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Current Concepts Review

The global track concept for evaluation of bipolar bone loss in anterior shoulder instability: Current concepts

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A R T I C L E I N F O

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A B S T R A C T

The identification of critical Hill Sachs lesions prone to engagement with the anterior glenoid rim is decisive for treatment decision making in anterior shoulder instability patients. Untreated critical Hill Sachs lesions can lead to recurrence of instability after surgical stabilization procedures. The glenoid track concept is currently used to quantify the likelihood of engagement of a Hill Sachs lesion but heavily relies on the difficult identification of the rotator cuff insertion and does not account for the laxity of the patient. Accordingly, studies have not been able to consistently confirm its accuracy in predicting recurrence of instability. The global track concept potentially allows for three-dimensional (3D) determination of the minimum rotation of the humeral head which in the worst arm position with alignment of the defects may lead to engagement of bipolar defects independent of rotator cuff insertion and laxity. Further validation steps and clinical studies to define critical values in different patient subpopulations are necessary before application in clinical practice.

Current concepts:

- Engaging Hill-Sachs lesions is a relevant risk factor for shoulder instability
- Identification and evaluation of Hill Sachs lesions is important for treatment decision-making
- The glenoid track concept can be used to distinguish off-track (engaging) from on-track (non-engaging) Hill Sachs lesions
- Heavily relies on the difficult identification of the rotator cuff insertion and does not account for the laxity of the patient

Future perspectives:

- The global track concept allows for 3D determination of the minimum rotation of the humeral head which may lead to the engagement of bipolar defects
- It is independent of arm position, rotator cuff insertion, and laxity.
- Further validation steps and clinical studies to define critical thresholds are needed

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INTRODUCTION

In the year 2000, Burkhard and DeBeer published their famous article on the importance of recognizing glenoid bone loss in anterior shoulder instability patients. Failure to do so will lead to unacceptably high failure rates after soft tissue Bankart procedures [1]. Based on several biomechanical and clinical studies, it has been determined that beyond 14 % of glenoid articular surface loss, bone grafting of the glenoid might be considered as surgical option depending on the level of demand of the patient [2–6]. With the exact threshold value still up for debate, recent research has focused on 3-dimensional analysis of the glenoid concavity as biomechanically and even clinically this seems to be a more suitable surrogate parameter to determine glenoid bone-mediated loss of stability of the shoulder than mere 2D surface measurements [7–10]. However, it has also been recognized that in order to perform these more complex measurements more sophisticated image analysis tools including 3D model creation will be required [11].

Even if a little delayed in time, similar to glenoid bone loss, also humeral bone loss in terms of engaging Hill-Sachs lesions has been recognized as a major risk factor for failed soft tissue stabilization procedures and a randomized trial showed a lower re-dislocation rate when addressing relevant Hill Sachs lesions in terms of a remplissage in addition to a Bankart repair [12,13]. Yamamoto et al. and Di Giacomo et al. have popularized the glenoid track concept which uses the width of the possibly damaged glenoid and the position of the Hill-Sachs lesion in relation to the posterosuperior rotator cuff insertion in order to determine whether a Hill-Sachs lesion is prone for engagement (off-track lesion) or not (on-track lesion) [14,15].

While the predictive value of this concept to identify Hill-Sachs lesions prone to engagement is under debate [16,17], the inter- and intraobserver reliability, as well as validity when tested against dynamic arthroscopic imaging, is low, which may negatively influence clinical decision-making [18–22]. A potential reason for limited reliability and validity is the reliance on the rotator cuff insertion as reference which is difficult to

