

Bone resorption following open reduction and internal fixation of condylar head fractures of the mandible: A systematic review

(Reabsorción ósea tras reducción abierta y fijación interna de fracturas de la cabeza condilar de la mandíbula: una revisión sistemática)

Karthik Shunmugavelu¹✉, Jeevanandam Loganathan², Clinton Sugirthsingh T³

¹ PSP medical college hospital and research institute Tambaram Kanchipuram main road Oragadam Panruti Kanchipuram district Tamilnadu 631604 India

² Department of Prosthodontics, Mahatma Gandhi Post Graduate Institute of Dental Sciences, Puducherry, India

³ Department of Pathology, Sree Balaji Medical College and Hospital, Chrompet, Chennai, Tamilnadu, India

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Abstract (english)

Open reduction and internal fixation (ORIF) have been the widely used management technique for displaced mandibular condylar head fractures. However, postoperative bone remodeling remains a problem, and its relation to long-term joint function and clinical outcomes remains unclear. The aim of this systematic review is to critically analyze the degree of bone resorption after ORIF, identify causative factors, and determine the effect of resorption on functional rehabilitation. A systematic review following PRISMA guidelines based on retrospective clinical studies was conducted. Retrospective clinical studies utilizing CBCT or CT to evaluate postoperative volumetric alterations were included in the review. Clinical outcomes were measured using standardized indices like the Helkimo Index and maximal interincisal opening (MIO). Bone resorption ranged from minimal (mean 5.16%) to moderate (mean 15.29%), and the majority of these changes occurred within the first six months after surgery. Importantly, no close correlation was found between the extent of resorption and clinical dysfunction. ORIF is associated with anticipated, clinically acceptable bone remodelling. Functional outcome remains satisfactory, supporting ORIF as a rational method of management for condylar head fractures.

Keywords(english)

Bone resorption. bone remodelling, Helkimo Index, maximal interincisal opening (MIO), Open reduction and internal fixation (ORIF).

Resumen(español)

La reducción abierta y fijación interna (RAFI) ha sido la técnica de tratamiento más utilizada para las fracturas desplazadas de la cabeza del cóndilo mandibular. Sin embargo, la remodelación ósea posoperatoria sigue siendo un problema, y su

✉ **Corresponding author:** Karthik Shunmugavelu Assistant Professor / Consultant Dental Surgeon / Consultant Oral and Maxillofacial Pathologist. Department of Dentistry/Oral and Maxillofacial Pathology. PSP medical college hospital and research institute Tambaram Kanchipuram main road Oragadam Panruti Kanchipuram district Tamilnadu 631604. Mobile 0091-9789885622/9840023697. <https://orcid.org/0000-0001-7562-8802>. Email. drkarthiks1981@gmail.com.

relación con la función articular a largo plazo y los resultados clínicos aún no está clara. El objetivo de esta revisión sistemática es analizar críticamente el grado de reabsorción ósea después de la RAFI, identificar los factores causales y determinar el efecto de la reabsorción en la rehabilitación funcional. Se realizó una revisión sistemática siguiendo las directrices PRISMA basada en estudios clínicos retrospectivos. Se incluyeron en la revisión estudios clínicos retrospectivos que utilizaron CBCT o CT para evaluar las alteraciones volumétricas posoperatorias. Los resultados clínicos se midieron utilizando índices estandarizados como el Índice de Helkimo y la apertura interincisiva máxima (AIM). La reabsorción ósea varió de mínima (media 5,16 %) a moderada (media 15,29 %), y la mayoría de estos cambios ocurrieron dentro de los primeros seis meses después de la cirugía. Es importante destacar que no se encontró una correlación estrecha entre la extensión de la reabsorción y la disfunción clínica. La RAFI se asocia con una remodelación ósea esperada y clínicamente aceptable. El resultado funcional sigue siendo satisfactorio, lo que respalda la reducción abierta y fijación interna (RAFI) como un método de tratamiento racional para las fracturas de la cabeza condilar.

Palabras clave(español)

Reabsorción ósea, remodelado óseo, índice de Helkimo, apertura interincisiva máxima (AIM), reducción abierta y fijación interna (RAFI).

