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Review

Reasons for Removal of Miniplates Used in Fixation of Maxillofacial Bone Fractures: Systematic Review and Meta-Analysis

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Abstract: Maxillofacial fractures are a prevalent occurrence, and the widespread use of miniplates to stabilize and secure these fractures during surgery is common. However, the post-surgical fate of these miniplates remains a subject of contention among surgeons. Some advocate for their removal, while others suggest leaving them in place. This study aims to perform an extensive meta-analysis of pertinent studies to ascertain the destiny of miniplates employed in maxillofacial surgery and discuss the consequences of either their extraction or retention. To execute this meta-analysis, a search was conducted across number of databases, including PubMed, Google Scholar, ResearchGate, Embase, and Scopus. Keywords such as "titanium miniplates", "screws", "maxillofacial surgery", "complications", and "removal" were utilized to identify pertinent studies. The search was constrained to studies published between 1989 and 2022. The analysis encompassed only studies reporting outcomes related to miniplates in maxillofacial surgery, including complication rates and removal frequencies. Eleven studies conformed to the inclusion criteria and were incorporated into the meta-analysis, encompassing a total of 2240 patients, ten of which were retrospectives and one prospective, with the largest study involving 434 patients. The overall complication rate was determined to be 13.3%. The most prevalent reasons for miniplate removal included patient preference, tooth extraction, and infections. The average time span for miniplate removal was 10.7 months, with the most prolonged reported duration being 24 years. These findings imply that immediate removal might not be imperative in the majority of instances. In conclusion, our meta-analysis underscores the necessity of removing miniplates in cases where hardware leads to a variety of complications and physical discomfort. Principal factors driving plate removal included patient requests, tooth extractions, and infections. Ordinarily, plate removal took place within the span of 6 to 12 months, with the mandible being the most frequent site for removal. These findings accentuate the significance of extended monitoring to assess the trajectory of miniplates in maxillofacial surgery and provide valuable insights for future clinical decisions. To validate these conclusions and gain deeper insights into the factors influencing plate removal in maxillofacial surgery, further research with larger participant cohorts and standardized outcome reporting is imperative.

Keywords: trauma; maxillofacial; titanium; miniplates; meta-analysis

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1. Introduction

Maxillofacial fractures are a common occurrence in trauma patients, and the use of miniplates for fixation has become a popular method since their introduction in the late 1970s [1]. Miniplates offer advantages such as a low-profile design, better visualization, stability, and strength, allowing for early mobilization and faster recovery; they have

also demonstrated high levels of biocompatibility and a low rate of hardware-related complications [2]. Miniplates are commonly used for mandibular, zygomatic, and maxillary fractures, as well as fractures of the nasal bones, orbit, and frontal bone [2]. Another advantage of miniplates is that they provide stability and strength to the fracture site. The use of miniplates also allows for easier removal of the fixation device, reducing the risk of complications and the need for additional surgeries. While miniplates have proven effective, their limitations should be considered. Complex fractures or patients with poor bone quality may require alternative fixation methods [3]. Metal sensitivity or allergies must also be considered before choosing miniplates [4,5]. The decision to remove or retain miniplates after jaw surgery is a topic of ongoing debate. Complications such as infection, plate loosening, and plate exposure are common reasons for removal [5,6]. Infections can be serious and may require removal to prevent further complications [7,8]. Loosening and plate exposure can compromise stability and cause discomfort or pain. However, removal itself carries risks, including pain, an increased infection risk, and reduced stability [5]. A few studies have reported additional issues related to miniplates, such as the formation of foreign body granulomas or entrapment of facial nerve branches [9,10].

Miniplates and screws are frequently utilized for the purpose of providing stability and support to fractured bones. Nevertheless, their presence in the body can result in various outcomes, both positive and negative. On the positive side, these miniplates play a crucial role in preserving bone alignment, facilitating the healing process, and restoring normal function. They effectively counteract the forces exerted on the fractured bone, allowing patients to regain mobility more quickly than traditional methods like casts or immobilization. A significant consideration in the field of orthopedics revolves around whether to remove these miniplates once the bone has fully healed. While the removal of miniplates may initially appear advantageous by eliminating potential discomfort, reducing the risk of infection, and preventing stress-induced weakening of the bone, it presents its own set of complexities. Surgical removal of miniplates carries inherent risks, including complications related to anesthesia, infection, and the potential for damage to surrounding tissues. Moreover, the procedures for miniplate removal contribute additional costs to the healthcare system and may extend patients' recovery periods. Conversely, the non-removal approach entails leaving the miniplates and screws in place after the bone has healed. This approach has gained popularity due to its perceived benefits, such as avoiding the risks associated with removal surgeries and alleviating the financial burden on both patients and healthcare systems. Nonetheless, the continued presence of these miniplates can potentially give rise to complications. Some studies have underscored the risk of stress shielding, in which the presence of miniplates may lead to a reduction in bone density around the miniplates site. This phenomenon can impact the overall structural integrity of the bone and potentially lead to long-term issues.

To guide decisions regarding removal, it is crucial to assess the rationale and factors influencing the decision. This study aims to conduct a meta-analysis of relevant studies to determine the rationale for maxillofacial fracture plate removal and explore the factors influencing the decision to remove or retain these miniplates. Long-term follow-up is essential to evaluate the fate of these miniplates and inform clinical practice.

2. Materials and Methods

This study constitutes a systematic review and meta-analysis. We formulated the research protocol by following the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) and registered it under PROSPERO registration number CRD42023399232.

2.1. Eligibility Criteria

To be considered for inclusion in this study, articles had to meet specific eligibility criteria, as outlined by both inclusion and PICOS criteria:

Inclusion Criteria:

1. Language Requirement: Articles had to be in English.
2. Full-Text Availability: The full text of the article needed to be accessible.
3. Patient Population: The study had to involve patients with fractured jaws who were treated using miniplate fixation and had a minimum follow-up duration of 12 months.
4. Intervention and Comparison: The study should investigate rigid internal fixation with miniplates, with or without plate removal.
5. Outcome Measure: The primary outcome of interest was the percentage of miniplates that were removed.
6. Study Design: Eligible studies included clinical trials, controlled trials, retrospective studies, and case series.