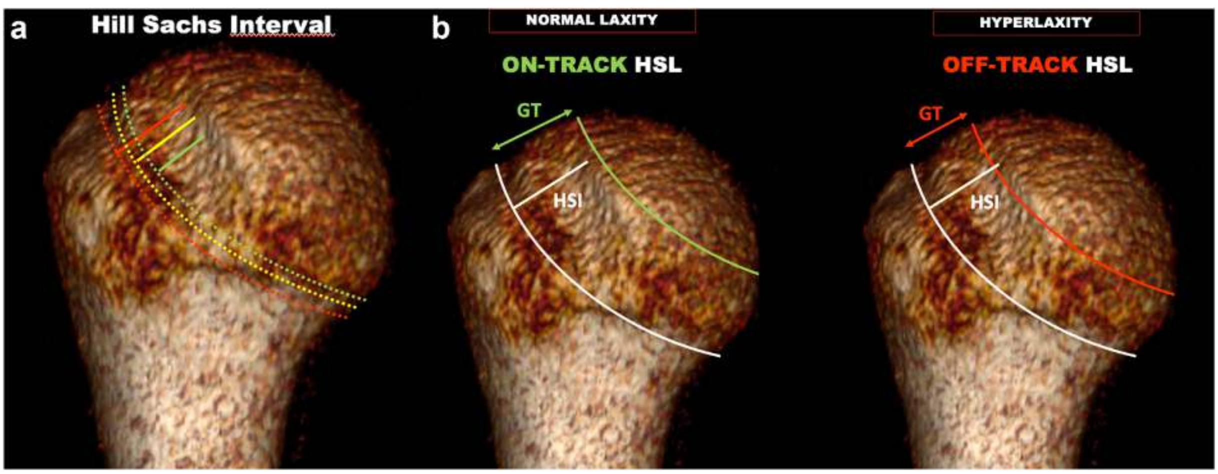

Fig. 1. a) Computed tomography scan of a Hill Sachs lesion (HSL) with unclear determination of the exact Hill-Sachs Interval (HSI: distance between cuff insertion and medial border of Hill-Sachs lesion) due to the difficulty in identifying the cuff insertion. b) The glenoid track (GT) of a patient will change based on its laxity as the 83 % reported in the literature is not a constant but rather determined by how much the glenoid can overlap with the cuff insertion. Thus an on-track Hill Sachs lesion (HSI is smaller than GT) can become off-track (HSI is greater than GT) if the patient is hyperlax. HSL = Hill Sachs lesion, HSI = Hill Sachs interval, GT = glenoid track.

Fig. 2. Image of the articular surface of the humeral head. The center of the articular surface (global apex, GA) and the center of a best-fit sphere (Center of Rotation, COR) are highlighted.

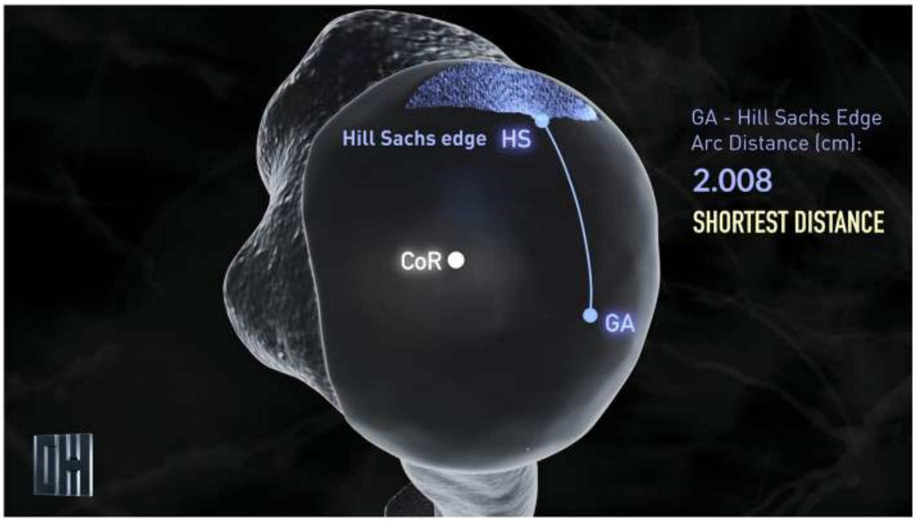

Fig. 3. The shortest arc distance from the global apex (GA) to the Hill Sachs lesion (HS) is measured. GA = global apex, COR = center of rotation, HS = Hill Sachs lesion.

Fig. 4. A line between the center of rotation (COR) and the global apex (GA) as well as the Hill Sachs lesion (HS) is drawn forming the angle alpha which describes the arc length (global track) that needs to be traveled across the articular surface from the global apex until reaching the edge of the Hill-Sachs lesion. GA = global apex, COR = center of rotation, HS = Hill Sachs lesion.

