were validated in a cadaveric specimen with a simulated bone loss angle that is approximately 45° different from what generally happens in a clinical scenario, we sought to better define the measurements of glenoid bone loss in a clinically relevant bone loss model. Accordingly, the purposes of our study were (1) to determine the differences in



**Figure 1.** Computed tomography scan of a glenoid from a 23-year-old patient with a traumatic shoulder dislocation, demonstrating the clinical appearance of glenoid bone loss along a line nearly parallel to the long axis of the glenoid (0° osteotomy clinical model).

glenoid bone loss measurements between a 45° inverted-pear osteotomy and a 0° clinically relevant osteotomy bone loss model, (2) to determine if the initial arthroscopic posterior portal position has any effect on the determination of glenoid bone loss, and (3) to determine if the location of measurement along the osteotomy has any effect on the determination of glenoid bone loss.

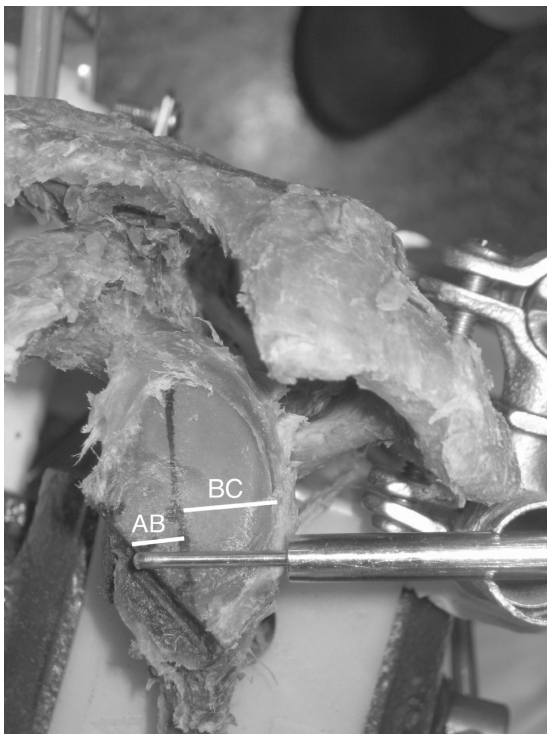
## MATERIALS AND METHODS

The glenoids of 14 matched, embalmed cadaveric shoulders (7 full cadaveric specimens, right and left shoulder from each; mean age, 81 years; range, 56-90) were dissected free of all soft tissues to expose the bony glenoid, leaving the bone scapula intact. Each glenoid was then digitized using a 10-megapixel digital camera mounted parallel to the glenoid face. A 30-mm sizing marker was placed flush with the glenoid rim to serve as a reference point for the digitizing software. The digital images of each glenoid were then loaded into a personal computer digitizer, and a best-fit circle<sup>17,21</sup> of the inferior two thirds of each individual glenoid was determined by commercial software (Adobe Photoshop CS [Adobe Systems Inc, San Jose, California] and the Universal Desktop Ruler [AVPSoft, Plimus Inc, San Diego, California]). The area of the best-fit circle was determined (in square millimeters) after it was digitally calibrated with the sizing marker using Universal Desktop Ruler software (Figure 2). The initial circular area of the inferior two thirds of each glenoid served as the starting point from which 2 sequential osteotomies, based on area calculation, would be determined.

Once the area of each matched pair of glenoids had been measured, the scapula was mounted in a custom apparatus that set the glenoid level with respect to the horizon. To ascertain the differences between the 2 types of glenoid osteotomies and simulated bone loss, the specimens were matched (right and left from the same cadaveric specimen) and then divided into 2 groups based on the type of glenoid osteotomy. In group 1, an osteotomy was produced at a 45°



**Figure 2.** Digital template of a glenoid in group 2 (0° clinical osteotomy), with simulated 25% bone loss that occurs along a line nearly parallel to the long axis of the glenoid as defined by Lo et al.<sup>14</sup> The osteotomy is made with a high-speed revolution Dremel device, and the correct amount of bone loss is confirmed with the template, based on digital measurements of glenoid bone loss in square millimeters.



