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Glenoid track «off-track» as a risk factor for recurrence of anterior glenohumeral instability in postoperative patients

El encarrilamiento glenoideo off-track *como factor de riesgo de recidiva de inestabilidad glenohumeral en pacientes postoperados*

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ABSTRACT. Introduction: Glenoid track is used to assess the engagement of Hill-Sachs lesions. The objective of this study was to identify if off-track glenoid track was a risk factor for recurrence of anterior glenohumeral instability in postoperative patients with arthroscopic anterior labrum repair. **Material and methods:** Sixty patients with glenohumeral instability who underwent arthroscopic repair of the anterior labrum were studied. Study group (patients with recurrence of postoperative dislocation) and control (no dislocation). Radiographic measurements were made on magnetic resonance imaging and computed tomography. Measurements of glenoid diameter, glenoid bone loss, as well as the presence and size of Hill-Sachs lesions were obtained. Later they were classified as «on-track» or «off-track». **Results:** Seven (11.67%) patients suffered recurrence, of which six (10%) were carriers of an off-track injury and 1 (1.67%) on-Track. 53 (88.33%) patients did not experience recurrence, of which 11 (18.33%) were carriers of an off-track injury and 42 (70%) on track. A 23.47 increased risk of recurrence of instability was interpreted in patients with «off-track» lesions compared to patients with «On track» lesions. **Conclusions:** Off-track injuries were a risk factor for recurrence of instability in patients who underwent Bankart-type arthroscopic repair. This allows us to recommend that the presence of lesions be

RESUMEN. Introducción: El encarrilamiento glenoideo se emplea para valorar el enganche de lesiones Hill-Sachs. El objetivo de este estudio fue identificar si el encarrilamiento glenoideo *off-track* fue un factor de riesgo de recidiva de inestabilidad glenohumeral anterior en pacientes postoperados de reparación de labrum anterior por vía artroscópica. **Material y métodos:** Se estudiaron 60 pacientes sometidos a reparación artroscópica del labrum anterior. Grupo de estudio (pacientes con recidiva de luxación postoperatoria) y control (sin luxación). Las mediciones radiográficas se realizaron en resonancia magnética y en tomografía axial computarizada. Se obtuvieron mediciones del diámetro glenoideo, pérdida ósea glenoidea así como la presencia y tamaño de lesiones de Hill-Sachs. Posteriormente se clasificaron como *on-track* u *off-track*. **Resultados:** Siete (11.67%) pacientes sufrieron recidiva, de los cuales seis (10%) eran portadores de lesión *off-track* y uno (1.67%) *on-track*. 53 (88.33%) pacientes sin recidiva, de los cuales 11 (18.33%) eran portadores de lesión *off-track* y 42 (70%) *on-track*. Se interpretó un aumento de riesgo de recidiva de inestabilidad de 23.47 en los pacientes portadores de lesión de tipo *off-track* en comparación con los pacientes portadores de lesiones *on-track*. **Conclusiones:** Las lesiones *off-track* fueron un factor de riesgo de recidiva de inestabilidad en los pacientes a quienes se realizó reparación artroscópica

Level of evidence: III

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routinely studied and classified as «on-track» or «off-track» to provide a better therapeutic approach.

Key words: Glenoid track, instability, surgery, arthroscopy, failure.

tipo Bankart, lo cual nos permite recomendar que de forma rutinaria se estudie la presencia de lesiones y clasificarlas como *on-track* u *off-track* para brindar un mejor abordaje terapéutico.

Palabras clave: Encarrilamiento glenoideo, inestabilidad, cirugía, artroscopia, falla.