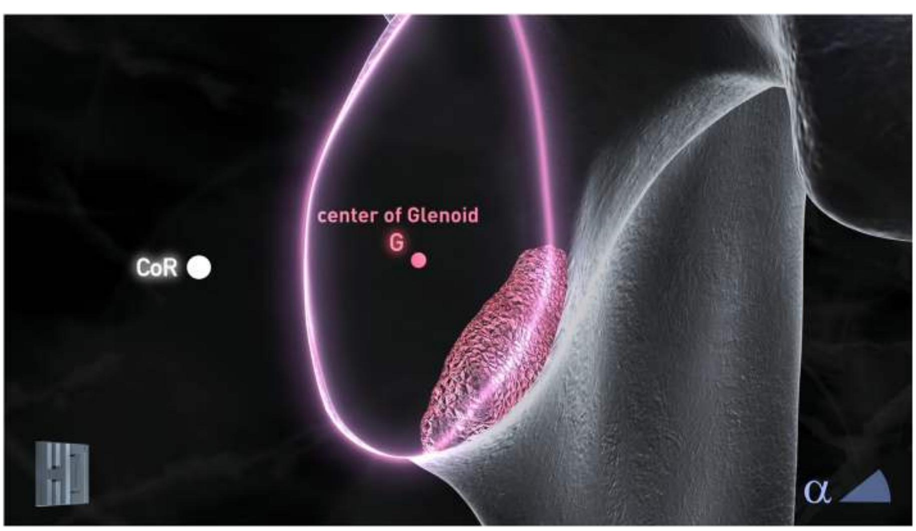

Fig. 5. Image of the articular surface of the glenoid. The center of the articular surface (G) and the center of rotation of the humeral head (COR) are highlighted. G = center of articular surface of glenoid, COR = center of rotation.

Fig. 6. The shortest arc distance from the center of the articular surface of the glenoid (G) to the glenoid defect (GD) is measured. G = center of articular surface of glenoid, GD = glenoid defect.

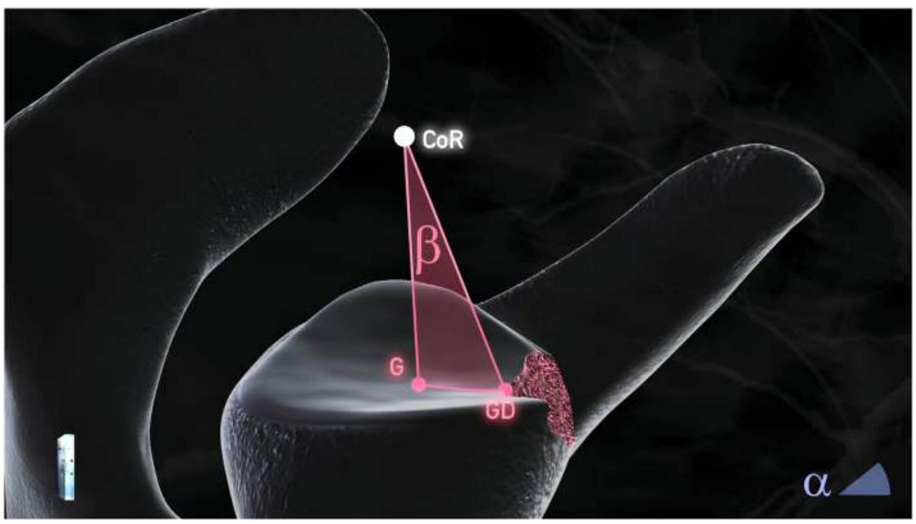

Fig. 7. A line between the center of rotation (COR) and the center of the articular surface of the glenoid (G) as well as the glenid defect (GD) is drawn forming the angle beta which describes the arc length (global track) that needs to be traveled across the articular surface from the center of the glenoid until reaching the edge of the glenoid defect. G = center of articular surface of glenoid, GD = glenoid defect, COR = center of rotation.

localize on CT scans routinely used for preoperative evaluation purposes [19]. Conversely, MRI allows for precise localization of the cuff insertion, however usually does not allow for retrospective multiplanar reconstructions that would allow to perform the measurements in the correct plane. A further main issue is the fact that the glenoid track width, originally defined as 83 % of the glenoid width, largely depends on arm position and laxity of the patient which limits the applicability of the glenoid track concept [23,24]. It has been attempted to refine the glenoid track method by introducing the concept of near-track lesions which are generally on-track but might nonetheless become critical in hyperlax patients or collision sports athletes [25–28]. However, other authors were not able to confirm any accuracy in predicting the recurrence of instability for this refined interpretation of the glenoid track method [29]. (Fig. 1).