**Figure 3.** Glenoid osteotomy in group 1 (45° osteotomy) for a 25% model, with the arthroscopic probe entering from the 3-o'clock portal and measuring the amount of bone loss from the glenoid bare spot to the middle third of the glenoid.

angle to the long axis of the glenoid from the 3-o'clock position to the 6-o'clock position as defined by Lo et al.<sup>14</sup> and Itoi et al.,<sup>11</sup> which has served to define the inverted-pear<sup>5,14</sup> glenoid (Figure 3). Specimens in group 2 had a “clinical”



**Figure 4.** Glenoid osteotomy in group 2 (0° clinical osteotomy) for a 12.5% bone loss model, with the arthroscopic probe entering from the 3-o'clock portal, measuring bone loss from the glenoid bare spot.

osteotomy, with bone loss as defined clinically by Saito et al.<sup>19</sup> and Sugaya et al.<sup>21</sup>, which approximates an osteotomy line parallel to the 12-o'clock and 6-o'clock positions, essentially parallel to the long axis of the glenoid (0° bone loss simulation model) (Figure 4). The cadaveric specimens were thus matched (right shoulder group 1, left shoulder group 2 from the same cadaveric specimen) and then alternated for each subsequent trial.

Two sequential osteotomies at 12.5% and 25% of bone loss were performed based on the area calculation of the best-fit circle. The initial area of the circle (in square millimeters) was used to calculate the exact area loss corresponding to 12.5% and 25%. The digitizer was then used to print a template for each osteotomy in either a 45° or 0° orientation to the long axis of the glenoid. The bone loss as determined by the area calculation technique served as the gold standard for measurement comparison in the remainder of the study. Each glenoid osteotomy was made using a 0.5-mm-diameter high-speed Dremel saw set to 15 000 rpm to minimize bone loss. Care was taken to ensure that the template remained in place after each osteotomy to ensure that the correct amount of bone was removed. For group 1 (45° osteotomy), the osteotomy was made at a 45° angle connecting the 3-o'clock and 6-o'clock positions; for group 2 (0° clinical osteotomy), it was made along a line parallel to the long axis of the glenoid.

Multiple measurements were made to determine the amount of measured bone loss from 2 different simulated posterior portal positions anatomically fixed at approximately the 2-o'clock and 3-o'clock posterior portal locations for a left shoulder (for a right shoulder, the 10-o'clock and 9-o'clock portals, respectively), based on a clock face with 12 o'clock corresponding to the supraglenoid tubercle. From each posterior portal, a calibrated arthroscopic probe with digital calipers attached (accuracy of 0.01 mm) measured the amount of bone loss based on the glenoid bare spot.<sup>5,14</sup> The arthroscopic probe was placed in the center of the defect for the 12.5% bone loss osteotomies. However, for the 25% bone loss model, the osteotomy length was measured, divided equally into thirds, and a mark was placed to



identify these 3 distinct areas of the glenoid osteotomy. Three measurements of anterior glenoid bone loss were obtained in the 25% loss model from the glenoid rim to the bare spot at the upper third of the osteotomy, the middle third of the osteotomy, and the lower third of the osteotomy (Figure 5). At the same time each anterior measurement from anterior glenoid rim to the bare spot was made, the distance from the bare spot to the most posterior aspect of the glenoid bone rim was measured along a straight line using the arthroscopic probe. The percentage of bone loss was calculated for each of the 3 anterior measurements, defined by Lo et al<sup>14</sup> as

$$\frac{\text{posterior measurement (BC)} - \text{anterior measurement (AB)}}{2 \times \text{posterior measurement (BC)}}$$

Each measurement was performed by 3 observers, and the mean value was taken as final for each data point. Thus, comparisons between groups included the differences between group 1 (45° osteotomy) and group 2 (0° clinical osteotomy) for amount of glenoid bone loss; the differences between amounts of measured bone loss from the 2-o'clock versus the 3-o'clock portal, with 25% bone loss; and the differences between amounts of measured bone loss to 3 different locations on the 25% bone loss osteotomy (upper, middle, and lower thirds). The observers were 1 sports fellowship-trained orthopaedic surgeon and 2 residents (postgraduate years 2 and 5). All underwent protocol training on 2 pilot cadaveric specimens before taking specimen measurements.