Exclusion Criteria:

1. Language Exclusion: Articles published in languages other than English were excluded.
2. Non-Human Studies: Studies conducted on animals or in vitro were not considered.
3. Duplicate Publications: Duplicate articles, which could introduce bias, were excluded.
4. Insufficient Information: Articles lacking complete and detailed information about miniplate sites and numbers were excluded.
5. Publication Types: Editorial letters, case reports, and review articles were excluded.
6. Short Follow-Up: Studies with a follow-up duration of less than 12 months were also excluded.

The screening process involved a review of article titles and abstracts, followed by a thorough examination of the full-text publications of potentially relevant studies. Two independent reviewers (NA and NI) conducted this eligibility assessment in a standardized, non-blind manner. The agreement level between the reviewers was assessed using the kappa statistic for all screening steps. The kappa value obtained was 0.83, indicating excellent agreement. Any disagreements between reviewers were resolved through consensus, and if necessary, a third reviewer (MJ) was consulted.

2.2. Information Sources

Following the guidelines outlined in the PRISMA statement, we conducted an electronic search of various databases, including PubMed, Google Scholar, ResearchGate, Embase, and Scopus. We also performed a search for grey literature using OpenGrey Version 1 and manually checked the references in the articles we found. We included studies published from 1989 to 2022 in our meta-analysis.

2.3. Search Strategy

To identify studies related to maxillofacial trauma surgery, we used three terms: "facial injuries surgery", "maxillofacial trauma", and "jaw trauma surgery". For plate removal, we employed nine terms: "plate removal", "plates removal", "plate failure", "plates failure", "maxillofacial fractures", "titanium miniplates", "screws", "complications", and "removal". We used Boolean operators: "OR" to broaden the search, and "AND" to combine different areas. The search equations for each database were as follows:

Search strategy for identifying studies in primary electronic databases:

- PubMed: ("facial trauma surgery" OR "jaw bone surgeries") AND ("plate removal" OR "plates removal" OR "plate failure" OR "plates failure")
- Scopus: ("facial trauma surgery" OR "jaw bone surgeries") AND ("plate removal" OR "plates removal" OR "plate failure" OR "plates failure")
- Embase: ("facial trauma surgery" OR "jaw bone surgeries") AND ("plate removal" OR "plates removal" OR "plate failure" OR "plates failure")
- Google Scholar: ("facial trauma surgery" OR "jaw bone surgeries") AND ("plate removal" OR "plates removal" OR "plate failure" OR "plates failure")
- ResearchGate: ("facial trauma surgery" OR "jaw bone surgeries") AND ("plate removal" OR "plates removal" OR "plate failure" OR "plates failure").

The selected studies for analysis were those that reported on the outcomes of using miniplates in maxillofacial surgery, including details on complications and removal rates.

2.4. Selection

Two independent reviewers, NA and NI, assessed the titles and abstracts of all the works found in the initial search. If abstracts did not provide sufficient information, the reviewers examined the full text to determine whether to include or exclude the work. They then reviewed the full texts of all remaining articles. Any discrepancies in the results between reviewers were resolved through consensus, and if agreement could not be reached, a third researcher (MJ) was consulted.

2.5. Data Collection Process

We reviewed all research papers centered on the removal of miniplates in patients undergoing trauma and maxillofacial surgery. Information gathered from each study encompassed details such as the study's participant demographics, research methodology, sample size, age distribution, gender distribution, the quantity of miniplates both inserted and removed, the location of miniplate placement and removal, the specific type of miniplates employed, the rationale behind removal, and the duration between miniplate insertion and subsequent removal. Two separate assessors collected the following data from articles meeting the inclusion criteria: author names, publication year, study design, the number of patients and plates inserted, average patient age, gender ratio, the location of miniplate placement (mandible or maxilla), reasons for miniplate removal, and the average follow-up duration in months. To assess the level of agreement between these assessors, the kappa statistic, applying the same criteria used during the study selection phase, was utilized. In cases of discrepancies, the assessors resolved them through discussion. If a consensus could not be reached, a third evaluator (MJ) was consulted to provide an assessment.

2.6. Study Risk of Bias Assessment

The review incorporated 11 articles that met our inclusion criteria, published between 1989 and 2022. We utilized the Newcastle–Ottawa Scale (NOS) to assess the quality of the selected studies, categorizing them as "Good", "Fair", or "Poor". Good quality studies received 3 or 4 stars in the selection domain, 1 or 2 stars in the comparability domain, and 2 or 3 stars in the outcome/exposure domain. Fair quality studies received 2 stars in the selection domain, 1 or 2 stars in the comparability domain, and 2 or 3 stars in the outcome/exposure domain. Poor quality studies received 0 or 1 star in the selection domain, 0 stars in the comparability domain, or 0 or 1 star in the outcome/exposure domain. The resulting classification (Good, Fair, or Poor) reflected the overall study quality, based on these criteria. One study [11] was categorized as "Fair", while all the remaining studies were deemed to be of "Good" quality, as summarized in Table 1.

2.7. Statistical Analysis

The data underwent analysis using CMA-V4 software, employing a random effects model for estimating the combined prevalence and its corresponding 95% confidence intervals (Cis). Within this analysis, we evaluated heterogeneity among the studies using Cochran's Q statistic, the I-squared statistic describing the percentage of total variation across the included studies due to heterogeneities, and the tau square (T^2) test.

To further interpret the meta-analysis results, we conducted a sensitivity analysis, removing one study at a time to gauge its impact on the overall outcomes. This approach assessed the resilience of the findings and potential influence of any individual study on the overall effect estimation. The sensitivity analysis confirmed that removing any single study did not significantly alter the overall effect estimate. The results remained consistent, with the effect size falling within the overall estimate range.