Currently, it can be observed that many surgeons do not measure the glenoid track in their clinical routine even though they generally do regard bipolar bone loss during their clinical decision-making process [30].

The global track concept

In a recent study, a modification of the glenoid track method has been proposed called the global track concept [31]. Instead of relying on the insertion of the postero-superior rotator cuff, the apex of the articular surface of the humeral head is used as reference point to determine the closest angular distance between this center–point and the Hill-Sachs lesion. The measurement value obtained indicates how many degrees the humeral head can turn until the glenoid reaches the Hill-Sachs lesion.

In the following description the use of the global track method will be expanded into a bipolar defect scenario in order to provide a 3D measurement parameter that allows to determine the degree of rotation the humeral head can undergo in a patient with bipolar bone loss until engagement occurs (rotation-to-dislocation).

The articular surface of the humerus is used as a reference to define the center of rotation (CoR) of a best-fit sphere and the global apex (GA) on top of the articular surface of the humeral head (Fig. 2). The point on the edge of the Hill Sachs lesion (HS) with the shortest arc distance to the global apex is determined (Fig. 3). The central angle alpha is determined by a line connecting the CoR and HS and a line connecting CoR and GA. This angle describes the arc length (global track) that needs to be traveled across the articular surface from the global apex until reaching the edge of the Hill-Sachs lesion (Fig. 4). The center of the glenoid (G) is defined by taking the glenoid articular surface as a reference while maintaining the CoR of the humeral head (Fig. 5). The point on the edge of the glenoid defect (GD)

