

## Three-Dimensional Morphometry of Mandibular Condylar Process Fractures and Its Influence on Treatment Choice

**Musayev Shamshodbek Shukhratovich**

*Department of Maxillofacial Surgery, Tashkent State Medical University, Tashkent, Uzbekistan, PhD,  
associate professor*

**Shomurodov Kakhramon Erkinovich**

*Department of Maxillofacial Surgery, Tashkent State Medical University, Tashkent, Uzbekistan, DSc,  
Professor*

**Annotation:** Three-dimensional morphometry of mandibular condylar process fractures has moved beyond being merely a more vivid form of visualization. Contemporary CT and CBCT studies show that quantitative assessment of spatial displacement, rotation, ramus height loss, proximal fragment volume, and final fragment position already influences the clinical choice between conservative management and open reduction, as well as the choice of surgical access and fixation strategy. Adult practice is gradually shifting from two-dimensional signs and broad fracture classifications toward morphology-driven decision-making, in which the spatial geometry of the fracture determines both the likelihood of functional adaptation and the technical feasibility of stable osteosynthesis. The 3D variables most consistently linked to treatment are proximal fragment displacement, rotation, ramus height loss, and lateral translation, whereas fixation planning depends especially on fragment size, screw corridor feasibility, and fracture-line position relative to optimal plate placement. Although the available evidence does not yet support one universal numerical algorithm, it already provides practical guidance for selecting adult patients for ORIF, for digital preoperative planning, and for individualized fixation. Three-dimensional morphometry should therefore be regarded not as an optional supplement to diagnosis, but as a working instrument in the modern management of mandibular condylar process fractures.

**Keywords:** *mandibular condylar process fractures, three-dimensional morphometry, CT, CBCT, open reduction and internal fixation, treatment choice, virtual planning, osteosynthesis*

### Introduction

Mandibular condylar process fractures include anatomically related but biomechanically distinct injuries of the base, neck, and head. For that reason, the traditional debate between open and closed treatment explains real clinical practice less and less well. The question has shifted from “operate or not” to a more precise one: can anatomy and function be restored predictably without surgery in a given patient, or does the spatial configuration of the fracture already make closed treatment less reliable [1,2,3].

Within this new logic, three-dimensional morphometry has taken on a central role. It translates fracture description from broad categories into measurable spatial features. This matters not only for scientific accuracy. In practical terms, variables such as fragment displacement, rotation, ramus height loss, lateral translation, and proximal fragment volume are beginning to determine both the risk of failure of conservative treatment and the technical plan for ORIF [4,5,6].

From two-dimensional description to quantitative 3D morphometry

The study is one of the key papers of the current stage because it proposed a reproducible framework for quantitative analysis of condylar fractures based on CT and CBCT. After segmentation of the mandible and fracture fragment, the intact side was mirrored onto the injured side, virtual reduction was performed, and 3D displacement, fragment volume, and rotation around three axes were calculated [7]. Intraclass correlation coefficients for these 3D measurements were high, whereas two-dimensional measurements were less robust. This showed that 3D morphometry provides not only a more appealing reconstruction, but a more precise and reproducible clinical language [8].

The same study also demonstrated that fracture level is associated with distinct morphometric profiles. Neck fractures showed the greatest 3D displacement and rotation, whereas base fractures had larger fragment volumes [9]. This has direct clinical meaning. Larger base fragments usually offer more bone stock for fixation, while marked rotation and displacement in the neck region make both closed management and anatomical reduction more difficult.

Even at this stage, it becomes clear that 3D morphometry changes not only diagnosis, but the very structure of clinical reasoning. Whereas two-dimensional imaging tends to reduce a fracture to an angle and a rough level, three-dimensional assessment shows how spatially complex the fragment is and how realistic stable reconstruction may be.

