RESEARCH PAPER

Comparison of Different Types of Plates Used in Condylar Fractures: A Narrative Review

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Abstract:

Mandibular condylar fractures are among the most frequently encountered mandibular fractures and present considerable challenges owing to the complex anatomy of the temporomandibular joint and the multidirectional biomechanical forces acting on the condylar region. Stable fixation is essential to achieve anatomical reduction, restore mandibular function, maintain occlusion, and facilitate early rehabilitation. Over the years, fixation methods have evolved from conventional single and double miniplate osteosynthesis to dedicated three-dimensional (3D) plate systems and, more recently, patient-specific fixation devices. This review summarizes the current concepts in the fixation of mandibular condylar fractures, with emphasis on the biomechanical rationale, clinical applications, and performance of commonly used plate designs, including single miniplates, double miniplates, delta, trapezoidal, lambda, rhombic, Y-shaped, and mechanically optimized plates. Current evidence indicates that although double miniplate fixation continues to provide the highest biomechanical stability, modern 3D plate systems achieve comparable clinical outcomes while reducing surgical exposure, operative time, and hardware-related complications. Recent advances in computer-aided design/computer-aided manufacturing (CAD/CAM), virtual surgical planning, finite element analysis, three-dimensional printing, and patient-specific implants have further improved fixation accuracy and surgical precision. The integration of artificial intelligence and advanced biomaterials is expected to enhance implant design and
be individualized according to fracture configuration, available bone stock, surgical approach, and biomechanical requirements. Continued clinical research and technological innovation are expected to further optimize the management of mandibular condylar fractures and improve long-term functional outcomes.

Keywords:

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Introduction and Background:

One of the most frequent locations for mandibular fractures is the mandibular condyle or subcondylar region, which accounts for roughly 25–35% of all mandibular fractures and 30–37% of fractures in patients who are dentulous or edentulous, respectively [1]. Conservative and surgical treatment are part of management, but there is not a clear agreement on the best course of action because it varies on the patient's age, overall health, and fracture features [2]. Only when fracture pieces are perfectly aligned (rotation <30°) with minimum ramus height loss (<2 mm) a presentation observed in comparatively few cases—is conservative therapy usually recommended [3].

Because it offers precise anatomical reduction, stable fixation, early functional recovery, shorter intermaxillary fixation times, higher patient compliance, and superior occlusal results compared to conservative treatment, open reduction and internal fixation (ORIF) has been widely accepted [4-6]. However, due to restricted access and the proximity to critical neurovascular systems, surgical management is still technically challenging, and insufficient fixation can result in problems like plate fracture or screw loosening [3].

Two lines of stability are necessary for adequate attachment, according to the principles of osteosynthesis: one along the superior border to withstand tensile pressures during mastication and another along the posterior border to counteract bending and rotational loads [5]. In order to achieve reliable osteosynthesis, fixation plate design and location are essential. Condylar fracture fixation is currently accomplished using a variety of plate systems, such as micro plates, trapezoidal, delta, and strut plates [7].

In order to support evidence-based surgical decision-making and enhance patient outcomes, this review compares the plate systems currently in use for managing mandibular condylar fractures, emphasizing their biomechanical principles, clinical performance, benefits, drawbacks, and recent technological advancements.

Anatomy of normal condyle and condylar fractures:

Meckel's cartilage gives rise to the mandibular condyle through intramembranous ossification, where the primitive condyle is formed by mesenchymal condensation lateral to Meckel's cartilage [8]. It is a knuckle-shaped projection that emerges from the mandibular ramus's posterosuperior side. Its dimensions are roughly 15–20 mm mediolaterally and 8–10 mm anteroposteriorly, with a posterior angulation of 15–33° and an angle of 145–160° to the ramus. The medial pole is rounded, while the lateral pole is roughened and blunt [8].

Age, sex, face type, occlusal force, functional loading, malocclusion, and laterality all influence the condyle's size and shape. It is typically oval in shape, measuring 8–10 mm anteroposteriorly and 15–20 mm mediolaterally. As people age, degenerative changes become increasingly prevalent [9]. Condylar morphology was initially divided into convex, flattening, angled, and rounded kinds by Yale et al. in 1961 [10]. Additional flat, round, convex, concave, and angled morphologies were reported in later CT-based studies, with the convex variety being the most common. Males typically have larger condyles; however, growth may be impacted by occlusal variables and midline disparities [11].