Introduction

Mandibular condylar fractures are one of the most common skeletal maxillofacial trauma injuries, with a prevalence of around 25% to 35% of all mandibular fractures. Of these, condylar head fractures are of particular note given the essential anatomical and functional functions of the temporomandibular joint (TMJ).[1] The condylar head, which articulates with the glenoid fossa of the temporal bone, provides continuity of mandibular height, facial symmetry, and coordinated mandibular movements necessary for mastication, speech, and aesthetics.[2]

The condylar area is anatomically unique due to its comparably thin cortical bone, rich vascular supply, and intricate biomechanical setting, which create fracture management specially demanding. Destruction of condylar head integrity may lead to loss of height of the vertical ramus, opening deviation on mouth, disharmony in occlusion, limited mandibular movement, and, in extreme cases, TMJ ankylosis or osteoarthritis.[3]

Historically, treatment philosophies for condylar head fractures have ranged from closed conservative management to open reduction and internal fixation (ORIF). The advocates of closed reduction relied on the avoidance of the hazards of surgery, namely facial nerve damage and cosmetic disfigurement. However, several studies have gone to demonstrate that conservative

treatment is likely to lead to poorer anatomical reduction, persistent functional impairment, and more TMJ dysfunction.[4]

Improved techniques for advanced surgical approach, namely the modified preauricular, endaural, and retroauricular approach paths, together with improvements in technology related to osteosynthesis equipment (small-fragment screws, microplates, resorbable devices), enable secure and precise ORIF in even displaced and comminuted condylar head fractures.[5, 6] Thus, based on progressively expanded experience with and increased emphasis upon thorough presurgical assessment coupled with sound preselection, ORIF is gradually accepted in selectively treated cases of more obvious displacement, loss of height of occlusal level, or malocclusion.

Despite this, there are continuing concerns regarding postoperative complications. The risk of postoperative condylar head bone resorption has specifically evoked interest. Bone resorption, or loss of bony volume or mass following surgical procedure, can have the potential to jeopardize joint stability, alter mandibular function, and predispose to late-onset TMJ dysfunction.

Bone resorption after ORIF can be caused by a combination of mechanical, biological, and iatrogenic factors such as ischemia due to stripping of the soft tissue, mechanical instability of the fixation, inappropriate functional loading, or systemic host factors influencing bone

metabolism.[7] In addition, it is not clear whether volumetric decreases seen are an indicator of pathological bone loss or physiological remodeling reactions to changed mechanical environments, as propounded by Wolff's law.[8]

Since the trend towards the use of ORIF to treat condylar head fractures continues to rise, it is important to understand thoroughly the occurrence, extent, timing, and clinical importance of bone resorption postoperatively. It directs operative planning, counseling of the patient, postoperative rehabilitation practice, and late prognosis.

Therefore, this systematic review aims to critically evaluate clinical evidence available on postoperative bone resorption after ORIF of mandibular condylar head fractures, particularly its volumetric magnitude, temporal profile, risk factors involved, and influence on function recovery.

Material and methods

A systematic review was conducted in accordance with PRISMA guidelines.[9] The review protocol entailed an extensive search strategy, study selection against predetermined criteria, data extraction, and critical appraisal of included studies.

Search Strategy: Databases like PubMed, Scopus, Web of Science, and Google Scholar were searched with a mix of keywords: "mandibular condylar head fracture," "open reduction internal fixation," "bone resorption," "3D imaging," and "functional outcomes." Only studies published in English were included in the search.

Eligibility Criteria:

- ☐ Retrospective or prospective clinical human studies.

- ☐ Minimum follow-up of six months.

- ☐ Assessment of postoperative bone resorption using CT or CBCT scanning.

- ☐ Standardized index measurement of functional outcomes.

Study Selection: Two reviewers separately screened the title and abstracts for inclusion eligibility. Articles passing the inclusion criteria were subjected to full-text screening. In case of any disagreement, they resolved by consensus. (Figure 1)

Data Extraction: The extracted variables were study design, sample size, mean duration of follow-up,

imaging method, percentage of bone resorption, methodology used for measurements, fixation method, and clinical outcome.

Results

Six studies fulfilling the inclusion criteria were analysed.