Table 1. Quality of the selected studies on the Newcastle–Ottawa Scale (NOS).

Author/Year	Selection			Comparability	Outcomes			Score
	Representativeness of the Exposed Cohort	Selection of the Non-Exposed Cohort	Ascertainment of Exposure	Demonstration That Outcome of Interest Was Not Present at Start of Study	Comparability of Cohorts on the Basis of the Design or Analysis	Assessment of Outcome	Was Follow-Up Long Enough for Outcomes to Occur	Adequacy of Follow-Up of Cohorts	
Brown et al., 1989 [12]	★	★	★	★	★★	★	★	★	9
Islamoglu et al., 2002 [13]	★	☆	☆	★	★☆	★	★	★	6
Murthy et al., 2005 [14]	★	★	★	★	★☆	★	☆	★	7
Rallis et al., 2006 [15]	★	☆	★	★	☆☆	★	★	★	7
Dae-Kyun et al., 2007 [16]	★	★	★	★	★☆	★	★	★	8
O'Connell et al., 2009 [17]	☆	★	★	★	★☆	★	★	★	7
Pan et al., 2013 [18]	★	★	★	★	★★	★	★	★	9
Liandro et al., 2015 [19]	★	★	★	☆	★☆	★	★	★	8
Gorrela et al., 2019 [20]	★	☆	★	★	★☆	★	★	★	7
Sukegawa et al., 2020 [21]	★	★	★	★	★★	★	★	★	9
Sadiq et al., 2021 [11]	☆	★	☆	☆	★☆	★	★	★	5

The Newcastle–Ottawa Scale.

Furthermore, we assessed heterogeneity among the incorporated studies using a chi-squared test and the I-squared statistic. The chi-squared test yielded a significant result ($p < 0.001$), signifying substantial heterogeneity among the studies. The I-squared statistic was 86.4%, indicating a considerable degree of heterogeneity.

To explore potential sources of this heterogeneity, we conducted a subgroup analysis based on the indication for plate removal. This analysis demonstrated a reduction in heterogeneity when grouping studies based on the indication for plate removal. The I-squared statistic decreased to 69.2% for infection, 79.1% for tooth extraction, and 43.2% for other reasons.

Additionally, we utilized a funnel plot to evaluate potential publication bias in the encompassed studies. The plot displayed a relatively symmetrical distribution of studies, suggesting no significant publication bias (Figures 1 and 2).

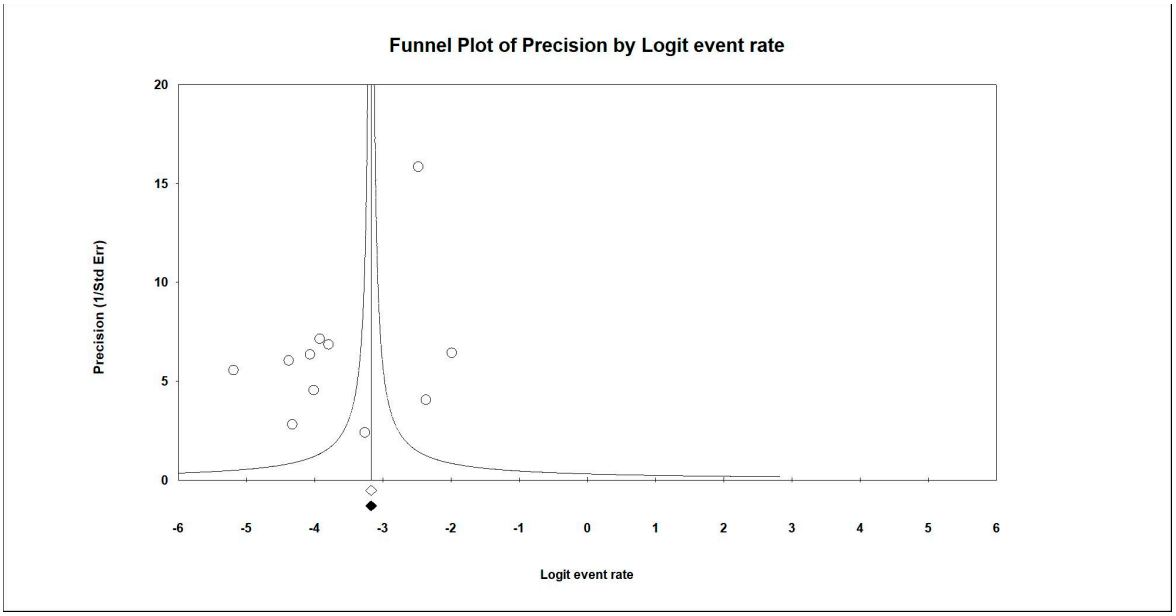


Figure 1. Funnel plot for all combined studies included in the meta-analysis.