The superficial temporal, posterior tympanic, posterior deep temporal, and transverse face arteries feed blood to the condyle, and matching veins provide venous drainage. The face and auriculotemporal nerves are the primary sources of innervation. Protrusive and lateral mandibular movements are made possible by the lateral pterygoid muscle, which inserts into the pterygoid fovea. During surgical approaches to the condyle, it is crucial to understand the facial nerve branches, especially how they relate to the inferior mandibular border and external auditory canal [12].

Condylar fractures account for about 30% of fractures in dentulous and 37% in edentulous mandibles, making mandibular fractures the second most common facial fractures after nasal bone fractures. The biomechanical contrast between the relatively weaker condylar neck and the stiff mandibular ramus, which leaves the condyle vulnerable to indirect stresses, is the reason for their high incidence. Road traffic accidents, falls, interpersonal aggression, sports injuries, industrial trauma, and gunshot wounds are common causes, although osteomyelitis, tumors, or muscle spasms during electroconvulsive therapy can induce pathological fractures [13].

For the best functional and aesthetic results, accurate diagnosis, anatomical reduction, stable fixation, and prevention of complications are crucial because condylar fractures can result in long-term complications like malocclusion, mandibular growth disturbances, temporomandibular joint dysfunction, and impaired mandibular function [13].

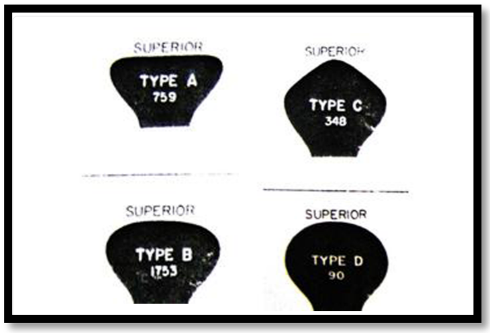

Figure 1: Classification of shape of the condyle [9]

Mechanism of injury [14]:

Lindahl described the trauma that caused the condylar fracture. Understanding the pattern is crucial because it indicates the kind of injury that was sustained.

1. Kinetic energy, which is produced when a body falls on a stationary object. The lower edge of the mandible transmits this axial force to the condyle. Both the injury site and the condyles at a higher level are susceptible to fracture. The force cannot be lessened by occluding teeth. may potentially lead to tooth fractures.

2. The momentum that a moving object creates against a stationary target is known as kinetic energy. typically observed in attacks or sports-related injuries. Both at the impact site and at the condyle on the other side, more or less horizontal forces will cause a fracture. Usually, a fracture occurs at the condyle's base.

3. When the aforementioned two are combined, it might lead to more serious injuries in a car collision. When an external stress is applied, it usually spreads throughout the entire mandible.

Nevertheless, these forces cause the weak subcondylar area, which is vulnerable to tensile stresses, to fracture. In the condylar area, a counter-coup injury is frequently observed. This keeps the condyles from moving into the middle cerebral fossa, particularly in cases of bilateral fractures brought on by traumas to the chin.

Restoring normal anatomical structures and functions is the main goal of open reduction and internal fixation (ORIF) for subcondylar fractures. To do this, fixation must be strong enough to resist the physiological forces of tension and compression. Due to their efficiency and suitability for the particular requirements of subcondylar fracture management, titanium plates and screws have become the most commonly used materials for this purpose [15]. Numerous procedures and fixing methods have been documented throughout the history of surgery. Miniplates of various sizes and forms are among the various fixing techniques used to treat symphyseal and parasymphyseal fractures. When a midline fracture occurs, all fixation devices that can be utilized to treat the fracture must be able to withstand the various moments of force, such as bending and torsion [16]. In numerous experimental and clinical investigations, a number of methods and plate types, including adaptation miniplates, minidynamic compression plates, resorbable plates, and double plates, have been assessed biomechanically. But there does not seem to be agreement on which kind of osteosynthesis is the best.

Review:

A Narrative literature review was conducted using PubMed, Scopus, and Google Scholar to identify studies evaluating fixation, methods and plate designs for mandibular condylar fractures. Relevant studies addressing biomechanical stability, clinical outcomes, complications, and recent developments in plate design were considered.

Evolution of plate designs used in mandibular condylar fractures:

The requirement to accomplish stable anatomical reduction while withstanding the intricate compressive, tensile, bending, shear, and torsional stresses operating on the condylar region during mandibular function has fuelled the development of fixation devices for mandibular condylar fractures. As a result, fixation techniques have evolved from basic plates to anatomically shaped implants that offer minimum surgical morbidity and multidirectional stability.