Introduction

Anterior glenohumeral instability represents one of the most frequent causes of shoulder pathology. This entity has a risk of recurrence after the surgical event of 3.4-19%.[1,2] In economic terms, a second intervention reduces the cost benefit of any treatment and forces us to look for alternatives to correct it. There are currently various and confusing therapeutic approach protocols, which makes it difficult to define the best way to evaluate these patients.[3]

For many years, the percentage of glenoid bone loss has determined the treatment of glenohumeral instabilities.[4] A little over 10 years ago, the concept of glenoid track emerged,[5] which was intended to predict the risk of recurrence of instability[6,7,8,9,10] although this has been questioned in recent studies.[11]

Yamamoto et al,[5] proposed the concept of glenoid track in 2007, through a biomechanical study where they defined the area of contact between the superolateral portion of the humeral head and the glenoid during external rotation, horizontal extension, and shoulder abduction. They found that this contact zone comprised 84 ± 14% of the glenoid diameter. Subsequently, Omori et al,[12] applied the same concept in living patients, with the use of magnetic resonance imaging to assess the same area of contact. They found that this was 83% at 90º abduction. Metzger et al,[13] were the first to corroborate the clinical relevance of this concept and analyzed its relationship with Hill-Sachs lesions. Using magnetic resonance imaging, they classified as off-track lesions those in which the Hill-Sachs lesion was greater than the glenoid track and on-track lesions when the size of the Hill lesion -Sachs was less than glenoid track, and they confirmed this behavior under direct vision during arthroscopy.

Recently, Nakagawa et al,[11] questioned the usefulness of the concept of glenoid track and applied another classification system for the lesions, which considered three factors: the size of the Hill-Sachs lesions, the size of the glenoid defect and the physical activity carried out by the patients. He proposed that such a classification system represents a better predictor of recurrence regardless of glenoid track.

The objective of this work is to report the results of the application of the glenoid track concept to a series of patients operated on in our hospital to know its usefulness in predicting the probability of recurrence of glenohumeral dislocation.

Table 1: Demographic and pathology studied variables.

Variable		Total (%)	RI group (%)	NRI group (%)	p
Number of shoulders studied		60 (100)	7 (11.67)	53 (88.33)	Not applicable
Sex	Male	42 (70)	6 (10.00)	36 (60.00)	0.305*
	Female	18 (30)	1 (1.67)	17 (28.33)	
Age in years		Average 34 (range, 16-74)	Average 41 (range, 24-74)	Average 32 (range 16-68)	0.128*
Comorbidities		20 (100)	3 (15)	17 (85)	Not applicable
Asthma		6 (30)	1 (5)	5 (25)	
Major depression		4 (20)	1 (5)	3 (15)	
Hypermobility		3 (15)	0 (0)	3 (15)	
Hypertension		3 (15)	1 (5)	2 (10)	
Hypothyroidism		2 (10)	0 (0)	2 (10)	
Diabetes mellitus		1 (5)	0 (0)	1 (5)	
Osteoporosis		1 (5)	0 (0)	1 (5)	
Affected side	Right	35 (58.33)	3 (5.00)	32 (53.33)	0.381*
	Left	25 (41.67)	4 (6.67)	21 (35.00)	
Evolution of instability (months)		Average 67 (range, 2-490)	Average 144 (range, 5-490)	Average 57 (range, 2-190)	0.177*
Dislocations prior to surgery		Average 11.45 (range, 1-70)	Average 18.14 (range, 3-35)	Average 10.56 (range, 1-70)	0.110‡

RI = recurrence of instability, NRI = no recurrence of instability,* Fisher exact test, ‡ Mann Whitney's U test.

Material and methods

A case-control study was carried out in which two homogeneous groups of patients were compared, who underwent artroscopic surgery for anterior capsular plication from January 2017 to September 2018. The RI group (recurrence of instability) included 7 shoulders in which we observed a recurrence of the glenohumeral dislocation after the surgical intervention. The NRI group (no recurrence of instability) included 53 shoulders in whom adequate stability was achieved after surgery. The institutional ethics committee approved the completion of this study (Folio F-2019-3701-005).