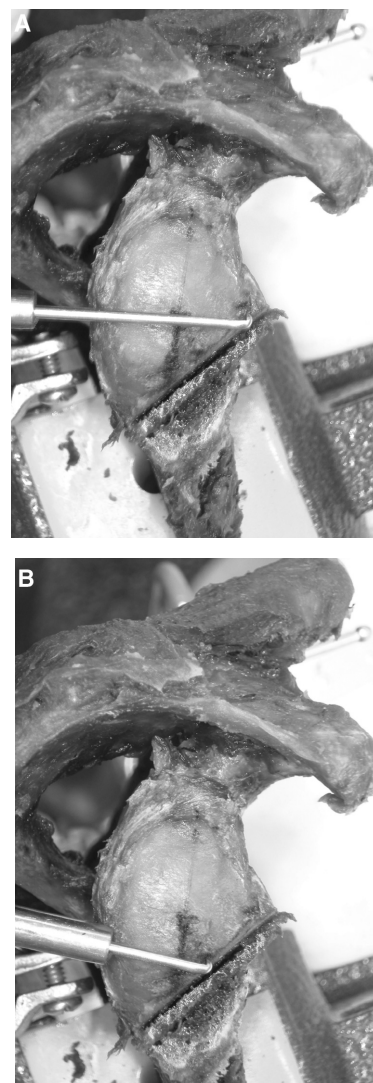
The measurements of glenoid bone loss obtained by each group were compared using Wilcoxon signed rank tests, and the differences in bone loss measurement obtained between the 2 posterior portal positions and also at the 3 different levels of measurement along the glenoid osteotomy were compared using the Wilcoxon-Mann-Whitney test. Level of significance was set at  $P < .05$ .

## RESULTS

There were no significant differences in the distance from the bare spot to the anterior glenoid rim (12.4 mm; range, 10.0-14.2) and the posterior glenoid rim (13.6 mm; range, 10.9-15.3) ( $P = .461$ ) in the intact glenoid state (Table 1). Interobserver reliability was very good, with a minimum  $\kappa$  value of 0.71 (range, 0.71-0.91) and a mean  $\kappa$  of 0.80 for comparison of all measurements.

For the 12.5% bone loss model, group 1 (45° osteotomy) statistically overestimated the actual amount of bone loss from both the 2-o'clock and 3-o'clock portals (23.1% and 22.2%, respectively) (Table 2). This was also statistically overestimated in group 2 (clinical bone loss osteotomy) from both the 2-o'clock and 3-o'clock portals (17.4% and 17.9%, respectively). Overall, the measurements obtained in the clinical bone loss model (0° osteotomy) were closer to the actual true bone loss of 12.5%. There were no differences between the locations of the posterior portal on determination of glenoid bone loss at 12.5%.

In the 25% bone loss model, when measured to the middle of the glenoid defect, group 1 (45° osteotomy) measured



**Figure 5.** Glenoid osteotomies in group 1 (45° osteotomy) for a 25% bone loss with the arthroscopic probe entering posteriorly from the 2-o'clock portal and measuring bone loss from the glenoid bare spot to the upper third (A) and middle third (B) of the osteotomy.

31.5% loss, whereas group 2 (clinical osteotomy) measured 28.4% ( $P = .15$ ) from the 2-o'clock portal and 30.4% and 23.5% ( $P = .021$ ) from the 3-o'clock portal, respectively (Table 3). The bone loss measurements were statistically overestimated when measured in the lower third of the osteotomy for group 1 (39.8%) versus group 2 (30.3%) ( $P = .001$ ) at 2 o'clock and were similarly overestimated at 3 o'clock (38.2% and 28.8%, respectively) ( $P = .001$ ). When measured to the upper third of the osteotomy, group 1 underestimated the amount of bone loss (12.3%) versus group 2 (24.0%) ( $P = .01$ ) at 2 o'clock; these values were 8.2% and 27.6% ( $P = .0001$ ) from the 3-o'clock portal. The mean amount of anterior bone loss in the 25% model varied between 6.0 and 7.1 mm, depending on where along the osteotomy the measurement was taken.