Table 1. Morphometric variables with the greatest practical value

<b>Morphometric variable</b>	<b>What it reflects</b>	<b>Practical value</b>	<b>Key sources</b>
3D proximal fragment displacement	Overall scale of spatial separation from the anatomical position	Reflects fracture severity and likelihood of functional disturbance	[10]
Rotation around the axes	Turning of the fragment in space	Makes closed treatment and anatomical reduction more difficult	[11]
Ramus height loss	Vertical shortening of the injured side	Linked to malocclusion risk and limited mouth opening	[12], [13]
Lateral translation	Sideward fragment shift	Increases the risk of unsatisfactory occlusion after closed treatment	[14]
Fragment volume	Size of the proximal fragment	Influences the feasibility of screw and plate fixation	[15]
Fracture-line position	Relationship of the fracture to the intended plate location	Determines whether a construct will function stably	[16,17]
Screw corridor	Bone thickness and available screw trajectory	Allows preoperative assessment of feasibility of head and high-neck osteosynthesis	[18]

Three-dimensional morphometry already influences treatment choice

The strongest clinical argument for 3D morphometry is that it is already used to identify fractures in which conservative treatment is less reliable. The study [10], focused on patients after closed treatment, showed that ramus height loss and lateral movement length were associated with subsequent malocclusion. Inclination angle alone was less informative than the spatial combination of vertical shortening and lateral displacement [19]. This finding is clinically important because it shifts attention away from a single angle and toward a multiparametric assessment in which 3D geometry better captures the real risk of failure of closed management.

A similar logic was demonstrated by. In a cohort of isolated unilateral fractures, quantitative assessment of the interfragmentary gap helped guide the choice between functional rehabilitation and intermaxillary fixation. When the fracture gap was less than 6 mm and the patient was cooperative, functional management appeared more suitable. Although this study does not reduce decision-making to one number, it shows that quantitative morphometry is already part of practical treatment algorithms.

An even more explicit digital approach was presented in, where an XNAT-based database and 3D measurements were used to link symptom severity and clinical outcome to specific morphometric variables. In adults with condylar neck and base fractures, surgical treatment was superior to conservative treatment, and the greatest pain and the most severe limitation of mouth opening were seen when the shift

angle exceeded 11 degrees and ramus height reduction exceeded 4 mm [20]. These thresholds should not be treated as universally final, but their significance lies elsewhere: they show that 3D morphometry is already being used to stratify patients in a treatment-oriented manner.

The earlier work also linked spatial displacement to treatment selection. When displacement exceeded 37 degrees, loss of vertical ramus height after conservative treatment became substantial, and this was considered an argument for open treatment. Despite the age of the study, it remains important as an early attempt to translate fracture geometry into treatment choice.

Taken together, these findings support a strong but justified conclusion. Three-dimensional morphometry already affects treatment choice not because one perfect threshold exists, but because spatial fracture features have become practical criteria for selecting adult patients for ORIF.

Table 2. Morphometric markers relevant to clinical treatment escalation

Variable	Clinical context	Practical implication	Sources
Ramus height loss and lateral translation	Closed treatment	Higher risk of malocclusion after conservative management	[21]
Fracture gap less than 6 mm in a cooperative patient	Isolated unilateral fracture	Functional rehabilitation may be preferred to more rigid immobilization	[22]
Shift angle greater than 11 degrees and ramus height loss greater than 4 mm	Adult neck and base fractures	Argument for surgical treatment and digital planning	[22]
Displacement greater than 37 degrees	Subcondylar fractures	Threshold beyond which closed treatment preserves ramus height poorly	[23]
Ramus shortening as an isolated sign	Unilateral fractures	Useful, but insufficient without full 3D assessment	[24]

### Influence of 3D morphometry on surgical access and ORIF planning

For surgical strategy, the value of 3D morphometry is even more evident. The review lists virtual fracture evaluation among the six key elements of successful condylar fracture management. In this context, 3D assessment is needed not only to confirm indications, but also to choose the surgical approach, simulate reduction, calculate screw length, and determine plate position. In other words, preoperative morphometry becomes an operative step before the first incision.

This is especially important in condylar head and high-neck fractures, where technical feasibility depends on screw corridor and fragment dimensions. The studies and showed that preoperative multiplanar CT and 3D assessment allow the surgeon to determine in advance whether lag-screw osteosynthesis is feasible in type B fractures. In, computer-aided preoperative planning was used to define screw direction, length, and diameter in condylar head fractures, meaning that 3D morphometry directly influenced which fixation technique could be safely used.