The inclusion criteria were as follows: Patients with skeletal maturity and anterior glenohumeral instability, who underwent arthroscopic anterior capsular plication for the first time. The patients must have a minimum postoperative follow-up of 6 months. Men and women were included. The exclusion criteria were as follows: Patients in whom magnetic resonance imaging (MRI) or computed tomography (CT) had not been performed in the preoperative study protocol. Patients with multidirectional instability and those cases with non-concordance in at least 4 of the 6 measurements provided by the evaluators were excluded. Those cases with post-operative infection and those who did not sign the informed consent were eliminated.

The method to classify the lesions as off-track or on-track consisted of 3 steps: 1. Measurement of the glenoid component: Burkhart established through studies in live patients with trans-surgical measurements during arthroscopy and in cadaver dissection that the lower part of the glenoid forms a perfect circle between its edges: posterior, inferior and anterior.[4] To obtain this measurement, the perfect circle method proposed by Sugaya was used.[14] where a circle is drawn in a sagittal section of the glenoid, which must coincide with its posterior and inferior edge. The diameter of this circle represents the expected diameter of the glenoid and is multiplied by the constant 0.83.[12] When the front edge of the circle does not coincide with the front edge of the glenoid, it means glenoid bone loss, so the distance between the front edge of the glenoid and the front edge of the circle is measured and subtracted from the measurement previously obtained. 2. Hill-Sachs measurement: Obtained in an axial section of the humeral head. This was achieved by drawing a line that crossed the lesion from medial to lateral in its area of greatest diameter, then another line was drawn from the lateral edge of the lesion to the medial edge of the rotator cuff insertion (medial limit of the trochiter), called bone bridge and both distances were added. 3. The third step consisted of comparing both measures. If the Hill-Sachs interval was less than the glenoid component, it was called an on-track lesion; on the contrary, if the Hill-Sachs interval was greater than the glenoid component, it was classified as off-track.[5,6,7,13,15]

The recurrence of the dislocation in the postoperative period was verified with plain radiographs and clinical evaluation. In addition to demographic variables, the surgical findings, the number of anchors used and the position used during the surgical intervention were taken into account.

Statistical analysis was performed with SPSS statistical software (SPSS Inc., Chicago, USA). Sample size was obtained according to the Hulley table for descriptive studies of a dichotomous variable, based on an case expected ratio of 0.20,[16] at a confidence interval width of 0.30 and with a 95% confidence level. To determine the association between glenoid track and recurrence of instability, the odds ratio formula was used. Fisher's exact test and Mann Whitney's U were used for qualitative variables. The concordance tests were performed with the Kappa test. A significant difference was considered when p was less than 0.05.

Results

A total of 70 shoulders were studied, of which 10 were excluded due to lack of imaging studies or lack of information

Table 2: Variables regarding the surgery performed.

Variable		Total (%)	RI group (%)	NRI group (%)	p
Position	Lateral decubitus	41 (68.33)	5 (8.33)	36 (60.00)	0.85*
	Beach chair	19 (31.67)	2 (3.33)	17 (28.34)	
Number of anchors					
1		9 (15.00)	2 (3.33)	7 (11.67)	0.28*
2		31 (51.66)	4 (6.66)	27 (45.00)	0.75*
3		19 (31.67)	1 (1.67)	18 (30.00)	0.59*
4		1 (1.67)	0 (0.00)	1 (1.67)	n. a.
Aggregate injuries		26 (100.00)	1 (3.80)	25 (96.20)	1*
SLAP		16 (61.50)	1 (3.80)	15 (57.70)	0.54*
RC injury*		4 (15.40)	0 (0.00)	4 (15.40)	n.a.
Perthes		4 (15.40)	0 (0.00)	4 (15.40)	n.a.
Chondral lesions		2 (7.70)	0 (0.00)	2 (7.70)	n.a.

RI = recurrence of instability, NRI = no recurrence of instability, * Fisher exact test, SLAP = superior labral tear from anterior to posterior, RC = rotator cuff, n.a. = not applicable.

Table 3: Variables regarding measurements in imaging studies.