First Generation: Conventional Fixation

Maxillomandibular fixation (MMF), which was used in the early treatment of condylar fractures, was linked to extended immobility, temporomandibular joint stiffness, malocclusion, muscle atrophy, and delayed functional recovery. Dynamic compression and reconstruction plates increased fracture stability with the advent of open reduction and internal fixation (ORIF), but their size and thickness necessitated significant surgical exposure. Due to their ease of adaptation and low exposure, titanium single straight miniplates later gained popularity. Nevertheless, their inability to withstand multidirectional functional forces led to increased rates of plate fracture, screw loosening, and fixation failure, especially in displaced fractures [17].

Second Generation: Double Miniplate Fixation

Double miniplate fixation was created based on Champy's osteosynthesis concepts in order to get around the drawbacks of single miniplates. Tensile and compressive forces are successfully neutralized by two parallel plates positioned along the anterior and posterior borders of the condylar neck, enhancing resistance to bending, torsional, and shear stresses and enabling early functional recovery. Despite being the biomechanical reference standard, this method is technically difficult for severe condylar neck fractures since it necessitates more surgical exposure, longer operating times, higher implant costs, and sufficient proximal bone stock [18].

Third Generation: Three-Dimensional Anatomically Optimized Plates

The biomechanical benefits of double miniplates were combined with the ease of single-plate anchoring to create three-dimensional (3D) condylar plates. By distributing functional loads over several planes, their interconnected construction lessens surgical exposure while increasing resistance to compression, tension, bending, and torsional pressures.

Since then, a number of 3D plates with anatomical designs have been created, such as Delta, Trapezoidal, Lambda (λ), Rhombic, A-shaped, Y-shaped, Strut, Three-Dimensional Condylar Plate (TCP), and Dynamic Compression Condylar Plate (DCCP). Each design seeks to enhance screw purchase, stress distribution, fixation stability, and condylar anatomical adaptability. These techniques require fewer implants than traditional fixation, maintain the periosteal blood flow, lessen hardware-related issues, and promote early mandibular function. Clinical and biomechanical research has demonstrated stability that is on par with or better than traditional double miniplate fixation [15].

Fourth Generation: Patient-Specific Fixation Systems

Patient-specific titanium fixation devices have been made possible by recent developments in CAD/CAM technology, virtual surgical planning, and three-dimensional printing. By closely matching the patient's anatomy, customized plates reduce fractures, minimize intraoperative plate bending, speed up surgery, and improve fixing accuracy. Despite these benefits, their increased cost, need for specialized equipment, and lengthier preoperative planning continue to restrict their general use [19].

Overall, biomechanically optimized, anatomically contoured, and patient-specific implants have replaced traditional fixation techniques in the advancement of condylar fracture fixation. Instead of adding more plates, modern three-dimensional and tailored plate systems prioritize better implant geometry, which increases stability, preserves vascularity, minimizes surgical trauma, and encourages early functional rehabilitation.

Plate designs for mandibular condylar fracture fixation:

Single Straight Miniplate:

Because of its straightforward design, ease of adaptation, quicker operating time, and minimal soft tissue dissection, the single straight miniplate is one of the oldest and most popular fixation devices for mandibular condylar fractures. Usually, two monocortical screws are used on either side of the fracture to secure a 2.0-mm titanium miniplate. It only offers single-plane fixation and is unable to sufficiently withstand multidirectional functional pressures, which leads to increased fracture displacement, plate bending, screw loosening, and hardware failure even if it is effective in slightly displaced fractures with good bone contact [20,21]. As a result, its application is primarily restricted to fractures with minimum displacement.

Double Miniplate Fixation:

Because two plates placed along the compression and tension zones efficiently neutralize functional forces and offer superior resistance to bending, torsional, and rotational stresses, double miniplate fixation is considered the biomechanical gold standard. Compared to a single miniplate, this method provides consistent reduction, early functional rehabilitation, and fewer hardware-related issues. However, it is technically challenging in cases of severe condylar neck fractures since it necessitates larger surgical exposure, a longer operating time, and sufficient proximal bone stock [22].