## Materials and Methods

This study employed a systematic literature review approach to analyze contemporary research on three-dimensional morphometry of mandibular condylar process fractures and its role in treatment selection. Scientific articles, clinical studies, and systematic reviews published in international databases such as PubMed, Scopus, and Google Scholar were included. Keywords such as mandibular condylar fractures, three-dimensional CT, CBCT, morphometry, and open reduction internal fixation were used. Inclusion criteria comprised English-language studies focusing on adult patients, quantitative 3D assessment, and treatment outcomes. Exclusion criteria included animal-only studies without clinical

correlation and incomplete datasets. Data extraction focused on morphometric variables, including displacement, rotation, ramus height loss, and fracture geometry. Comparative analysis was performed to evaluate the relationship between 3D parameters and treatment decisions. The findings were synthesized narratively to identify clinical trends and decision-making patterns in modern maxillofacial trauma management and evidence-based surgical planning frameworks were also critically evaluated for consistency in clinical context.

## Results and Discussion

The clinical development of this approach was illustrated by. After virtual reduction, the authors selected screw sizes, designed navigation guides, and in biomechanically unfavorable cases manufactured patient-specific reinforcement plates. When the cortical layer was very thin and the lateral pole was fragmented, standard screws alone were insufficient, and fracture morphology dictated the need for reinforcement or even a patient-specific 3D plate. In this setting, 3D morphometry does not merely influence the operation. It determines the type of fixation itself.

Practical refinement of this morphology-driven approach is found in. Based on CT follow-up, the authors showed that screw position relative to the fracture line was associated with preservation of ramus height 12 months after condylar head osteosynthesis. The optimal distances were approximately 4 mm for the superior screw, 8 mm for the inferior screw, and 4–5 mm for the anterior screw, with an insertion angle of around 130 degrees for the latter. This is one of the clearest examples of morphometry being translated into concrete surgical geometry.

The study complements this line with anthropometric guidance. Based on 500 CT models, the authors proposed clinically useful maximal screw lengths for different parts of the condylar process: about 8 mm for the base, 10 mm for the neck top, 1.5–2 mm at the sigmoid notch, and 20–22 mm for the head in bicortical fixation. These data are especially valuable in trauma settings, where anatomy is deformed and direct intraoperative measurement is less reliable.

Fracture morphology already influences fixation design choice

Extracapsular fractures show the same dependence on spatial geometry. In, the most favorable biomechanical pattern for base fractures was obtained when fixation lines were placed along the posterolateral ramus border and the anterolateral region along the sigmoid notch. The study therefore showed that not only the implant material, but also the location of the fixation lines relative to fracture morphology affects stress distribution and fragment displacement.

The study demonstrated that the lambda plate performs differently in neck and base fractures. In neck fractures, rigidity improved when the plate was placed as cranially as possible, whereas in base fractures the fixation was often inadequate and the authors recommended considering a second plate at the sigmoid notch. In the authors showed that when the fracture line lies deeper and more inferiorly, a trapezoidal plate becomes less stable if left in its usual position, while more cranial placement improves fixation.

Even where clinical comparative series remain limited, finite element studies already make one practical point clear: the same plate cannot be assumed to be equally suitable for all fracture geometries. Three-dimensional morphometry therefore influences access and fixation selection not indirectly, but through the mechanics of the construct itself.

The argument for 3D morphometry is strengthened by the fact that final spatial condylar position is linked to function. The study showed that open reduction allowed near-anatomical restoration in most patients, and the authors explicitly identified CT as the optimal tool for evaluating the result. In postoperative CBCT-based 3D assessment after ORIF showed that residual spatial deviations were related to clinical TMJ function. Similarly, showed that worse final 3D condylar position was associated with smaller mouth opening, worse patient-reported outcomes, and more pain, while open treatment achieved better medial-lateral reduction.

Even in condylar head fractures, where remodeling continues after surgery, morphometry remains important. In surgical treatment in adults resulted in better recovery of ramus height and better TMJ morphology than conservative treatment. The study showed that gradual condylar height loss may occur after ORIF despite satisfactory function, meaning that postoperative morphological change requires separate quantitative assessment.