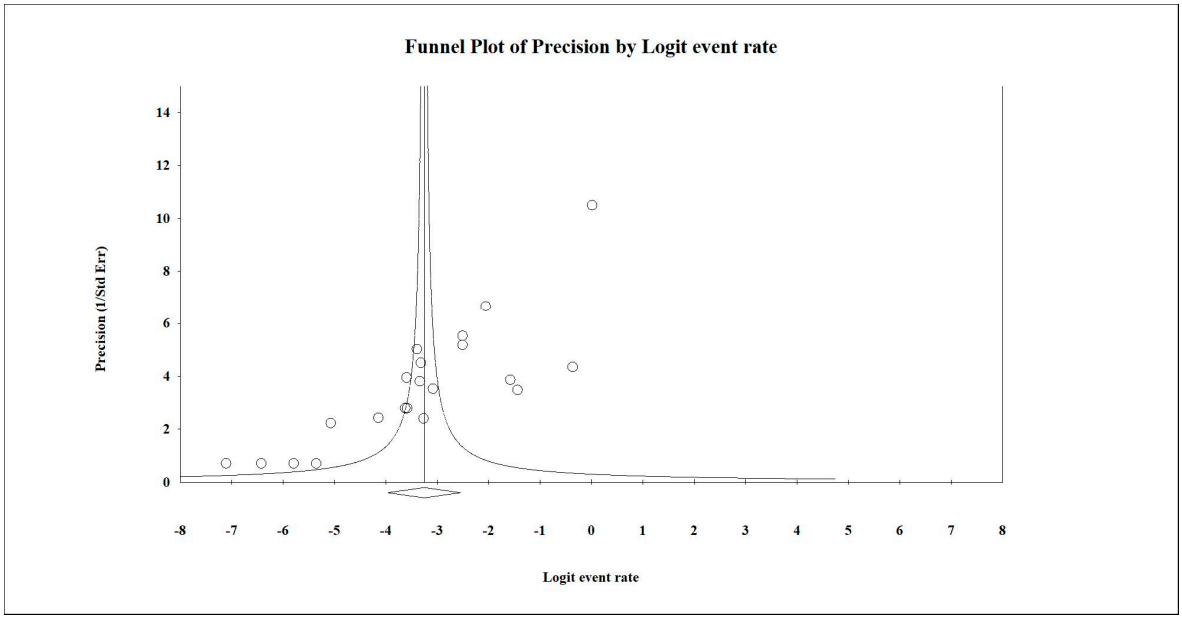


Figure 2. Funnel plot for studies included in the meta-analysis based on site of removal.

3. Results

A total of 259 articles were identified, of which 248 were excluded. The eleven remaining articles satisfied our criteria and were included in our review (Figure 3), ten of which were retrospectives and one prospective. A risk of bias assessment was carried out following the NOS (Newcastle–Ottawa Scale, (Table 1)).

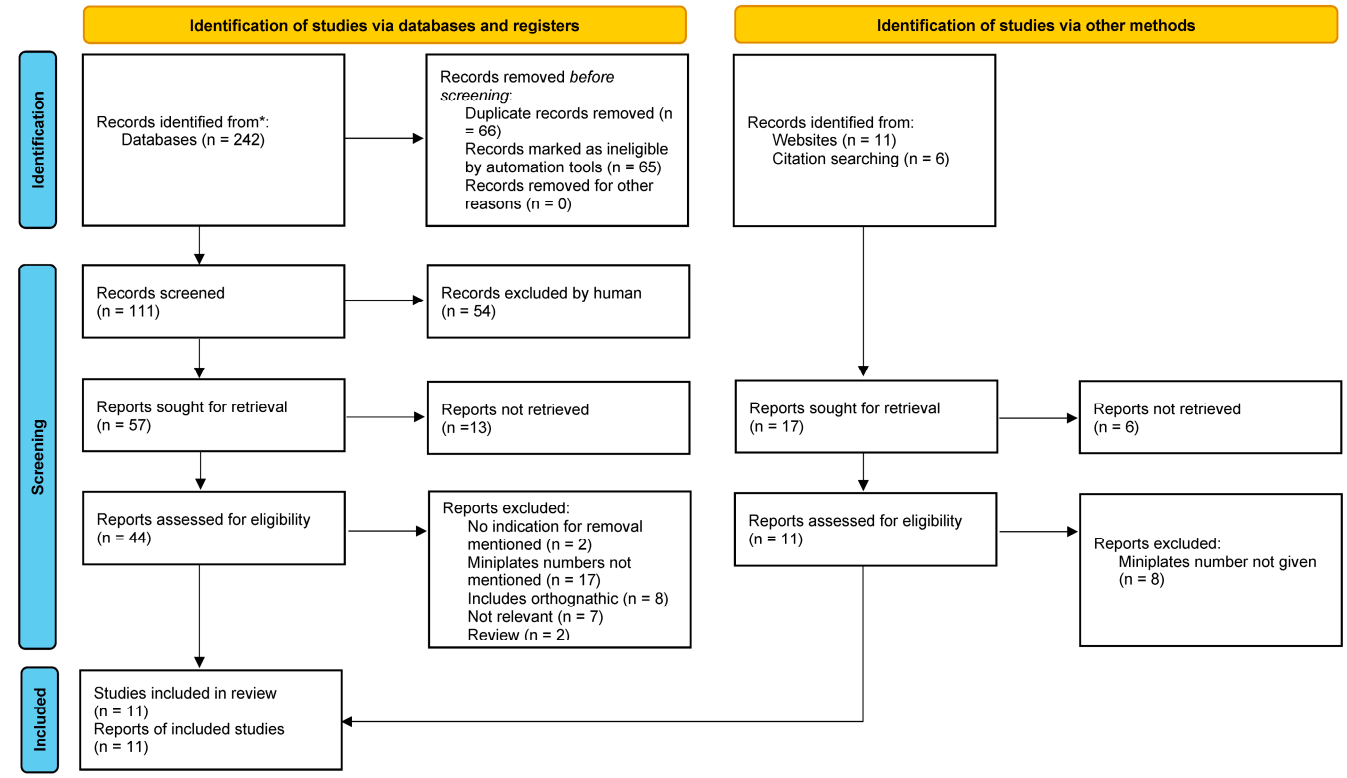


Figure 3. PRISMA flow diagram [22].

Eleven studies were included in the meta-analysis, and a total of 2240 patients were assessed, the M/F ratios of which ranged from 4:1 [17] to 27:1 [20]. The studies were all retrospective in nature, with the largest study including 434 patients [17] (Table 2). The total number of miniplates inserted was 4218, and the total number of miniplates removed was 564 (13.3%), the mean time to removal was 10.9 months, with the longest time to removal being 24 years.