Geometric Plates (Three-Dimensional Plates):

In order to combine the simplicity of a single implant with the stability of double miniplates, three-dimensional (3D) geometric plates were created. L-shaped, Y-shaped, Delta, Trapezoidal, Lambda, Rhombic, Strut, and other specific condylar plate designs are among them. By distributing stresses in three dimensions, their interconnected system reduces surgical exposure, operating time, and hardware failure while enhancing resistance to compression, tension, bending, and torsion [23].

Y-Shaped Plate:

The Y-shaped plate offers secure fixation with good resistance to multidirectional stresses because to its single inferior stem and two diverging superior arms. It provides comparable clinical results to trapezoidal plates, easier application, and shorter operating times. It works best for low condylar neck and condylar base fractures, but it needs sufficient proximal bone stock [23].

Delta Plate:

The Delta plate is a three-dimensional, triangular implant that uses a single plate to give multidirectional stability. With less implant mass, it provides effective stress distribution, simple adaptation, reduced operating time, better mouth opening, and outstanding postoperative stability. Although sufficient proximal bone stock is necessary, it is mostly recommended for condylar base and low condylar neck fractures [1].

Trapezoidal Plate:

A quadrilateral 3D fixation device called the Trapezoidal plate was created to replicate the stability of two miniplates using a single implant. It minimizes surgical exposure and operating time while offering superior resistance to functional pressures. It is less dependable in high condylar neck fractures with little proximal fragments, but it works well for low-neck and condylar base fractures with adequate bone stock [1].

Lambda Plate:

For high condylar neck fractures with little proximal bone stock, the Lambda (λ) plate is intended. Its anatomical design minimizes periosteal stripping, maintains vascularity, permits numerous screw trajectories, and is ideal for transoral endoscopic fixation. Its application is restricted in cases of severely comminute fractures or low condylar basis [24].

Rhombic Plate:

The Rhombic plate is a three-dimensional implant with a diamond shape that offers biomechanical stability and balanced stress distribution on par with double miniplates. It has demonstrated outstanding functional and occlusal results and enables less invasive fixation with less soft tissue dissection. Although it is less appropriate for highly comminute fractures, it is very helpful for condylar neck and base fractures [25].

Mechanically Optimized (Modus) Plate:

Using a single low-profile implant, the Mechanically Optimized (Modus) plate, which was created using finite element analysis, offers stability on par with multiple miniplates. Although its increased cost and scant long-term clinical data limit its widespread use, it offers better stress distribution, fewer hardware-related problems, and simpler fixation. For displaced condylar fractures that need stable fixation with low surgical morbidity, it is recommended [26].

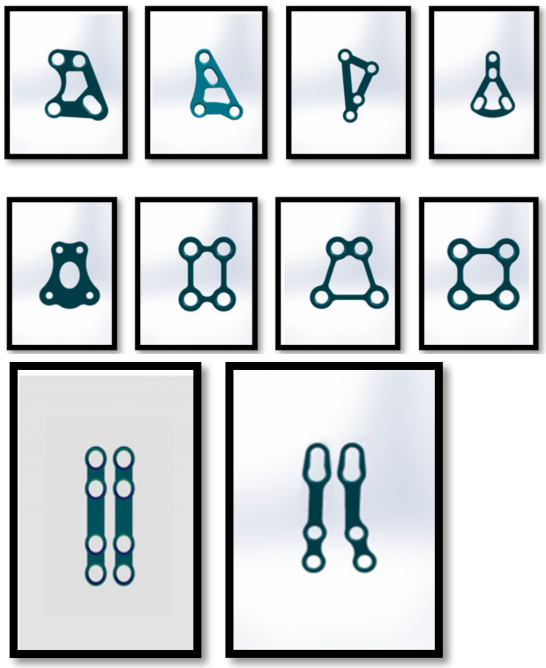

Figure 2: Various Plates used in Fixation of Condylar Fracture [2]

Table 1: Mechanical Comparison

Plate	Bending	Rotation	Fatigue	Ease of Insertion
Single plate	Poor	Poor	Poor	Excellent
Double plates	Excellent	Excellent	Excellent	Moderate
Delta	Excellent	Excellent	Excellent	Good
Trapezoid	Excellent	Excellent	Excellent	Good
Lambda	Very good	Very good	Good	Moderate
Rhombic	Very good	Excellent	Very good	Moderate
Y plate	Good	Good	Good	Good

Discussion:

The efficacy of various osteosynthesis plates for mandibular condylar fractures has been assessed in a number of biomechanical studies, systematic reviews, and clinical investigations. Due to its exceptional resistance to bending, torsional, and rotational pressures, double miniplate fixation was defined as the biomechanical gold standard by Asprino et al. (2006) [27] and the systematic review by Dayi and Ömezli (2011) [28]. The superior mechanical performance of parallel double miniplates for condylar neck fractures was further confirmed by recent biomechanical studies by Okulski et al. (2024) [2] and Hassani et al. (2026) [29], while Chen et al. (2024) [18] showed that a two-hole double-plate technique offers comparable stability with less surgical dissection. Dedicated three-dimensional (3D) plates have been developed as a result of advancements in implant design with the goal of offering comparable stability with lower surgical morbidity. According to clinical research by Seemann et al. (2007) [26], Ahuja et al. (2018) [30], and Ganguly et al. (2021) [31], delta plates provide equivalent fixation stability with shorter operating times, simpler adaption, and fewer hardware-related issues than traditional miniplates. While Smolka et al. (2020) [32] suggested trapezoidal plates for condylar base fractures and lambda plates for high condylar neck fractures, Ben Achour et al. (2019) [33] and Leonhardt et al. (2019 [34], 2025[25]) showed that rhombic plates provide biomechanical stability comparable to double miniplates with excellent functional outcomes. While Kumar et al. (2021, 2023 [35]) and Santhosh Kumar Kuna et al. (2024) [15] discovered that different 3D plate designs produced clinical outcomes comparable to double miniplates, Niranjana et al. (2023) [1] reported superior stability and lower hardware failure with trapezoidal plates compared with conventional miniplates. Additionally, Pfister et al. (2024) [36] and Kozakiewicz et al. (2023) [24] stressed that the primary factor influencing fixation stability is implant geometry rather than plate quantity or thickness. All of the information that is now available suggests that while double miniplate fixation is still the biomechanical standard, contemporary 3D anatomical plate systems offer similar clinical results with easier surgical application, shorter operating times, and decreased surgical morbidity. Future advancements in CAD/CAM technology, patient-specific implants, and virtual surgical planning are anticipated to further improve condylar fracture management. As a result, implant selection should be customized based on fracture morphology, biomechanical requirements, surgical approach, and surgeon experience.

Table 2: Summary of the published studies comparing plates designs for mandibular condylar fracture

Author	Year of publication	Plate	Clinical outcome	References
Asprino et al.	2006	Double mini plate	The biomechanical reference standard for condylar fractures is double plating because double four-hole miniplates showed noticeably better biomechanical stability than single miniplate fixation	[27]
Meyer at al.	2006	Three-dimensi	Improved	[37]

		onal plate	fixation stability and the creation of three-dimensional plates with anatomical contours for condylar fracture were made possible by dedicated condylar plate designs.	
Seemann et al.	2007	Mechanically Modus Plate	The mechanically optimized (Modus) condylar plate reduced hardware-related issues and operational complexity while achiving clinical outcomes comparable to double	[26]

			miniplates	
Dayi and Omezli	2011	Double miniplate	Based on their systemic review, they found out that the use of double miniplates is still the most stable technique compared to single plate and a bio-resorbable plate when treating condylar fracture	[28]
Anirudhan et al.	2013	Delta plate	Clinical examination revealed that the indigenous design of the delta plate gave good fixation with satisfactory post-operative	[38]

			functions in sub condylar fracture	
Ahuja et al.	2018	Delta plate and conventional miniplate	The results achieved through delta plates and conventional miniplates were similar, nevertheless, the adaptation period was shorter in the former case because it was sufficient to use only one plate along the four screws.	[30]
Ben Anchour et al.	2019	Rhombic 3D plate	The rhombic 3D plate had similar biomechanical characteristic to that of double miniplate fixation with the	[33]

			need for just one plate and fewer screws in the proximal segment.	
Leonhardt et al.	2019	Rhombic plate	Successful clinical application of the rhombic plate using the transoral endoscopic technique produced a successful reduction of the fracture, proper mandibular movement, and minimal complication, thus making it suitable for condylar neck fracture	[34]

Ganguly et al.	2021	3D delta plate	3D delta plates decreased operation time and increased mouth opening and bite efficiency after surgery in comparison with conventional miniplates, without any effect on the fracture healing	[31]
Kozakiewicz et al.	2023	Double straight plate	A comparison study of 51 plate design for condyle revealed that double straight plates still represent the biomechanical gold standard although some dedicated 3D plates proved equally stable. Mechanical Excellence Factor (MEF) has been suggested as an aid for prediction of fixation stiffness based on the shape of the plate	[24]
Franke et al.	2025	Rhombic plate	Long-term follow up revealed highly satisfactory radiological and functional results with rhombic plates. It was concluded that the shape of the fracture was the key determinant for treatment	[25]