**TABLE 1**  
 Cadaveric Specimen Information Regarding the Intact Bare Spot Measurements,  
 Standard Deviations, and Glenoid Bone Loss Area<sup>a</sup>

Distance From the Bare Spot	Mean (mm)	SD (mm)	Range (mm)	Statistical Differences ( <i>P</i> Value)
To posterior glenoid rim	13.6	1.5	10.9-15.3	N/A
To the anterior glenoid rim	12.4	1.3	10.0-14.2	Anterior vs posterior, <i>P</i> = .461 <sup>b</sup>
To the inferior glenoid rim	13.5	1.2	12.4-16.2	Anterior vs inferior, <i>P</i> = .388 <sup>c</sup>
To the superior glenoid rim	19.8	1.4	18.4-21.9	N/A
Total superior to inferior, (12 to 6 o'clock)	33.3	1.3	29.1-35.7	N/A

<sup>a</sup>SD, standard deviation; N/A, not applicable.

<sup>b</sup>Compared statistically, the differences between the anterior and posterior distances to the bare spot.

<sup>c</sup>Compared statistically, the differences between the anterior and inferior distances to the bare spot.

**TABLE 2**  
 The 12.5% Glenoid Bone Loss Model, Demonstrating the Differences in Measurements of  
 Bone Loss Between the 45° Bone Loss Osteotomy and the 0° Clinical Bone Loss Osteotomy<sup>a</sup>

Posterior Portal Position	45° Osteotomy, Mean (SD)			0° Clinical Bone Loss Osteotomy, Mean (SD)			<i>P</i> Value % Losses <sup>c</sup>
	AB Length, mm (SD)	BC Length, mm (SD)	% Loss (SD)	AB Length, mm (SD)	BC Length, mm (SD)	% Loss (SD)	
2 o'clock	6.5 (1.4)	12.1 (1.1)	23.1 (3.6)	8.1 (1.2)	12.7 (2.0)	17.4 (4.6)	.031 <sup>d</sup>
3 o'clock	5.1 (1.5)	11.2 (1.0)	22.2 (4.2)	7.9 (1.2)	12.5 (1.7)	17.9 (4.7)	.049 <sup>d</sup>
<i>P</i> value differences <sup>b</sup>			.662			.701	.701

<sup>a</sup>SD, standard deviation; AB, anterior glenoid bone loss measurement to the bare spot; BC, posterior glenoid bone measurement to the bare spot.

<sup>b</sup>Difference between % bone loss at the 2-o'clock and 3-o'clock posterior portal positions.

<sup>c</sup>Differences between % bone loss for the 45° osteotomy and the clinical bone loss osteotomy models.

<sup>d</sup>*P* < .05, statistically significant.

**TABLE 3**  
 The 25% Glenoid Bone Loss Model, Illustrating the Differences in the Measurements of  
 Bone Loss Between the 45° Bone Loss Osteotomy and the 0° Clinical Bone Loss Osteotomy<sup>a</sup>