In terms of the reasons for miniplate removal, request by the patient was most common (216 cases, 38.2%), followed by infection, which was reported in 139 cases (24.6%), and tooth extraction (46 cases, 8.1%). Other indications included palpable plate (31 cases, 5.4%), pain (27 cases, 4.8%), plate exposure (18 cases, 3.1%), and loose plates (14 cases, 2.4%). Other relatively less common reasons that resulted in miniplate removal included prosthetic rehabilitation, wound dehiscence, temperature sensitivity, malunion, nonunion, fibrous union, miniplate displacement, and facial deformity (Table 3).

The duration of time until miniplate removal was reported in a few studies, with some studies reporting a mean duration of 6 months, while others reported up to 10 years. For example, O'Connell et al. [17] reported a mean duration of 3.3 years, while Sukegawa et al. [21] reported a mean duration of 10 years.

The site of miniplate removal also varied, with some studies reporting a higher incidence of removal in the mandible (411 incidences, 72.8%), especially the symphysis/parasymphysis region (122 incidences, 29.7%)and the angle of mandible (88 incidences, 21.4%), compared to the maxilla (153 incidences, 27.1%), especially the zygomatic buttress (31 incidences, 20.3%) and the piriform fossa (20 incidences, 13.0%) (Table 4).

Table 2. Characteristics of the selected studies.

Author/ Year	Country	# of pts	Age Range (yrs.)	M:F Ratio	Site of Plate Placement	Type of Plates	# of Plates	Surgical Approach	Reasons for Plate Removal	Duration between Insertion and Removal	Site of Plate Removal
O'Connell et al., 2009 [17]	Ireland	434	3–72	4:1	• Mandible, • Orbito-zygomatic complex, • Maxilla	Titanium miniplates	800	Intraoral	• Infection, • Tooth extraction • Plate exposure, • Fibrous union, • Temperature • Plate fracture, • Implant placement, • Prior to ortho surg, • Palpable plate, • Pediatric patient	2.5–68 months average: 19 months	• Le Fort I • Le Fort II • Zygomatic complex
Brown et al., 1989 [12]	UK	62	15–80	-	• Mandible • Ramus • Angle • Mental/Symphysis • Maxilla and midface • Buttress • Piriform fossa	Stainless steel	105	Intraoral	• Infection, Pain	3–24 months	
Islamoglu et al., 2002 [13]	Turkey	66	6–64	51:15 (17:5)	Mandible • Symphysis • Body • Angle Maxilla and midface • Le Fort I • Le Fort II • Le Fort III • Inferior orbital rim • Zygomatic complex • Zygomaticofrontal	Titanium	296	Intraoral Extraoral	• Infection, • Extrusion, • Facial deformity, • Pain, • Malunion, • Plate fracture.	3–14 months	
Llandro et al., 2015 [19]	UK	216	17–69	91:9	• Zygomatic-complex	Titanium	307	Intraoral extraoral	• Infection, • Exposure	111–972 days 180 days	• Zygomatic complex
Murthy et al., 2005 [14]	USA	76	14–71	62:14 (31:7)	Mandible • Ramus • Angle • Body • Symphysis Maxilla and midface • Frontal • Nasal • Frontozygmatic • Zygoma • Infraorbital rim • Piriform area • Zygomatic buttress	Titanium	163	Intraoral extraoral	• Infection	No average	• Pan facial • Midface • Zygoma • Blowout • Mand. angle • Mand. ramus • Mand. symphysis

Table 2. *Cont.*

Author/ Year	Country	# of pts	Age Range (yrs.)	M:F Ratio	Site of Plate Placement	Type of Plates	# of Plates	Surgical Approach	Reasons for Plate Removal	Duration between Insertion and Removal	Site of Plate Removal
Pan et al., 2013 [18]	China /India	156	12–60	128:28 (32:7)	Mandibular • Body • Symphysis/parasym • Angle • Condyle Maxilla and midface • Zygomatic buttress • Frontozygomatic • Infraorbital rim • NOE/frontal bone • Pyriform aperture	Titanium	384	Intraoral extraoral	• Infection • wound dehiscence, • Reconstruction • Growth, • Plate exposure, • Pain, • Palpable plates, • Heat/cold • Dental or nerve damage, • Broken hardware, • Prosthodontic	0–36 months	• Mandibular fracture • ZMC • Maxillary • Frontal bone/NOE complex
Rallis et al., 2006 [15]	Greece	280	17–75	20:7	Maxilla and midface • Frontal bone • Frontozygomatic • Frontonasal suture • Infraorbital rim • Zygomatic arch • Anterior wall of the antrum • Zygomatic buttress Mandible • Ramus + condyle • Ext oblique ridge • Angle • Body of mandible • Mental area	Titanium	599	Extraoral	• Infection, • Exposure, • Patient's request, Palpation, • Re-operation, • Nonunion, • Plate displacement	0.5–36 months Average 11.5 months	
Sukegawa et al., 2020 [21]	Japan	158	8–91	112:46 (56:2)	Maxilla and midface • Zygomatic buttress • Pyriform aperture • Infraorbital rim • Frontozygomatic Mandible • Condyle • Symphysis • Angle • Parasymphysis • Body	Titanium	440	Intraoral and extraoral	• Infection • wound dehiscence • Plate exposure, • Broken hardware, • Palpable plates, • Screw loosening, • Patient's request, • Growth, • Teeth extraction, • Prosthodontic	258 days	• Maxilla and midface • Zygomatic buttress • Pyriform aperture • Infraorbital rim • Frontozygomatic • Mandible • Condyle • Symphysis • Angle • Para symphysis • Body

Table 2. *Cont.*

Author/ Year	Country	# of pts	Age Range (yrs.)	M:F Ratio	Site of Plate Placement	Type of Plates	# of Plates	Surgical Approach	Reasons for Plate Removal	Duration between Insertion and Removal	Site of Plate Removal
Gorrela et al., 2019 [20]	India	234	14–59	172:62 (86:3)	Mandible • Parasymphysis • Angle • Condyle • Body Maxilla and zygomatic complex	Stainless steel	437	Intraoral	• Infection • Dehiscence • Loose plates • Palpable plates • Patient request • Non-union		-
Dae-Kyun et al., 2007 [16]	Korea	419	Mean: 41.4	340:79		Titanium Absorbable	609	Intraoral	• Infection • dehiscence • Palpable • Patients preference • 2nd operation	<3 months–>3 years	• Cranial • Facial • Mandibular • Combined
Sadiq et al., 2021 [11]	Pakistan	139	21–63	30:2 (15:1)	Mandible • Angle • Symphysis • Para symphysis • Body • Condyle Maxilla and midface • Zygoma • Frontozygomatic • Body • Arch	Titanium	78	Intraoral Extraoral	• Infection • Sensitivity + pain • Palpability • Fracture of plate • Cancer phobia	3–36 months	-
Total	-	2240	6–91		-	-	4218	-	-	0.5 months–>3 yrs	-

Table 3. Location and indication for plate removal.