Future directions:

The goal of future advancements in mandibular condylar fracture fixation is to decrease surgical morbidity while increasing biomechanical stability, surgical accuracy, and biological healing. Customized fixation plates with better anatomical fit, better load distribution, less intraoperative plate bending, and faster operating durations are now possible thanks to developments in CAD/CAM technology, 3D printing, and patient-specific implants (PSIs). Implant design, plate positioning, screw placement, and patient-specific treatment planning are anticipated to be further optimized by the integration of artificial intelligence (AI), virtual surgical planning, and finite element analysis (FEA). Topology-optimized plate designs, innovative biomaterials including beta-titanium alloys, carbon fiber-reinforced PEEK, graphene composites, and nanostructured titanium, as well as bioactive coatings that encourage osseointegration and lessen infection, are examples of emerging advances. Biodegradable fixation systems, Nitinol shape-memory alloys, smart implants, robotic and navigation-assisted surgery, augmented reality-guided procedures, and biological therapies like platelet-rich fibrin (PRF), bone morphogenetic proteins (BMPs), stem-cell therapy, exosomes, and drug-eluting implants are some other exciting developments. When combined, these developments should make it possible to treat mandibular condylar fractures in a more individualized, minimally invasive, and biomechanically optimal manner, improving long-term patient care and functional results.

Conclusions:

Due to the intricate anatomy and biomechanical requirements of the temporomandibular joint, mandibular condylar fractures continue to be a difficult problem in oral and maxillofacial surgery. For properly chosen fractures, open reduction and internal fixation (ORIF) has replaced conservative care due to advancements in surgical methods and fixation technologies. Due to its exceptional resistance to functional pressures, double miniplate fixation remains the biomechanical gold standard; however, its application may be restricted by increased surgical exposure and operating time.

By offering durable fixation with lower surgical morbidity and easier application, specialized three-dimensional (3D) plates such as the delta, trapezoidal, lambda, rhombic, and Y-shaped plates have greatly revolutionized the management of condylar fractures. According to available data, there is not a single plate design that works best for every fracture pattern. As a result, fracture morphology, fragment size, bone quality, surgical technique, and surgeon expertise should all be taken into consideration when choosing an implant. It is anticipated that future developments in finite element-guided plate designs and patient-specific CAD/CAM implants will enhance treatment results. All things considered, stable fixation, early functional rehabilitation, and favorable long-term clinical results continue to depend on an evidence-based, fracture-specific approach.

References:

1. Niranjana B, Kumar A, Basu P, Sharma A, Bhutani H, Kaushik S. A systematic review on management of condylar fracture. Asian J Dent Sci. 2023;6(1):84-95.
2. Okulski J, Kozakiewicz M, Krasowski M, Zieliński R, Szymor P. Optimal Plate Choice for High-Neck Mandibular Condyle Fracture: A Mechanistic Analysis of 16 Options. J Clin Med. 2024 Feb 4;13(3):905. doi: 10.3390/jcm13030905.
3. Kocaaslan ND, Karadede Ünal B, Çavuş Özkan M, Karadede B, Çelebiler Ö. Comparison of different treatment techniques in the mandibular condyle fracture. Ulus Travma Acil Cerrahi Derg. 2022;28(1):99-106. doi:10.14744/tjtes.2020.94992.
4. Yao S, Zhou J, Li Z. Contrast analysis of open reduction and internal fixation and non-surgical treatment of condylar fracture: A meta-analysis. J Craniofac Surg. 2014;25(6):2077-2080. doi:10.1097/SCS.0000000000001010.
5. Shakya S, Zhang X, Liu L. Key points in surgical management of mandibular condylar fractures. Chin J Traumatol. 2020;23(2):63-70. doi:10.1016/j.cjtee.2019.08.006.
6. Chaudhary M, Pant H, Singh M, Vashistha A, Kaur G. Evaluation of trapezoidal-shaped 3-D plates for internal fixation of mandibular subcondylar fractures in adults. J Oral Biol Craniofac Res. 2015;5(3):134-139. doi:10.1016/j.jobcr.2015.09.006.
7. Zachariades N, Mezitis M, Mourouzis C, Papadakis D, Spanou A. Fractures of the mandibular condyle: A review of 466 cases. Literature review, reflections on treatment and proposals. J Craniomaxillofac Surg. 2006;34(7):421-432. doi:10.1016/j.jcms.2006.07.854.
8. Almpani K, Tran H, Ferri A, Hung M. Assessment of condylar anatomy and degenerative changes in temporomandibular joint disorders: A scoping review. J Oral Biol Craniofac Res. 2023;13(6):764-780. doi:10.1016/j.jobcr.2023.10.004.
9. Hegde S, Praveen BN, Shetty SR. Morphological and radiological variations of mandibular condyles in health and diseases: A systematic review. Dentistry. 2013;3(1):154. doi:10.4172/2161-1122.1000154.
10. Yale SH, Rosenberg HM, Ceballos M, Haupt-Fuehrer JD. Laminagraphic cephalometry in the analysis of mandibular