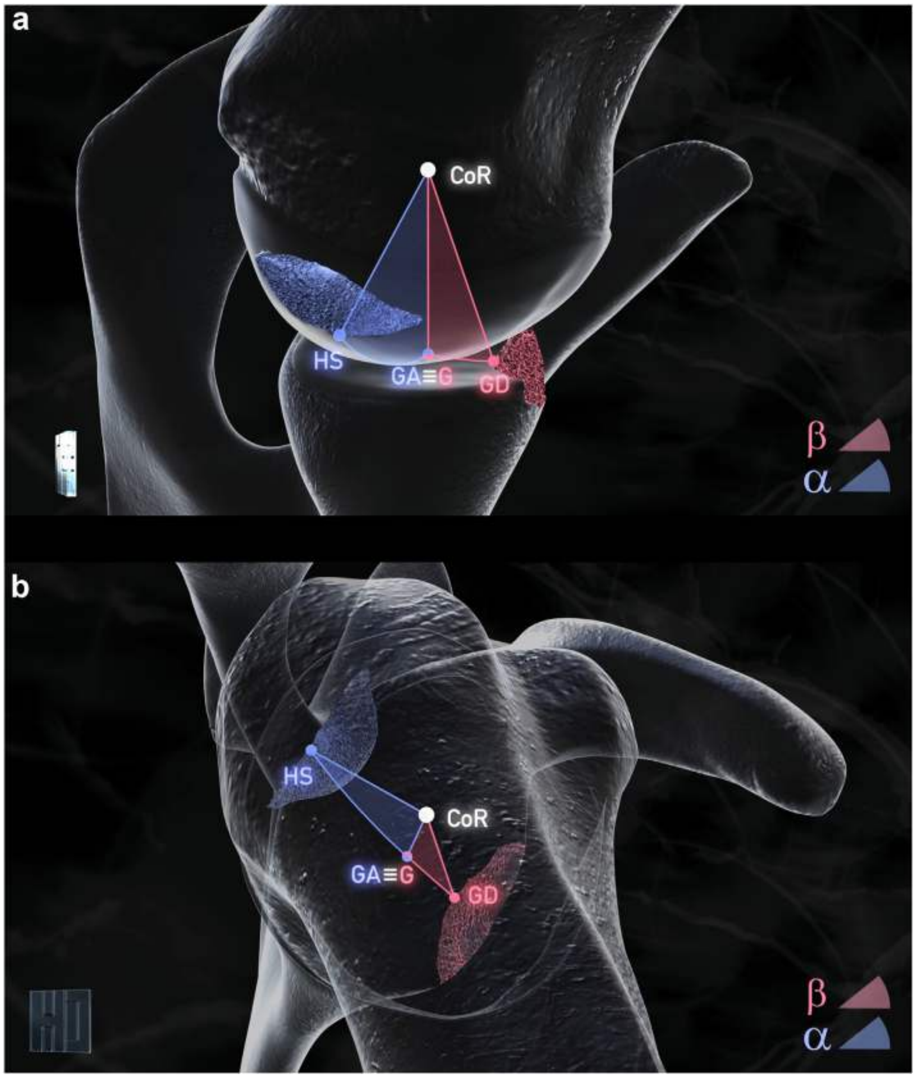

Fig. 8. Depending on the humerus position in relation to the scapula the rotation planes alpha and beta may or may not be aligned. HS = Hills Sachs lesion, GA = global apex, G = center of articular surface of glenoid, GD = glenoid defect, COR = center of rotation.

with the shortest arc distance to the center of the glenoid is determined (Fig. 6). The central angle beta is determined by a line connecting the CoR and GD and a line connecting CoR and G. This angle describes the arc length (global track) that needs to be traveled across the articular surface from the center of the glenoid until reaching the edge of the glenoid defect (Fig. 7). If the glenoid center (G) aligns with the global apex (GA) of the humeral head the planes of the angle alpha and the angle beta may or may not be aligned depending on the arm position (Fig. 8). If aligned, the likely original position of the humerus in relation to the scapula during dislocation is reached where a rotation of the humeral head by the amount of alpha and beta combined (delta angle) resembles the smallest amount of humeral head rotation (global track) after which an engagement of the similarly oriented defects might occur (Fig. 9) (Video 1).

DISCUSSION

The identification of critical bipolar bone defects in anterior shoulder instability is paramount when choosing an adequate surgical stabilization procedure. Critical bipolar defects may be addressed by means of adding a remplissage to a Bankart repair or by means of a glenoid bone augmentation procedure. In order to determine whether a bipolar defect is critical or not, surrogate measurement parameters are employed that indicate the biomechanical likelihood of engagement of the defect during motion. The global track method is a new concept that potentially allows to determine the minimum glenohumeral rotation in the plane of motion with alignment of the defects after which engagement might occur (rotation-to-dislocation). The independent calculation of the minimum arc distance from the articular center to the respective humeral and glenoid defect edge seems to make a determination of minimum rotation till engagement is possible irrespective of the variable arm position, defect position, and defect orientation. The measurement method was proven to be reliable, however only when performed with the help of a semi-automated software as it involves a more complex 3D analysis of the humeral defect scenario difficult to perform manually on 2D imaging alone [31]. Therefore its clinical application will depend on the availability of instability-dedicated preoperative planning software. A validation of the concept has yet to occur. A limitation of the concept is the lack of accounting for translation which may further reduce the minimum rotation-to-dislocation due to a shift of the contact point between the humeral head and the glenoid [32,33]. Nonetheless, the COR stays fairly steady during different motions in a non-pathological shoulder. When interpreting the global track with calculated delta angle (minimum rotation-to-dislocation) patient specific factors need to be taken into account. Hyperlaxity may allow a patient to reach a more extreme end-range of motion thus potentially turning a subcritical delta angle into a critical delta angle. Nonetheless, the absolute measurement value of the