Author/Year	Number of Plates	Indications for Plate Removal										Total No (%)
		Infection	Tooth Extraction	Plate Exposure	Prosthetic Rehabilitation	Pain	Plate Fracture	Palpable Plate	Loose Fixation Device	Patients Preference	Other Reasons	
Brown et al., 1989 [12]	105	14	-	-	-	4	-	-	-	-	-	N = 18 17.14%
Islamoglu et al., 2002 [13]	296	6	-	-	-	3	1	-	-	-	Malunion: 2 Extrusion: 5 Facial deformity: 4	N = 21 7.095%
Murthy et al., 2005 [14]	163	6	-	-	-	-	-	-	-	-	-	N = 6 3.680%
Rallis et al., 2006 [15]	599	9	-	8	-	-	-	7	-	8	Re-operation: 2 Non-union: 2 Plate displaced: 1	N = 37 6.18%
Dae-Kyun et al., 2007 [16]	609	26	-	-	-	-	-	5	-	4	2nd operation: 6	N = 41 6.73%
O'Connell et al., 2009 [17]	800	12	7	2	2	-	1	1	-	-	Fibrous union: 2 Temp conduction: 1 Prior to orthg. surgery: 1 Peds patient: 2	N = 31 3.88%
Pan et al., 2013 [18]	384	16	-	1	6	6	-	1	-	-	Cold intolerance: 1 Plate Failure: 2 Dental/nerve damage: 2	N = 35 9.11%
Llandro et al., 2015 [19]	307	3	-	5	-	-	-	-	-	-	-	N = 8 2.60%
Gorrela et al., 2019 [20]	437	15	-	-	-	-	-	5	8	5	Wound Dehiscence: 12 Non-union: 3	N = 48 10.98%
Sukegawa et al., 2020 [21]	440	12	39	2	6	-	-	4	6	199	Growth facilitation: 3 Unknown: 1 (not presented)	N = 272 61.81%
Sadiq Ali et al., 2021 [11]	78	20	-	-	-	14	2	8	-	-	Cancer phobia: 3	N = 47 60.26%
Total	4218	139	46	18	14	27	4	31	14	216	55	564

Table 4. Number and locations of miniplates placed and removed.

Author/ Year	No and % of Miniplates Placed (Maxilla and Mandible)	No and % of Miniplates Removed (Maxilla and Mandible)	No and Location of Miniplates Placed in Mandible	No and Location of Miniplates Removed from Mandible No (%)	No and Location of Miniplates Placed (Maxilla and Zygoma)	Location of Miniplates Removed from Maxilla No (%)
Brown et al., 1989 [12]	105	18 (17.14%)	Angle: 29 Mental area: 21 Symphysis: 46 Ramus: 2 Total = 98	Angle: 2 Mental area: 6 Symphysis: 10 Ramus: 0 Total = 18 (17.14%)	Zygomatic Buttress: 5 Piriform fossa: 2 Total = 7	Zygomatic Buttress: 0 Piriform fossa: 0 Total = 0
Islamoglu et al., 2002 [13]	296	21 (7.09%)	Body: 56 Symphysis: 20 Angle: 22 Total = 98	Body: 3 Symphysis: 10 Angle: 0 Total = 13 (4.39%)	Maxillary: 96 Other: 102 Inferior orbital rim Zygomatic region Total = 198	Maxilla: 8 Other:0 Total = 8 (2.70%)
Murthy et al., 2005 [14]	163	6 (3.68%)	Mand ramus: 6 Mand angle: 15 Mand body: 7 Mand symphysis: 25 Total = 53	Mand ramus: 0 Mand angle: 3 Mand body: 0 Mand symphysis: 3 Total = 6 (3.68%)	Frontal: 4 Nasal: 8 Frontozyg suture: 30 Zygoma: 4 Infraorbital rim: 23 Piriform area: 10 Zyg maxillary buttress: 31 Total = 110	Frontal Nasal Frontozyg suture Zygoma Infraorbital rim Piriform area Zyg maxillary buttress Total = 0
Rallis et al., 2006 [15]	599	37 (6.18%)	Ramus: 28 Ext oblique ridge: 22 Angle: 16 Body: 68 Mental area: 169 Total = 303	Ramus: Ext oblique ridge: 3 Angle: 1 Body: 9 Mental area: 8 Total = 21 (3.50%)	Frontal: 8 Frontozyg suture: 129 Frontonasal suture: 6 Infraorbital rim: 73 Zygomatic arch: 1 Ant. wall of antrum: 39 Zyg buttress: 40 Total = 296	Frontal Frontozyg suture: 2 Frontonasal: 2 Infraorbital rim: 4 Zygomatic arch: Ant. wall of antrum: 6 Zyg buttress: 2 Total = 16 (2.67%)
Dae-Kyun et al., 2007 [16]	609	41 (6.73%)	Mandible = 222	Mandible = 11 (1.8%)	Maxilla = 387	Maxilla = 30 (4.93%)
O'Connell et al., 2009 [17]	800	31 (3.88%)	Mandible: 402	Mandible: 26 Total 26 (3.25%)	Maxilla: 92 Orbitozygomatic: 306 Total = 398	Maxilla: 3 Orbitozygomatic: 2 Total = 5 (0.63%)
Pan et al., 2013 [18]	384	35 (9.11%)	Body: 92 Symph/parasymph:75 Angle: 38 Condyle: 31 Total = 236	Body:15 Symphysis/Para symphysis:12 Angle: 1 Condyle: 1 Total = 29 (7.55%)	Zygomatic buttress: 44 Frontozygomatic: 33 Infraorbital rim: 42 NOE/frontal bone: 14 Piriform aperture: 15 Total = 148	Zygomatic buttress: 2 Frontozygomatic: 2 Infraorbital rim: 2 NOE/frontal bone: Piriform aperture: Total = 6 (1.56%)
Llandro et al., 2015 [19]	307	8 (2.61%)	-	-	Buttress: 192 Zygomatico-frontal: 86 Infraorbital: 28 Left zygomatic arch: 1 Total = 307	Buttress: 7 Zygomatico-frontal: Infraorbital: 1 Left zygomatic arch: Total = 8 (2.61%)