condyle morphology: A preliminary report. Oral Surg Oral Med Oral Pathol. 1961;14(7):793-805. doi:10.1016/0030-4220(61)90343-7.
11. Tadej G, Engstrom C, Borrman H, Christiansen EL. Mandibular condyle morphology in relation to malocclusions in children. Angle Orthod. 1989 Fall;59(3):187-94. PMID: 2774295.
12. Różyło-Kalinowska I, Orhan K, editors. *Imaging of the temporomandibular joint*. Cham (Switzerland): Springer Nature Switzerland AG; 2019. doi:10.1007/978-3-319-99468-0.
13. Choi KY, Yang JD, Chung HY, Cho BC. Current concepts in the mandibular condyle fracture management part I: overview of condylar fracture. Arch Plast Surg. 2012 Jul;39(4):291-300. doi: 10.5999/aps.2012.39.4.291. Epub 2012 Jul 13. PMID: 22872830; PMCID: PMC3408272.
14. Yadav A. Principles of internal fixation in maxillofacial surgery. In: Bonanthaya K, Panneerselvam E, Manuel S, Kumar VV, Rai A, editors. Oral and Maxillofacial Surgery for the Clinician. Singapore: Springer; 2021. p. 779-791. doi:10.1007/978-981-15-1346-6_51.
15. Kuna SK, Jain A, Kuna V. Two Miniplates Versus Three-Dimensional Plate in Management of Mandibular Condylar Fractures: A Systematic Review and Meta-Analysis. Craniomaxillofacial Trauma & Reconstruction. 2024; 17(4):72. https://doi.org/10.1177/19433875241252979
16. Mohammed AA. Effect of the shape of mini plate on the stability of mandibular fracture. Int J Dent Res. 2017;2(2):49–52. doi:10.31254/dentistry.2017.2207.
17. Ahmad W, Ganguly A, Hashmi G, Ansari M, Rahman T, Mohammad A. Fixation in maxillofacial surgery—Past, present and future: A narrative review article. FACE. 2024;5. doi:10.1177/27325016231221424.
18. Chen C-C, Chiu T-H, Yan C-Y, Hou Y-P, Lin T-S. Single versus Double Plate Fixation in Condylar Neck Fractures: Clinical Results and Biomechanics Simulation. Bioengineering. 2024; 11(7):704. https://doi.org/10.3390/bioengineering11070704
19. Smolka W, Liokatis P, Obermeier K, et al. Patient-specific devices for surgical treatment of mandibular condylar head fractures: Case series of early experiences and pitfalls. J Maxillofac Oral Surg. 2026;25:412-420. doi:10.1007/s12663-025-02799-4.
20. Hammer B, Schier P, Prein J. Osteosynthesis of condylar neck fractures: A review of 30 patients. Br J Oral Maxillofac Surg. 1997;35:288–91. doi: 10.1016/s0266-4356(97)90050-4.
21. Sriraam KG, Vignesh KRA. Diagnosis and management of mandibular condyle fractures. In: Sridharan Gokul, editor. Oral and Maxillofacial Surgery. Rijeka (Croatia): IntechOpen; 2021. Chapter 7. doi:10.5772/intechopen.93795.
22. Bischoff EL, Carmichael R, Reddy LV. Plating options for fixation of condylar neck and base fractures. Atlas of the Oral and Maxillofacial Surgery Clinics of North America. 2017;25(1):69-73
23. Bhowmick RS, Bhowal K, Ghosh S. Plating systems for 3D stability of subcondylar fracture: A research article with review of literature. International Journal of Orthopaedics. 2019;5(2):681-683
24. Kozakiewicz M, Okulski J, Krasowski M, Konieczny B, Zieliński R. Which of 51 Plate Designs Can Most Stably Fixate the Fragments in a Fracture of the Mandibular Condyle Base? J Clin Med. 2023 Jul 5;12(13):4508. doi: 10.3390/jcm12134508. PMID: 37445541; PMCID: PMC10343011.
25. Leonhardt H, Matschke J, Bräuer C, Remschmidt B, McLeod N, Lauer G, Franke A. Treatment of mandibular condyle fractures with a rhombic 3D condylar fracture plate – Does the surgical approach matter? J Craniomaxillofac Surg. 2025;53. doi:10.1016/j.jcms.2025.01.029.
26. Seemann R, Schicho K, Reichwein A, Eisenmenger G, Ewers R, Wagner A. Clinical evaluation of mechanically optimized plates for the treatment of condylar process fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104:e1-e4.
27. Asprino L, Consani S, de Moraes M. A comparative biomechanical evaluation of mandibular condyle fracture plating techniques. J Oral Maxillofac Surg. 2006;64:452-456.
28. Dayi E, Omezli MM. Review of biomechanical experimental studies on different plating techniques of mandibular condyle fractures. Ann Maxillofac Surg 2011;1:48-52.
29. Hassani K, Ghazi MA, Khorramymehr S. A model for different internal fixation of the mandibular condyle fractures. Biomed