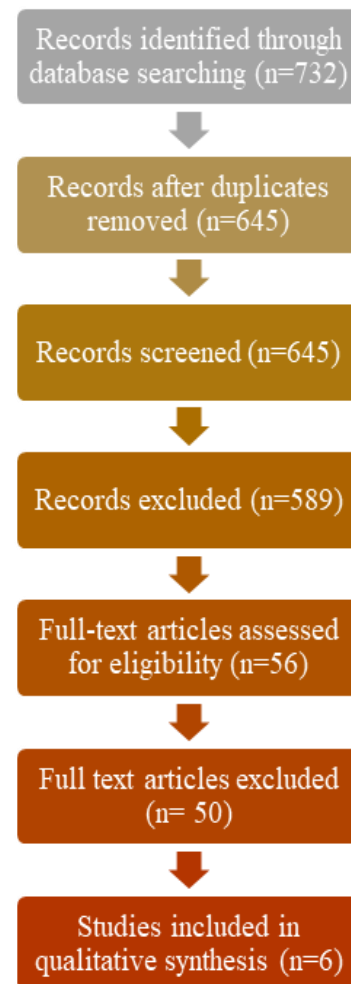


Figure 1. PRISMA Flowchart

Table. 1. Overview of Included Studies.

Author	Study	Sample Size	Mean Follow-up	Mean Bone Resorption	Measurement Method	Functional Outcome Evaluation
Prasad et al. (2022) ^[10]	Bone resorption post open reduction and internal fixation of mandibular condylar head fractures: An original research.	150 patients	25.6 months	5.16%	3D CBCT superimposition	MMO, Occlusion
Johner et al. (2021) ^[11]	Volumetric Evaluated Bone Resorption After Open Reduction and Internal Fixation of Condylar Head Fractures of the Mandible.	19 patients	15.6 months	15.29%	3D CBCT segmentation	Helkimo Index
Neuhaus et al. (2021) ^[12]	Minimal bone resorption after open treatment of mandibular condylar head fractures.	18 patients	15.1 months	No significant resorption	3D CBCT analysis	TMJ Clinical Parameters
Vasanthakumar et al. (2021) ^[13]	Evaluated bone resorption after open reduction and internal fixation of condylar head fractures of the mandible: an original research	75 patients	18 months	Moderate resorption	Radiographic assessment	Clinical examination
Smolka et al. (2018) ^[14]	Resorption behaviour of the articular surface dome and functional outcome after open reduction and internal fixation of mandibular condylar head fractures using small-fragment positional screws.	48 patients (55 fractures)	6 months	0.7 mm vertical loss	Multiplanar CT	Helkimo Index
Jensen et al. (2006) ^[15]	Open reduction and rigid internal fixation of mandibular condylar fractures by an intraoral approach: a long-term follow-up study of 15 patients.	15 patients	23 months	Severe resorption in 1 patient	Radiography	RDC/TMD criteria

Discussion

The outcomes of this systematic review show bone resorption following open reduction and internal fixation (ORIF) of mandibular condylar head fractures to be a measurable but generally restricted process which does not jeopardize functional outcomes. The level of postoperative remodeling varied throughout the included studies; however, functional rehabilitation results were always favorable. A comprehensive comparison between studies provides important information on the determinants of bone resorption and clinical success.

Jensen et al. (2006)[15] observed severe condylar head resorption in a small proportion of patients treated via an intraoral approach. This finding highlights the technical limitations inherent to restricted surgical access, potentially leading to inadequate reduction and unstable fixation. On the contrary, Smolka et al. (2018)[14], in a preauricular method employing small-fragment screw fixation, showed little resorption and lost a mere 0.7 mm of vertical height on average. These contrary results also reiterate that surgical access and fixation stability are major determinants to ensure minimal bone loss post-surgery. Smolka's[14] findings are also consistent with those of Neuhaus et al. (2021)[12], who, through careful reduction and strict fixation with positional screws, had minimal volumetric resorption and significant functional improvement, again testifying to the importance of surgical technique. Johner et al. (2021)[11] had a mean volumetric bone loss of 15.29%, with a higher rate of remodeling compared to the previous research studies. Ironically, in spite of this quantifiable resorption, clinical results ascertained by employing the Helkimo Index[16] were hardly influenced. In comparison to their results of Prasad et al. (2022)[10], whose mean bone resorption rate was significantly lower at 5.16%, the disparity may be due to differences between fixation systems and rehabilitation procedures following surgery. Johner et al. (2021)[11] utilized conventional mini-screw systems, while Prasad et al. employed microplate and miniplate fixation, which may offer superior mechanical support particular to the anatomy of the condylar head. Prasad et al.'s[10] longer follow-up period of 25.6 months also gives reassuring evidence that following initial early remodeling, bone resorption will stabilize without further deterioration.