Table 4. *Cont.*

Author/ Year	No and % of Miniplates Placed (Maxilla and Mandible)	No and % of Miniplates Removed (Maxilla and Mandible)	No and Location of Miniplates Placed in Mandible	No and Location of Miniplates Removed from Mandible No (%)	No and Location of Miniplates Placed (Maxilla and Zygoma)	Location of Miniplates Removed from Maxilla No (%)
Gorrela et al., 2019 [20]	437	48 (10.98%)	Para symphysis: 126 Angle: 52 Condyle: 25 Body: 42 Total = 245	Para symphysis: 12 Angle: 12 Condyle: Body: 9 Total = 33 (7.50%)	Maxilla:140 Zygomatic complex: 52 Total = 192	Maxilla: 6 Zygomatic complex: 9 Total = 15 (3.43%)
Sukegawa et al., 2020 [21]	440	272 (61.82%)	Condyle: 98 Symphysis: 79 Angle: 62 Para symphysis: 48 Body: 30 Total = 317	Condyle: 59 Symphysis: 59 Angle: 53 Para symphysis: 37 Body: 14 Total = 222 (50.45%)	Zygomatic buttress: 41 Pyriform aperture: 34 Infraorbital rim: 30 Frontozygomatic: 18 Total = 123	Zygomatic buttress: 22 Pyriform aperture: 20 Infraorbital rim: 3 Frontozygomatic: 5 Total = 50 (11.36%)
Sadiq et al., 2021 [11]	78	47 (60.26%)	Angle: 21 Symphysis: 15 Para symphysis: 7 Body: 8 Condyle: 4 Total = 55	Angle: 16 Symphysis: 8 Para symphysis: 4 Body: 3 Condyle: 1 Total = 32 (41.0%)	Maxilla: 7 Zygoma: 16 Total = 23	Maxilla: 6 Zygoma: 9 Total = 15 (19.2%)
Total	4218	564 (13.37%)	2029	411	2189	153

Meta-analysis of studies:

We conducted a meta-analysis based on eleven studies. The effect size index was the event rate. A random effects model was applied for the analysis. The studies considered in the analysis were viewed as a random sample from a larger pool of potential studies, and this analysis aims to draw inferences for that broader population. The calculated mean effect size was 0.026, falling within a 95% confidence interval of 0.014 to 0.048. This interval represents the range within which the mean effect size in the comparable universe of studies could potentially lie.

The Q-statistic was used to test the null hypothesis that all studies in the analysis share a common effect size. The computed Q-value was 472.749 with 10 degrees of freedom, yielding a p-value less than 0.001. Employing an alpha significance criterion set at 0.100, we reject the null hypothesis, implying that the true effect size may vary among the studies. The I-squared statistic was found to be 98%, indicating that a significant portion (98%) of the observed effect variance is attributed to true effects rather than sampling error.

Assuming a normal distribution of true effects (in logit units), we estimated the prediction interval to be between 0.002 and 0.247. Within this interval, the true effect size in 95% of all comparable populations is expected to fall.

Analysis Based on Site of Removal:

When considering the site of removal, the mean effect size was 0.034, with a 95% confidence interval spanning from 0.019 to 0.060. This range reflects the potential variation in the mean effect size within the universe of comparable studies. The I-squared statistic for this analysis was 97.5%, indicating that a substantial portion (97%) of the observed effect variance is due to true effects rather than sampling error.

4. Discussion

The use of miniplates for the fixation of facial bone fractures has gained popularity due to their effectiveness in achieving stability and facilitating rapid recovery. However, there are instances where the removal of these miniplates becomes necessary post-surgery due to various reasons.

In this study, a total of 2240 patients were assessed, encompassing a wide range of age groups from pediatric patients to elderly individuals. The majority of studies showed a higher representation of male patients. The studies were conducted in various countries, potentially reflecting differences in healthcare practices and patient demographics. The rationales for plate removal varied across studies, spanning from infections and pain to more specific concerns such as plate exposure, growth issues, and considerations for prosthetic rehabilitation. These discrepancies highlight the intricacies of maxillofacial surgeries and how patient characteristics may influence the decision to remove plates. These differences also underscore the importance of thorough patient assessment and personalized interventions in these surgical procedures.

The decision on whether to keep or remove miniplates utilized in maxillofacial surgery is frequently influenced by several factors, such as the patient's age, medical history, and the location and nature of the fracture. The presence of infection or exposure of the plate may necessitate removal, while the absence of complications might indicate that retaining the plates is a viable option.