	Osteotomy Type	2-O'Clock Portal			3-O'Clock Portal			<i>P</i> Value <sup>c</sup>
		AB, mm (SD)	BC, mm (SD)	% Bone Loss (SD)	AB, mm (SD)	BC, mm (SD)	% Bone Loss (SD)	
Upper third	45° bone loss	9.5 (0.8)	12.2 (1.5)	12.3 (3.8)	9.9 (1.2)	12.0 (1.8)	8.2 (4.0)	.04 <sup>d</sup>
	0° clinical bone loss	6.4 (1.2)	12.4 (1.9)	24.0 (6.2)	5.5 (1.2)	12.4 (2.0)	27.6 (6.9)	.188
	<i>P</i> value <sup>b</sup>			.01 <sup>d</sup>			.0001 <sup>d</sup>	
Middle third	45° bone loss	4.7 (1.1)	12.5 (1.4)	31.5 (3.1)	4.4 (1.1)	11.4 (1.2)	30.4 (5.3)	.556
	0° clinical bone loss	5.5 (1.4)	12.6 (1.9)	28.4 (6.3)	6.8 (1.0)	12.9 (2.6)	23.5 (7.2)	.144
	<i>P</i> value <sup>b</sup>			.15			.021 <sup>d</sup>	
Lower third	45° bone loss	2.6 (1.0)	12.8 (2.1)	39.8 (3.5)	2.3 (0.7)	9.8 (1.5)	38.2 (3.2)	.701
	0° clinical bone loss	4.6 (1.4)	11.6 (1.9)	30.3 (7.4)	4.5 (1.3)	10.6 (1.5)	28.8 (7.2)	.221
	<i>P</i> value <sup>b</sup>			.001 <sup>d</sup>			.001 <sup>d</sup>	
Mean, 45° bone loss			27.8			25.6		
Mean, 0° clinical bone loss			27.5			26.6		

<sup>a</sup>SD, standard deviation; AB, anterior glenoid bone loss measurement to bare spot; BC, posterior glenoid bone measurement to bare spot.

<sup>b</sup>Comparison of 45° bone loss osteotomy and clinical bone loss osteotomies at each measurement location of upper, middle, and lower thirds of the respective osteotomies.

<sup>c</sup>Comparison of the % bone loss measurements from either the 2-o'clock or the 3-o'clock portal position.

<sup>d</sup>Significant *P* value of < .05.

The only statistically significant measurement differences between the 2-o'clock and 3-o'clock portals were during measurement of the upper third of group 1 (45° osteotomy). There were no differences between the 2-o'clock and 3-o'clock portal positions for any of the measurements in group 2 (clinical bone loss osteotomy).

**DISCUSSION**

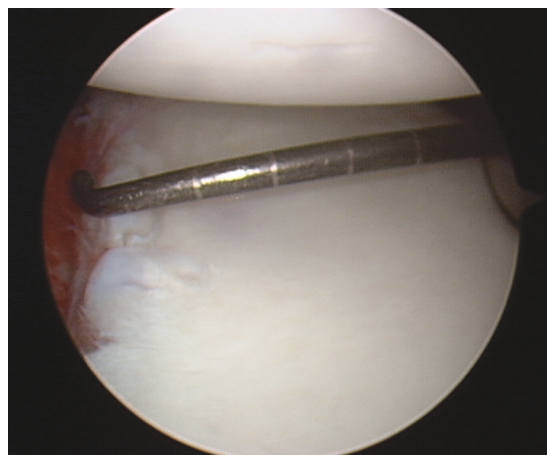
The principal findings of our study demonstrate that the 45° osteotomy, as initially described to simulate clinical bone loss in a cadaveric model, may not accurately assess the true amount of glenoid bone loss. There are several

reasons for this. First, it has been subsequently shown that the 45° osteotomy is not an accurate representation of the bone loss clinically, which characteristically happens in the setting of recurrent anterior instability.<sup>19,21</sup> Using CT analysis, Sugaya et al,<sup>21</sup> Saito et al,<sup>19</sup> and Itoi et al<sup>10</sup> have demonstrated that the bone defect typically occurs along a line parallel to the long axis of the glenoid. Thus, the use of the 45° osteotomy for determination of a method of measuring glenoid bone loss may not be applicable to the actual clinical situation. From the initial bone loss cadaveric study, Lo et al<sup>14</sup> stated that the 45° osteotomy was chosen based on reproducibility; the authors acknowledged that a less extreme osteotomy would give the appearance of an inverted-pear glenoid. Lo et al<sup>14</sup> noted that in clinical shoulder instability cases, glenoid bone loss when viewed from the anterosuperior arthroscopic portal (Figure 6) occurs along a line nearly parallel to the long axis of the glenoid. It was their bone loss description arthroscopically that led us to investigate the differences between the 0° and 45° bone loss osteotomies.