Mater Devices. 2026;4:3450-3460. doi:10.1007/s44174-025-00450-x
30. Ahuja SA, Galinde J, Asnani U, Mistry YA. Comparative evaluation of clinical outcomes using delta plates and conventional miniplates for internal fixation of mandibular condylar fractures in adults. J Oral Maxillofac Surg. 2018. doi:10.1016/j.joms.2017.12.018.
31. Ganguly A, Mittal G, Garg R. Comparison between 3D delta plate and conventional miniplate in treatment of condylar fracture: A randomized clinical trial. J Craniomaxillofac Surg. 2021. doi:10.1016/j.jcms.2021.01.026.
32. Smolka W, Liokatis P, Cornelius CP. Open reduction and internal fixation of unilateral mandibular condylar base and neck fractures using a lambda plate—Selection criteria for application. J Oral Maxillofac Surg. 2020. doi:10.1016/j.joms.2020.01.035.
33. Ben Achour A, Meißner H, Teicher U, Haim D, Range U, Brosius A, Leonhardt H, Lauer G. Biomechanical evaluation of mandibular condyle fracture osteosynthesis using the rhombic three-dimensional condylar fracture plate. J Oral Maxillofac Surg. 2019;77:1.e1-1.e15. doi:10.1016/j.joms.2019.04.010.
34. Leonhardt H, Franke A, Nowak A, et al. Clinical experience and results with a rhombic plate for transoral endoscopically-assisted osteosynthesis of fractures of the condylar neck. Br J Oral Maxillofac Surg. 2019. doi:10.1016/j.bjoms.2019.09.016.
35. Kumar S, Chugh A, Kaur A, G A, Srivastav S, P G G, Kumar P, Chaudhry K. Treatment Outcome Comparison Between two 3-Dimensional Plates (Y-Shaped Plate Versus Trapezoidal Condylar Plate) in Management of Mandible Condylar Fracture: A Randomized Control Trial. J Maxillofac Oral Surg. 2023 Mar;22(1):25-32. doi: 10.1007/s12663-021-01662-6. Epub 2021 Nov 3. PMID: 36703652; PMCID: PMC9871142.
36. Pfister J, Shazwani FN, Müller M, et al. Clinical results of two different three-dimensional plate types for the treatment of mandibular angle fractures: a retrospective analysis. Oral Maxillofac Surg. 2024;28:1501-1507. doi:10.1007/s10006-024-01275-6.
37. Meyer C, Serhir L, Boutemi P. Experimental evaluation of three osteosynthesis devices used for stabilizing condylar fractures of the mandible. Journal of Cranio-Maxillofacial Surgery. 2006 Apr 1;34(3):173-81.
38. Anirudhan A, Khalam SA, Zachariah RK. Evaluation of clinical use of indigenously developed delta plate in management of subcondylar fracture. Clinics and Practice. 2013 Oct 11;3(2):e28.