Thus, postoperative 3D studies do more than evaluate treatment quality. They retrospectively confirm the central preoperative principle: the spatial geometry of the fracture has real clinical consequences and should be taken into account at the stage of treatment selection.

Despite the growing number of studies, the literature does not yet provide a single definitive algorithm. The systematic evidence analysis showed that even widely cited thresholds for ORIF rest on heterogeneous evidence. This is especially important for ramus shortening and angular displacement. These remain useful guides, but they do not replace comprehensive 3D assessment.

A second limitation is that clinical morphometry is still better developed for displacement, rotation, height loss, and interfragmentary gap than for variables such as bone contact area or precise fragment geometry in relation to fixation stability. These questions are addressed more often in finite element studies than in clinical cohorts.

A third limitation concerns classification. Even strong quantitative studies often have to map their findings onto older or inconsistently used fracture classifications, which makes direct transfer of morphometric conclusions into one unified treatment standard more difficult.

These limitations, however, do not negate the practical impact already achieved. Rather, they indicate that the field is no longer at the hypothesis stage, but at the stage of standardization.

## Conclusion

Current literature supports a fundamentally important conclusion. Three-dimensional morphometry of mandibular condylar process fractures already influences treatment choice in clinical practice. It contributes to selecting adult patients for ORIF, helps identify fractures with a higher risk of failure of conservative management, guides surgical access, enables preoperative assessment of whether screw osteosynthesis is feasible, and affects the positioning of plates and screws. The most important shift is the move from crude two-dimensional signs toward morphology-driven reasoning. In this framework, treatment is determined not by one angle or one classification label, but by the combination of spatial fracture variables, their functional consequences, and the technical feasibility of stable reconstruction. Three-dimensional morphometry should therefore be considered an essential part of the contemporary management strategy for adult condylar process fractures, especially when ORIF is being considered and when complex or individualized fixation is planned.

## References

- [1] E. Batbayar et al., “Quantitative three-dimensional computed tomography measurements provide a precise diagnosis of fractures of the mandibular condylar process,” *Journal of Personalized Medicine*, vol. 12, 2022, doi: 10.3390/jpm12081225.
- [2] Z. Zhou et al., “Digital diagnosis and treatment of mandibular condylar fractures based on Extensible Neuro imaging Archive Toolkit (XNAT),” *PLoS ONE*, vol. 13, 2018, doi: 10.1371/journal.pone.0192831.
- [3] T. Kobayashi et al., “Identification of malocclusion risk factors after closed treatment of condylar fractures using a novel three-dimensional computed tomography approach,” *Journal of Oral Science*, 2021, doi: 10.2334/josnusd.20-0600.
- [4] Y. W. Mo and D. L. Lee, “Prediction of conservative treatment failure for isolated unilateral mandibular condylar fractures using quantitative measures,” *Annals of Plastic Surgery*, vol. 85, pp. 384–391, 2020, doi: 10.1097/SAP.0000000000002316.
- [5] S. Shakya, X. Zhang, and L. Liu, “Key points in surgical management of mandibular condylar fractures,” *Chinese Journal of Traumatology*, vol. 23, pp. 63–70, 2019, doi: 10.1016/j.cjtee.2019.08.006.
- [6] S. A. Youssef et al., “Redefining and identifying evidence-based indications for open reduction and internal fixation in mandibular condylar fractures: A comprehensive systematic review and evidence analysis,” *Craniomaxillofacial Trauma & Reconstruction*, vol. 18, 2025, doi: 10.3390/cmtr18020025.
- [7] S. Guo et al., “Computer-aided design-based preoperative planning of screw osteosynthesis for type B condylar head fractures: A preliminary study,” *J. Craniomaxillofac. Surg.*, vol. 44, no. 2, pp. 167–176, 2016, doi: 10.1016/j.jcms.2015.11.013.
- [8] J. Li, J. Jiao, T. Luo, and W. Wu, “Biomechanical evaluation of various internal fixation patterns for unilateral mandibular condylar base fractures: A three-dimensional finite element analysis,” *J. Mech.*