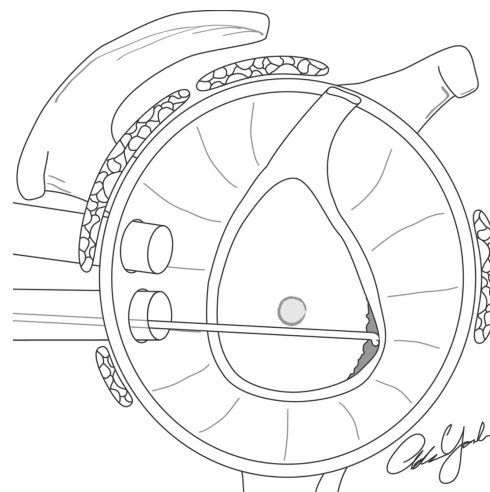
Second, the initial study to quantify bone loss in a cadaveric model used the 45° degree osteotomy<sup>14</sup>; however, it was not specified as to exactly where on the glenoid the defect was measured. We found that the location of measurement of the glenoid defect is very important to accurate determination of bone loss, and in our model, the 45° osteotomy was only accurate if measured to the upper third location on the osteotomy. Depending on the location of the measurement along the 45° osteotomy, the bone loss measured to the bare spot was between 12.3% and 39.8% in the case of a 25% bone loss osteotomy. However, the clinical 0° bone loss osteotomy provided consistent measurements at all locations of the osteotomy, between 23.5% and 28.8%, very close to the actual amount of loss of 25% as determined by digital area calculations.

Third, the location of the posterior portal can vary in any shoulder arthroscopy, and the potential to have an inaccurate assessment of the amount of posterior and/or remaining anterior glenoid bone exists. However, we found that the portal position had little effect on determination of glenoid bone loss only for the clinical 0° osteotomy group (Figure 7). This is probably due to the inherent trajectory of the portal and arthroscopic probe, as the amount of posterior bone measured (BC) decreased with a lower position on the glenoid, which allowed for the ratio to be preserved with a relatively small anterior glenoid bone loss (AB) measurement.

The 0° clinical bone loss model as described by Sugaya et al<sup>20-22</sup> and Saito et al<sup>19</sup> was based on 123 CT scans of patients with anterior shoulder instability. The finding has been consistently demonstrated in our practice, where the bone loss osteotomy is nearly parallel to the long axis of the glenoid (12 to 6 o'clock). However, as the amount of glenoid bone loss increases beyond 25%, it is not known whether the orientation of the rim of the damaged glenoid remains the same or is slightly altered to involve the 6-o'clock position, as Sugaya had very few patients with bone loss beyond 25%. However, if the 0° osteotomy is used for bone loss beyond 30%, then it is possible that the osteotomy line will extend into the anterosuperior portion of the glenoid, an area where bone



**Figure 6.** Arthroscopic view from the anterosuperior portal demonstrating 20% anterior glenoid bone loss. The 0° clinical bone loss is in an osteotomy line parallel to the long axis of the glenoid.



**Figure 7.** Schematic diagram of the glenoid and capsule in a patient with 2 posterior portals (2 and 3 o'clock), with the probe entering the 3-o'clock portal, measuring bone loss as referenced off the glenoid bare spot. (Diagram courtesy of Adam Yanke.)

loss typically does not occur. Thus, it is our contention that as glenoid bone loss becomes larger than 25%, the orientation of the damaged rim of the glenoid changes to a slightly more oblique angle.

The amount of bone loss that must be present before a recommendation to abandon soft tissue stabilization in favor of bony reconstruction is not clearly defined. Burkhart and DeBeer<sup>4</sup> originally presented a series of contact athletes and reported a failure rate of 61% in cases where an inverted pear-shaped glenoid was identified. They later quantified this glenoid appearance as occurring after a loss of 28.8% of the anteroinferior glenoid width. Recently, however, Mologne et al<sup>16</sup> have reported on a group of patients with significant anteroinferior glenoid bone loss treated with arthroscopic soft tissue reconstruction. The group contained both acute



bony Bankart lesions as well as cases of chronic bone loss. In this series, the recurrence rate was much lower at 14.3%. These defects were also recognized as a problem by Bigliani et al,<sup>2</sup> who found a recurrence rate of 12%. Others<sup>26,27</sup> have shown similar results.