Variable		Total	RI group	NRI group	p
Glenoid diameter (mm)		Average 27.68 (range, 24-34)	Average 27.29 (range, 24-29)	Average 27.74 (range, 24-34)	0.80*
Glenoid bone loss (mm)		Average 2.25 (range, 0-6)	Average 2.14 (range, 0-4)	Average 2.26 (range, 0-6)	0.91*
Glenoid bone loss percentage		Average 7.9% (range, 0-20%)	Average 7.7% (range, 0-20%)	Average 7.9% (range, 0-14.3%)	0.96*
Hill-Sachs lesion size (mm)		Average 14.7 (range, 0-29)	Average 17.7 (range, 12-29)	Average 14.3 (range, 0-25)	0.18*
On track (%)	On-track	43 (71.67)	1 (1.67)	42 (70.00)	0.001‡
	Off-track	17 (28.33)	6 (10.00)	11 (18.33)	

RI = recurrence of instability, NRI = no recurrence of instability, ‡ Fisher's exact test, * Mann Whitney's U test.

in the clinical file. 60 shoulders were included for statistical analysis. *Table 1* shows the demographic variables and those of the pathology studied, among which the evolution of instability and the number of dislocations prior to surgery stand out. No statistical difference was observed between the two groups in any of the variables. No statistical difference was observed between the choice of the position in which the surgery was performed, between the numbers of anchors used and also between the injuries observed between both groups *(Table 2)*. Intraobserver agreement for the MRI or computed tomography evaluator was 0.92.

For the analysis of the measurements in the imaging studies, the data obtained from the second measurement were taken into account. We found bone defects in the anterior portion of the glenoid in 45 (75%) of the cases, while the other 15 (25%) cases presented integrity in the glenoid. The average measure of the defect was 2.25 mm (from 0 to 6 mm). Measurements in the posterior region of the humerus showed a Hill-Sachs lesion in 58 (97%) of the patients with an average of 14.7 mm of bone involvement (from 0 to 29 mm). The pattern of bipolar bone injury was also analyzed, which was evident in 44 (73.33%) of the cases. In 17 (28.33%) cases an «off-track» type lesion was diagnosed, while in 43 cases (71.67%) an «on-track» type lesion was described *(Table 3)*.

One of the main observations was that within the study group 7 (11.67%) patients suffered recurrence of instability, of which 6 (10%) were carriers of an off track lesion and only 1 (1.67%) had on track lesion, while 53 (88.33%) patients had a favorable outcome without recurrence of dislocation. This was interpreted as an increased risk of recurrence of instability in patients with «off-track» lesions compared to patients with «on track» lesions in a ratio of 23.47 according to the odds ratio. It was found that six of the 17 cases with an «**o**ff-track» lesion suffered a recurrence, while only one of the 43 cases with an on track lesion. All patients with recurrence had off-track lesion while 11 of the patients in the group without recurrence had an off-track injury. The positive predictive value of an off-track lesion to present recurrence is 86% while the negative predictive value is 79% *(Tables 4 and 5)*.

Table 4: Contingency table for the analysis of off-track glenoid track as a risk factor for recurrence of glenohumeral dislocation.

	Total (%)	Off-track (%)	On-track (%)	p
Recurrence	7 (11.67)	6 (10.00)	1 (1.67)	0.003*
No recurrence	53 (88.33)	11 (18.33)	42 (70.00)	
Total	60 (100.00)	17 (28.33)	43 (71.67)	

* Fisher's exact test.

A subanalysis was performed in the 44 patients with bipolar bone injury. Recurrence of dislocation occurred in 14% (six of 44 patients). Of the six patients with recurrence, 5 (83%) had an off-track lesion and 1 (17%) was an On-Track type. Conversely, only 11 (29%) of the 38 patients with bipolar lesion who did not experience recurrence had an off-track lesion. The fact of classifying bipolar lesions as on-track or off-track correctly predicted the evolution of 32 (73%) patients *(Table 6)*.