Similarly, Vasanthakumar et al. (2021)[13] have shown moderate radiographic remodeling; however, the clinical findings on examination did not

reveal noteworthy mandibular movement or occlusal compromise. This observation is consistent with those of Smolka et al.[14] and Neuhaus et al.[12], where there was slight remodeling without functional consequence. All these results fortify the inference that changes seen on post-ORIF radiographs, though measurable, are not directly commensurate with clinical dysfunction.

The reported discrepancies in the magnitude of bone resorption between studies can represent differences not just in surgical approach and fixation devices but also in imaging techniques. Johner et al.[11] and Neuhaus et al.[12] applied high-resolution 3D CBCT volumetric analysis, having higher sensitivity in identifying small changes in volume than conventional radiographs used in the earlier studies such as Jensen et al.[15] Such technical advancement would account for higher percentages of resorption in studies using 3D imaging, although not necessarily implying a worse clinical or biological result.

Biological factors were also likely to have played a role in variability between studies. The initial phase of remodeling, largely within the first six months postoperative according to both Johner et al.[11] and Prasad et al.[10], is consistent with the expected healing cascade after fracture fixation. According to Wolff's law[8], bone structurally adapts to mechanical loads; therefore, limited resorption may be an adaptive, physiological response to changed loading conditions and not pathological bone loss.

Fixation method choice also affected outcomes. Investigations based on small-fragment screws (Smolka et al.[14], Neuhaus et al.[12]) also showed lower rates of resorption than those applying traditional miniplates (Johner et al.[11]). Rigid fixation would necessarily decrease micromovements between the fracture pieces, thereby enabling primary bone healing and restricting secondary remodeling. Conversely, research comparing microplate and miniplate systems, including Prasad et al.[10], indicated that microplates might have greater flexibility in adapting to the subtle condylar anatomy while resorption differences were not significant statistically.

Overall, across studies, the lack of robust correlation between the level of radiographic resorption and decline in functional measures like the Helkimo score, maximal interincisal opening (MIO), and occlusal stability is significant. These observations imply that limited volumetric loss following ORIF is not likely to equate with clinically relevant dysfunction, as long as anatomical reduction, stability of fixation, and early functional rehabilitation are attained.

In conclusion, comparative review of studies included offers evidence in support of the fact that while bone remodeling following ORIF is a ubiquitous finding, it remains physiologically acceptable and clinically insignificant in most cases. Surgical techniques, method of fixation, method of imaging, and rehabilitation protocol subsequent to it are significant parameters that regulate the rate of remodeling. With these being optimized, ORIF offers restitution of function with predictable certainty at negligible risk of detrimental resorption.

Limitations

- ❑ Prevalence of retrospective observational study causes inherent selection bias.
- ❑ Variability of studies in imaging modalities, volumetric measurement protocols, and fixation regimens restricts comparability.
- ❑ Short follow-up period does not allow for late TMJ degeneration or dysfunction assessment.
- ❑ Operator variability in terms of imaging segmentation may cause measurement error.
- ❑ No patient-related variables like systemic bone health and smoking status are published.

Future research directions

- ❑ Future multicenter randomized studies to compare fixation and surgical techniques are needed.
- ❑ Standardization of imaging protocols and outcomes to enable meta-analysis.

❑ Integration of 3D dynamic TMJ imaging and functional MRI could learn more about postrepair joint biomechanics.

❑ Research into bone substitutes and biomimetic fixation materials to improve condylar head regeneration.

❑ Patient-specific, individualized medicine strategies with respect to parameters like overall body health, age, and rates of bone resorption.

Conclusion

Open reduction and internal fixation of condylar head fractures is followed by minimal to moderate bone resorption, which is mainly seen during the early postoperative period. Remodeling, importantly, has little effect on functional outcome when proper technique in surgery, stable fixation, and early rehabilitation are utilized. Radiographically observed small volumetric changes are likely to be the result of physiological adaptation rather than pathological degeneration. Hence, ORIF remains a stable and successful mode of treatment for displaced condylar head fractures with a predictable functional restoration and good long-term prognosis.

Conflict of interest

None to declare.

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