From a biomechanical standpoint, it has been shown that with progressive loss of bone from the anteroinferior glenoid, the energy required to produce shoulder dislocation decreases significantly.<sup>7,11,24,27</sup> Conversely, the stress placed on an anterior soft tissue reconstruction will increase, predisposing the reconstruction to failure. On the basis of these clinical and biomechanical data, it is clear that accurate estimation and measurement of glenoid bone loss are important with regard to predicting recurrence and in helping to decide between arthroscopic soft tissue stabilization and open bony reconstruction.

There are several limitations to our study. First, the simulated posterior portal was hard-fixed to the glenoid-positioning apparatus. In reality, the posterior portals are somewhat mobile and may be translated superiorly and inferiorly depending on patient musculature. In addition, soft tissue restraints may prohibit the arthroscopic probe from passing directly across the bare spot to the anterior defect in a clinical setting. Variance in the age of patients or cadaveric specimens, as occurred in our study, is one of the factors that have been implicated as responsible for a variable location of the bare spot; however, we found consistent readings between the 2 portals, with little variation of the bone loss measurements depending on portal position. Second, it has been suggested that the bare spot may not be a consistent central landmark<sup>1,12</sup> for bone loss measurements, but this remains a subject of considerable debate.<sup>3</sup> However, we found consistent measurements with a very tight standard deviation using 2 different portals and 2 different osteotomies among 3 observers. The glenoid bare spot was also nearly in the center of our cadaveric glenoids, although the mean bare spot to inferior distance was slightly higher than prior studies.<sup>3,5</sup> Finally, the exact osteotomy tested in our study (0°) may not represent what clinically occurs in all patients; however, we believe that it is a reasonable approximation based on well-defined clinical CT data.<sup>19,21</sup>

Finally, because our technique was performed in a controlled setting, it allowed for very precise measurement of the distances in question using a digital caliper. It also allowed direct visualization of the entire circumference of the bony glenoid as the labrum was removed for all measurements. In the clinical scenario, measurements are made using arthroscopic visualization with a posterior labrum presumably intact, which makes determination of the exact posterior bony rim more challenging. Furthermore, the use of a graduated probe at 2-mm to 3-mm increments makes clinical precision difficult. Thus, in the clinical scenario, it is reasonable to assume some margin of error. If the bare spot to anterior glenoid measurement is 12 mm, then an error in measurement of 2 mm (from a 4-mm bone loss to a 6-mm bone loss) may result in an error of estimation of approximately 15%. In this scenario, a surgeon may decide to abandon an arthroscopic approach in favor of an open bony reconstruction based on an error in measurement. In the future, more accurate measurement techniques that can be

performed arthroscopically need to be developed. Currently, however, correlation between preoperative CT evaluation and intraoperative glenoid appearance and measurement can be used to guide treatment decisions.

## CONCLUSION

Glenoid bone loss determination in a 45° osteotomy model significantly overestimates the amount of true glenoid bone loss at both 12.5% and 25%. However, in a 0° clinical bone loss situation with bone loss near parallel to the long axis of the glenoid, the arthroscopic bare spot method of bone loss determination was sufficiently accurate at all 3 areas (upper, middle, and lower third) of bone loss. Both the 2-o'clock and 3-o'clock posterior portals were accurate to determine glenoid bone loss.

## ACKNOWLEDGMENT

The authors thank Adam Yanke for his invaluable artistic contribution.