Discussion

The main findings of this study demonstrated the following: the classification of lesions in on-track or off-track is better associated with a possible future recurrence event, compared to classifying lesions as bipolar or taking into account only the percentage of glenoid bone loss. This classification system showed an adequate clinical correlation, since 86% of the patients with recurrence were carriers of an off-track lesion, with a positive predictive value of 86% and an odds ratio of 23.47 (p = 0.003). No statistically significant difference was found in the average glenoid bone loss between the groups with recurrence and without recurrence (7.7 vs 7.9%, respectively), in the Hill-Sachs lesion (17.7 vs 14.3 mm) and the bone bridge (5.2 vs 2.7 mm).

It was identified that the patients with the highest number of dislocations prior to the surgical intervention were those who had larger Hill-Sachs lesions, so they had a greater

probability of having an off-track type lesion; regardless of the fact that the average of glenoid bone loss in the same group was 7.7% (from 0 to 14.3%). It was observed that none of the patients had a percentage of loss greater than the critical value of 20% and that, in addition, of the seven patients who presented with recurrence, 2 (28.5%) had no bipolar lesion.

Regarding the average of dislocations per patient, we found that in the group that developed recurrence the average was 18.1 dislocation events prior to surgery, but in the group of patients without recurrence the average was 10.5. This greater number of dislocations predisposes to the development of larger bone lesions, and that these same become off-track lesions, as Nakagawa et al had already pointed out,[17] stating that in the event of a first dislocation event a Hill-Sachs lesion develops first, however, in the event of recurrent events, glenoid bone loss increases gradually with each dislocation and the Hill-Sachs lesion progresses more discreetly.

Shaha et al,[9] had also noted that applying the concept of glenoid track showed a better correlation to predict post-surgical stability, rather than employing glenoid bone loss alone. In his study, 57 patients with 10 cases of recurrence were analyzed. After NMR radiographic measurements, they found eight patients with an off-track lesion, of which 6 had a recurrence, compared to 4 recurrences in 49 on-track patients. This gave a positive predictive value of 75%, which agrees with that obtained in this study (86%). Most of the therapeutic models are based on the increase of the glenoid surface, without taking into account the Hill-Sachs lesion and its magnitude. Our results reinforce the idea of the use of glenoid track for therapeutic decision making in patients with instability, as has been proposed by Donohue et al,[18] Trivedi et al,[16] Metzger et al,[13] Gyftopoulus et al[19] and Di Giacomo et al.[20]

Locher et al,[2] reported in their study that off-track lesions were associated with a higher rate of revision surgery for recurrence, with an odds ratio of 8.3, while we found an odds ratio of 23.4.

The concept of glenoid track is not yet the gold standard for the preoperative evaluation of patients with instability. Recently, other evaluation parameters have emerged which promise to have a better predictive value

Table 5: Contingency table showing the odds ratio to know the degree of association of off-track glenoid track as a risk factor for recurrence of glenohumeral dislocation.

	Event occurs (recurrence)	No event occurs (no recurrence)	p	Odds Ratio
Exposure (off-track)	(A) 6	(B) 11	0.003*	$\frac{A/B}{C/D}$
No exposure (on-track)	(C) 1	(D) 42		23.47

Table 6: Subanalysis regarding the presence of bipolar lesion.

	Bipolar lesion (%)	No bipolar lesion (%)	Total (%)
Recurrence	6 (10.00)	1 (1.67)	7 (11.67)
No recurrence	38 (63.33)	15 (25.00)	53 (88.33)
Total	44 (73.33)	16 (26.67)	60 (100.00)