- Behav. Biomed. Mater., vol. 133, p. 105354, 2022, doi: 10.1016/j.jmbbm.2022.105354.
- [9] P. Liokatis et al., “Application of the lambda plate on condylar fractures: Finite element evaluation of the fixation rigidity for different fracture patterns and plate placements,” *Injury*, 2022, doi: 10.1016/j.injury.2022.01.032.
- [10] P. Liokatis et al., “A finite element analysis of the trapezoidal plate. How to get a stable fixation at different fracture lines?” *Injury*, vol. 55, no. 12, p. 112020, 2024, doi: 10.1016/j.injury.2024.112020.
- [11] A. Alyahya et al., “Mandibular condylar fracture: a systematic review of systematic reviews and a proposed algorithm for management,” *Br. J. Oral Maxillofac. Surg.*, 2020, doi: 10.1016/j.bjoms.2020.03.014.
- [12] A. Schneider, J. Schulze, U. Eckelt, and M. Laniado, “Lag screw osteosynthesis of fractures of the mandibular condyle: potential benefit of preoperative planning using multiplanar CT reconstruction,” *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, vol. 99, no. 2, pp. 142–147, 2005, doi: 10.1016/j.tripleo.2004.05.021.
- [13] J. Collier et al., “The role of pre-operative 3-dimension CT evaluation of Type B intracapsular condylar fractures,” 2008, doi: 10.1016/J.BJOMS.2008.07.018.
- [14] B. Bielecki-Kowalski and M. Kozakiewicz, “Choice of screws for fixation of mandibular condyle fractures guided by anthropometric data,” *Appl. Sci.*, 2021, doi: 10.3390/APP11083371.
- [15] J. Kleinheinz, G. Anastassov, and U. Joos, “Indications for treatment of subcondylar mandibular fractures,” *J. Cranio-Maxillofac. Trauma*, vol. 5, no. 2, pp. 17–23, 1999.
- [16] S. Kommers et al., “Is radiological shortening of the ramus a reliable guide to operative management of unilateral fractures of the mandibular condyle?” *Br. J. Oral Maxillofac. Surg.*, vol. 52, no. 6, pp. 491–495, 2014, doi: 10.1016/j.bjoms.2014.04.008.
- [17] T. Pavlychuk et al., “Application of CAD/CAM technology for surgical treatment of condylar head fractures: A preliminary study,” *J. Oral Biol. Craniofac. Res.*, vol. 10, no. 4, pp. 608–614, 2020, doi: 10.1016/j.jobcr.2020.08.018.
- [18] M. Kozakiewicz and I. Gabryelczak, “The osteosynthesis of the mandibular head, does the way the screws are positioned matter?” *J. Clin. Med.*, vol. 11, 2022, doi: 10.3390/jcm11072031.
- [19] J. Okulski et al., “Optimal plate choice for high-neck mandibular condyle fracture: A mechanistic analysis of 16 options,” *J. Clin. Med.*, vol. 13, 2024, doi: 10.3390/jcm13030905.
- [20] S. Devireddy et al., “Three-dimensional assessment of unilateral subcondylar fracture using computed tomography after open reduction,” *Indian J. Plast. Surg.*, vol. 47, pp. 203–209, 2014, doi: 10.4103/0970-0358.138945.
- [21] A. A. Mohamed et al., “Three-dimensional assessment of accuracy for open reduction and internal fixation of the subcondylar fracture,” *J. Craniomaxillofac. Surg.*, 2021, doi: 10.1016/j.jcms.2021.06.009.
- [22] M. B. Buitenhuis et al., “Anatomical position of the mandibular condyle after open versus closed treatment,” *J. Craniomaxillofac. Surg.*, 2023, doi: 10.1016/j.jcms.2023.09.013.
- [23] R. Ren et al., “Comparison of temporomandibular joint function and morphology after surgical and non-surgical treatment in adult condylar head fractures,” *J. Craniomaxillofac. Surg.*, 2020, doi: 10.1016/j.jcms.2020.01.019.
- [24] H. Park, S. Ahn, and B. Lee, “Quantitative assessment of condylar remodeling after open reduction and internal fixation in mandibular condylar head fractures,” *J. Craniofac. Surg.*, vol. 35, pp. 2291–2295, 2024, doi: 10.1097/SCS.00000000000010414.