## REFERENCES

1. Aigner F, Longato S, Fritsch H, Kralinger F. Anatomical considerations regarding the "bare spot" of the glenoid cavity. *Surg Radiol Anat.* 2004;26:308-311.
2. Bigliani LU, Newton PM, Steinmann SP, Connor PM, McLlveen SJ. Glenoid rim lesions associated with recurrent anterior dislocation of the shoulder. *Am J Sports Med.* 1998;26:41-45.
3. Burkhart SS. The bare spot of the glenoid. *Arthroscopy.* 2007;23:449, author reply 449-450.
4. Burkhart SS, DeBeer 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;16:677-694.
5. Burkhart SS, Debeer JF, Tehrany AM, Parten PM. Quantifying glenoid bone loss arthroscopically in shoulder instability. *Arthroscopy.* 2002;18:488-491.
6. de Wilde L, Berghs B, Audenaert E. Glenoid rim morphology in recurrent anterior glenohumeral instability. *J Bone Joint Surg Am.* 2004;86:646, author reply 646-647.
7. Edelson JG. Localized glenoid hypoplasia: an anatomic variation of possible clinical significance. *Clin Orthop Relat Res.* 1995;321:189-195.
8. Edwards TB, Boulahia A, Walch G. Radiographic analysis of bone defects in chronic anterior shoulder instability. *Arthroscopy.* 2003;19:732-739.
9. Garth WP Jr, Slaphey CE, Ochs CW. Roentgenographic demonstration of instability of the shoulder: the apical oblique projection. *J Bone Joint Surg Am.* 1984;66:1450-1453.
10. Itoi E, Lee SB, Amrami KK, Wenger DE, An KN. Quantitative assessment of classic anteroinferior bony Bankart lesions by radiography and computed tomography. *Am J Sports Med.* 2003;31:112-118.
11. 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.
12. Kralinger F, Aigner F, Longato S, Rieger M, Wambacher M. Is the bare spot a consistent landmark for shoulder arthroscopy? A study of 20 embalmed glenoids with 3-dimensional computed tomographic reconstruction. *Arthroscopy.* 2006;22:428-432.
13. Lazarus MD, Sidles JA, Harryman DT 2nd, Matsen FA 3rd. Effect of a chondral-labral defect on glenoid concavity and glenohumeral stability: a cadaveric model. *J Bone Joint Surg Am.* 1996;78:94-102.
14. Lo IK, Parten PM, Burkhart SS. The inverted pear glenoid: an indicator of significant glenoid bone loss. *Arthroscopy.* 2004;20:169-174.

15. Manns RA, Davies AM. Glenoid hypoplasia: assessment by computed tomographic arthrography. *Clin Radiol*. 1991;43:316-320.
16. Mologne TS, Provencher MT, Menzel KA, Vachon TA, Dewing CB. Arthroscopic stabilization in patients with an inverted pear glenoid: results in patients with bone loss of the anterior glenoid. *Am J Sports Med*. 2007;35:1276-1283.
17. Nobuhara K. *The Shoulder—Its Function and Clinical Aspects*. 3rd ed. Tokyo: Igaku-Shoin; 2001.
18. Roukos JR, Feagin JA, Abbott HG. Modified axillary roentgenogram: a useful adjunct in the diagnosis of recurrent instability of the shoulder. *Clin Orthop Relat Res*. 1972;82:84-86.
19. 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;33:889-893.
20. Sugaya H, Kon Y, Tsuchiya A. Arthroscopic repair of glenoid fractures using suture anchors. *Arthroscopy*. 2005;21:635.
21. Sugaya H, Moriishi J, Dohi M, Kon Y, Tsuchiya A. Glenoid rim morphology in recurrent anterior glenohumeral instability. *J Bone Joint Surg Am*. 2003;85:878-884.
22. 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;87:1752-1760.
23. Theodorou SJ, Theodorou DJ, Resnick D. Hypoplasia of the glenoid neck of the scapula: imaging findings and report of 16 patients. *J Comput Assist Tomogr*. 2006;30:535-542.
24. Trout TE, Resnick D. Glenoid hypoplasia and its relationship to instability. *Skeletal Radiol*. 1996;25:37-40.
25. Vanhoenacker FM, Van de Perre S, De Schepper AM. Glenoid hypoplasia. *JBR-BTR*. 2003;86:27.
26. Wilson F, Hinov V, Adams G. Arthroscopic repair for anterior shoulder instability with a Bigliani type I glenoid rim fracture. *Arthroscopy*. 2002;18:E32.
27. Wirth MA, Lyons FR, Rockwood CA Jr. Hypoplasia of the glenoid: a review of sixteen patients. *J Bone Joint Surg Am*. 1993;75:1175-1184.