of evolution in patients with this pathology, such is the case of the scoring system proposed by Nakagawa et al,[11] who retrospectively evaluated the scans of 80 patients in their study. They classified the glenoid defects and the length, width and depth of the Hill-Sachs lesions and categorized them into 5 types, assigning them a value from 0 for «without defect» to 4 «larger defect», later, patients were classified with both measurements in 5 classes: class 1, 0-1 point; class 2, 2 points; class 3, 3 points; class 4, 4 points; and class 5, more than 5 points. The prevalence of recurrence of instability between the different classes was compared, likewise, the recurrence of instability of each class was compared, between the shoulders with on-track and off-track lesions, at the same time dividing the patients into 3 groups depending on the physical activity: rugby, American football and others. Results showed that there was no recurrence in class 1 patients who practiced rugby, football players in classes 1 and 2, and those who played other sports in classes 1, 2 and 3. However, when the recurrence cases were compared with on-track and off-track lesions, they found no significant difference, reporting 12% of cases with off-track type lesions, among which 33% evolved to recurrence, on the other hand, 18.2% of the patients with on-track lesions developed recurrence. Thus, the presence of off-track lesions may be a contraindication to arthroscopic Bankart-type repair, but the absence of an off-track lesion does not guarantee a favorable post-surgical evolution.

This study has several limitations, with respect to radiographic analysis, one of the main was that not all patients were evaluated with the same imaging study; most of our patients had MRI, with 42 (70%), followed by CT with 3D reconstruction in 11 (18%) and 7 (12%) of the patients had both studies. Huijsmans et al,[21] established that there is no significant difference between obtaining the measurements in NMR or 3D CT. For the calculation of glenoid bone loss, there is not yet a method cataloged as the gold standard, thus we opted for the perfect circle matching method proposed by Sugaya et al,[14] which has been used in multiple studies, however, problems arises when calculating it in the NMR sections, since if the sagittal cuts are not obtained with the same angulation of the glenoid surface, the measurements may be erroneous. This problem does not occur on CT with 3D reconstruction. Finally, regarding patient follow-up, in our series the average follow up was 14 months (from 9 to 21 months), but it must be considered that

recurrences of instability occur on average at 12.4 months.[18] We must also take into account that in our context surgical management may be delayed due to bureaucratic issues, we do not consider to analyze the time elapsed since the patient first came to consultation until the surgical procedure was performed, however this delay may condition that patients have a greater number of dislocations, therefore more Hill-Sachs lesions and larger glenoid bone losses and a greater probability of off-track lesions.

Despite the fact that off-track lesions can be predictive of recurrence of instability and of new therapeutic algorithms such as the one proposed by Di Giacomo et al,[20] There are still no studies that directly compare the evolution of patients in whom therapeutic management has been based on these algorithms. Future studies should focus on this area and evaluate the effectiveness and/or failure of such algorithms. In addition, our study takes as a sample population a heterogeneous group of patients with different physical activities, it would be interesting to stratify patients into different groups, based on physical activity, for example, to study particularly patients who practice contact sports and another group with low demand to define specific algorithms for each one.

In conclusion, we can establish that off-track lesions do constitute a risk factor for presenting recurrence of instability in patients who undergo arthroscopic anterior capsular plication, however, we cannot yet define it as the main factor or gold standard to predict recurrence. The results of our study allow us to recommend, in our health system, that imaging studies be routinely requested in patients with anterior glenohumeral instability, mainly CT with 3D reconstruction to better assess bone lesions, or, failing that, MRI, which also allows us to assess the presence of added soft tissue lesions, specifying to radiologists the importance of obtaining sagittal cuts orthogonal to the glenoid axis in order to obtain accurate measurements of the glenoid diameter.