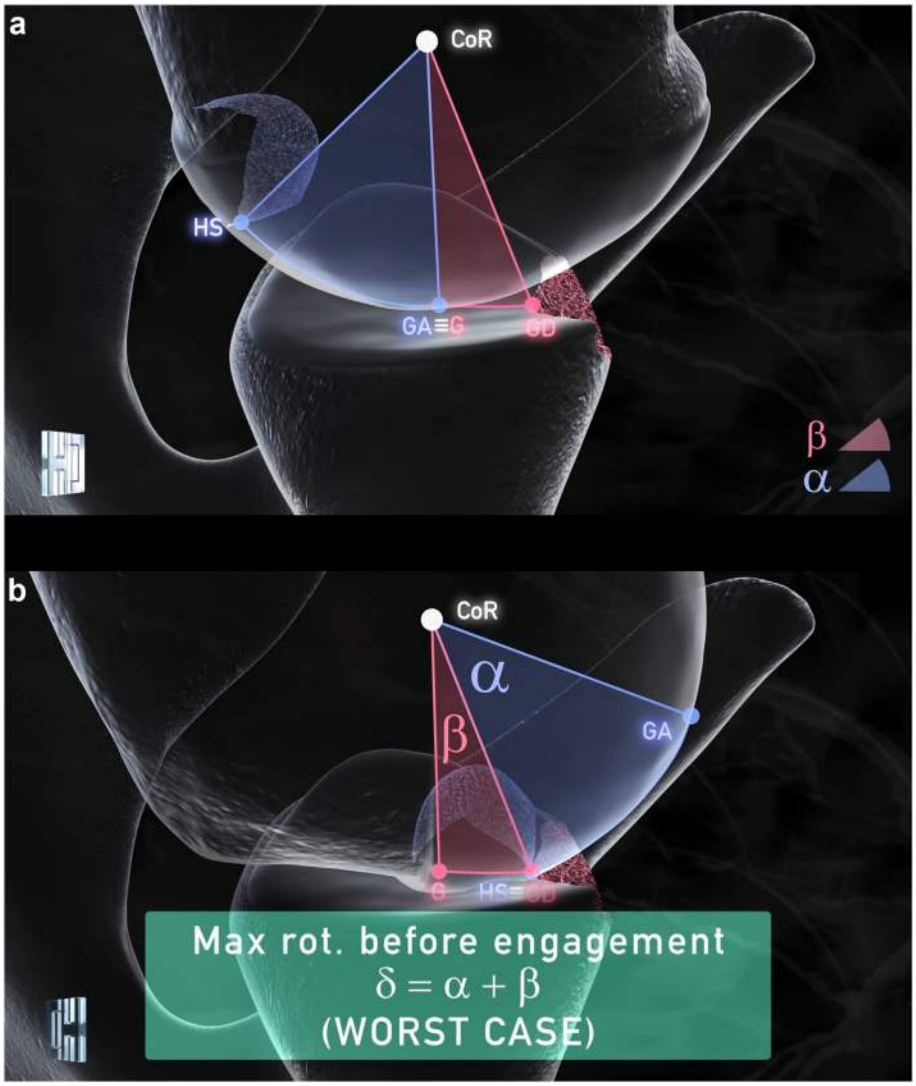

Fig. 9. A rotation of the humeral head by the amount of alpha and beta combined (delta angle) resembles the smallest amount of humeral head rotation (global track) in the plane of alignment of the defects after which an engagement might occur. HS = Hills Sachs lesion, GA = global apex, G = center of articular surface of glenoid, GD = glenoid defect, COR = center of rotation.

delta angle is independent of hyperlaxity and thus allows for interindividual comparison for study purposes. However, clinical studies are required to define critical values in different patient subpopulations before application in clinical practice. Other than laxity also the extent of shoulder-related activity needs to be taken into account as bony measurements alone are not sufficient to determine the appropriate treatment for patients with different shoulder-specific demand [17,34].

CONCLUSION

The global track concept represents a new 3D measurement method for bipolar bone loss in shoulder instability patients that potentially allows to quantify the minimum critical rotation of the humeral head which in the worst arm position with alignment of the defects may lead to engagement.

Ethical approval

No ethical committee approval is required for this type of article (expert opinion).

Declaration of competing interest

Giovanni Di Giacomo: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Philipp Moroder: The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Philipp Moroder reports a relationship with Arthrex Inc that includes: consulting or advisory and funding grants.

Matthew Provencher: The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Matthew Provencher reports a relationship with Arthrex Inc that includes: consulting or advisory, speaking and lecture fees, and travel reimbursement.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jisako.2025.100852.

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