References

1. Fox JA, Sanchez A, Zajac TJ, Provencher MT. Understanding the Hill-Sachs lesion in its role in patients with recurrent anterior shoulder instability. *Curr Rev Musculoskelet Med*. 2017; 10(4): 469-79.
2. Locher J, Wilken F, Beitzel K, Buchmann S, Longo UG, Denaro V, et al. Hill-Sachs off-track lesions as risk factor for recurrence of instability after arthroscopic bankart repair. *Arthroscopy*. 2016; 32(10): 1993-9.
3. Matsen FA, Chebli C, Lippitt S. Principles for the evaluation and management of shoulder instability. *J Bone Joint Surg Am*. 2006; 88(3): 648-59.
4. Burkhart SS, DeBeer JF, Tehrany AM, Parten PM. Quantifying glenoid bone loss arthroscopically in shoulder instability. *Arthroscopy*. 2002; 18(5): 488-91.
5. Yamamoto N, Itoi E, Abe H, Minagawa H, Seki N, Shimada Y, et al. Contact between the glenoid and the humeral head in abduction, external rotation, and horizontal extension: A new concept of glenoid track. *J Shoulder Elbow Surg*. 2007; 16(5): 649-56.
6. Gulati A, Dessouky R, Wadhwa V, Sanders D, Chhabra A. New concepts of radiologic preoperative evaluation of anterior shoulder instability: on-track and off-track lesions. *Acta Radiol*. 2018; 59(8): 966-72.
7. Ladermann A, Bohm E, Tay E, Scheibel M. Bone-mediated anteroinferior glenohumeral instability. *Orthopade*. 2018; 47(2): 129-38.
8. Su F, Kowalczuk M, Ikpe S, Lee H, Sabzevari S, Lin A. Risk factors for failure of arthroscopic revision anterior shoulder stabilization. *J Bone Joint Surg Am*. 2018; 100(15): 1319-25.
9. Shaha JS, Cook JB, Rowles DJ, Bottoni CR, Shaha SH, Tokish JM. Clinical validation of the glenoid track concept in anterior glenohumeral instability. *J Bone Joint Surg Am*. 2016; 98(22): 1918-23.
10. Younan Y, Wong PK, Karas S, Umpierrez M, Gonzalez F, Jose J, et al. *The glenoid track: a review of the clinical relevance, method of calculation and current evidence behind this method*. Vol. 46, Skeletal Radiology. Skeletal Radiology; 2017. 1625-34.
11. Nakagawa S, Hanai H, Mae T, Hayashida K, Yoneda M. Bipolar bone loss in male athletes with traumatic anterior shoulder instability: an evaluation using a new scoring system. *Orthop J Sport Med*. 2018; 6(7): 232596711878242.
12. Omori Y, Yamamoto N, Koishi H, Futai K, Goto A, Sugamoto K, et al. Measurement of the glenoid track *in vivo* as investigated by 3-dimensional motion analysis using open MRI. *Am J Sports Med*. 2014; 42(6): 1290-5.
13. Metzger PD, Barlow B, Leonardelli D, Peace W, Solomon DJ, Provencher MT. Clinical application of the "glenoid track" concept for defining humeral head engagement in anterior shoulder instability: a preliminary report. *Orthop J Sport Med*. 2013; 1(2): 8-10.
14. 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(5): 878-84.
15. Itoi E. 'On-track' and 'off-track' shoulder lesions. *EFORT Open Rev*. 2017; 2(8): 343-51.
16. Trivedi S, Pomerantz ML, Gross D, Golijanan P, Provencher MT. Shoulder instability in the setting of bipolar (glenoid and humeral head) bone loss: The glenoid track concept. *Clin Orthop Relat Res*. 2014; 472(8): 2352-62.
17. Nakagawa S, Iuchi R, Hanai H, Hirose T, Mae T. The development process of bipolar bone defects from primary to recurrent instability in shoulders with traumatic anterior instability. *Am J Sports Med*. 2019; 47(3): 695-703.
18. Donohue MA, Mauntel TC, Dickens JF. Recurrent shoulder instability after primary bankart repair. *Sports Med Arthrosc Rev*. 2017; 25(3): 123-30.
19. Gyftopoulos S, Beltran LS, Bookman J, Rokito A. MRI evaluation of bipolar bone loss using the on-track off-track method: a feasibility study. *AJR Am J Roentgenol*. 2015; 205(4): 848-52.
20. Di Giacomo G, Piscitelli L, Pugliese M. The role of bone in glenohumeral stability. *EFORT Open Rev*. 2018; 3: 632-40.
21. Huijsmans PE, Haen PS, Kidd M, Dhert WJ, van der Hulst VPM, Willems WJ. Quantification of a glenoid defect with three-dimensional computed tomography and magnetic resonance imaging: a cadaveric study. *J Shoulder Elbow Surg*. 2007; 16(6): 803-9.