Our research findings indicate that the most common reason for miniplate removal was patient request, followed by tooth extraction and infection at the surgical site. This discovery aligns with prior studies that have identified infection as the primary driver for miniplate removal [5,23]. Miniplates, positioned in sensitive submucosal tissues, are susceptible to environmental trauma and the forces generated during chewing, which can compromise their stability, lead to screw loosening, provoke inflammation, and increase the risk of infection. Insufficient suturing techniques and suboptimal cooling of bone during screw hole preparation have also been associated with miniplate failure due to infection. Patients involved in road traffic accidents, in particular, are at a higher risk of contaminated wounds and a heightened likelihood of future miniplate removal [24].

Infections linked to miniplates typically remain confined within the bone and seldom progress to osteomyelitis or delayed union. When infection arises within the initial 6 weeks after fixation, conservative management involving pus drainage and antibiotic therapy may suffice to facilitate fracture healing while retaining the fixed bone. Once the fracture is stable and healed, miniplate removal may be performed. However, if the infection extends to the underlying operated bone and bony union is incomplete, miniplate removal followed by external fixation and bone grafting might be necessary. Infections can stem from oral cavity bacteria or improper aseptic techniques during surgery. Brown et al. [12] documented 14 out of 105 miniplates being removed due to infection, while O'Connell et al. [17] noted 12 out of 800 miniplates being removed for the same reason.

In certain instances, infection can be attributed to tooth damage during the fixation surgery, the presence of teeth within the fracture line during trauma, or compromised blood supply in the edentulous mandible. However, when infection does not affect the bone, miniplates can be preserved through the application of antibiotics, cleaning, removal of infected tissue, and the elimination of infection sources. Small plates can harbor bacteria, which may lead to sustained inflammation and discomfort. Research indicates that the occurrence of infection in patients with retained small plates can reach up to 30% [25]. The probability of infection increases over time, implying that the longer a small plate remains within the body, the greater the likelihood of infection.

In our study, 4.8% of miniplate removals were attributed to pain. Other reasons for removal encompassed patient requests, growth limitations in pediatric cases, prosthetic rehabilitation requirements, deformities stemming from malunion or non-union, tooth extraction, wound reopening, palpability, nerve impairment, and cold intolerance. Mosbah et al. [26] reported a 14% incidence of post-surgery pain around the fixation site, while Bhatt et al. [27] identified pain in 24% of cases. For pediatric patients, miniplates should ideally be removed within two to three months after fracture surgery to prevent growth restrictions. Nevertheless, Cole et al. [28] suggest that removal should only be conducted in symptomatic cases. In our investigation, the removal rate was higher among patients under 40 years old, diverging from Park et al.'s [29] findings that indicated higher removal rates among patients under 30 years old. Nonetheless, the previous study discovered elevated miniplate removal rates in patients aged 30 years or older.

Hardware failure represents another reason for miniplate removal. Over time, miniplates, composed of metal, can corrode, become brittle, or fracture. Hardware failure can lead to pain, discomfort, or even bone displacement. The incidence of hardware failure ranges from 1% to 23%, with most cases occurring within the first year of fixation [30]. Retained miniplates might cause discomfort or pain, especially when located near facial muscles, nerves, or tendons. Such discomfort can impede the patient's quality of life, especially if the miniplate is situated in a visible region, such as the cheek or jawbone.

Miniplates may also become visible through the skin or lead to scarring, which can be a cosmetic concern for some patients, prompting them to consider removal. Although the benefits of using titanium-based alloy miniplates for osteosynthesis are well-established, questions persist regarding their long-term effects. Recent research has concentrated on assessing the tissue surrounding removed titanium materials, to investigate potential consequences. While the removal of titanium devices has typically been limited to cases of infection or exposure [17], there are concerns about the local cellular impact of metallic particles that can infiltrate nearby tissues [8,31,32] and potentially migrate through the lymphatic system to other organs [33]. Studies have pointed to local reactions and immune–inflammatory responses in fibrous connective tissue deposits, with titanium being implicated in the induction of oxidative stress [34]. Although allergic reactions to titanium-based alloys are rare, there have been reported cases of facial eczema [35,36]. Tooth extraction constitutes another rationale for miniplate removal. During orthodontic treatment, teeth may need to be extracted to facilitate proper alignment. This can result in the removal of miniplates used for fracture stabilization. O'Connell et al. [17] noted that out of 800 miniplates, 2 were removed due to tooth extraction.

Plate exposure arises when the miniplate becomes visible through the skin or mucosa. This can occur due to inadequate wound closure, insufficient soft tissue coverage, or suboptimal plate placement. Islamoglu et al. [13] documented 3 out of 296 miniplates being removed due to plate exposure, while Gorrela et al. [20] reported no cases of plate exposure among 437 miniplates.

Prosthetic rehabilitation serves as another cause for miniplate removal. Prosthetic rehabilitation involves dental implants, and in some instances, miniplates must be removed to facilitate this procedure. Islamoglu et al. [13] reported 4 out of 296 miniplates being removed due to prosthetic rehabilitation.

Pain emerges as another impetus for the removal of miniplates employed in treating maxillofacial fractures. Pain can stem from various sources, such as nerve damage or impingement, plate migration, or cold intolerance. Pan et al. [18] highlighted 1 case of miniplate removal due to cold intolerance, and 2 instances stemming from plate failure, out of 384 miniplates. Dae-Kyun et al. [16] outlined 5 cases of plate removal due to palpable plates, and 6 occurrences due to dental/nerve damage, out of 609 miniplates.

Miniplate fractures can occur due to various factors, including improper plate placement, or excessive stress on the plate. Brown et al. [12] detailed 4 cases of miniplate removal due to plate fracture out of 105 miniplates.

Loose fixation devices represent another cause for miniplate removal in maxillofacial fracture treatment. Loose fixation devices can result from several factors, including suboptimal plate placement, improper screw positioning, or undue stress on the plate. Rallis et al. [15] noted 7 instances of miniplate removal, due to the loose fixation, out of 599 miniplates.

Patient request constitutes another rationale for the removal of miniplates employed in maxillofacial fracture treatment. Furthermore, other reasons encompass poor aesthetics, exposure, cold intolerance, nerve impairment, and cancer phobia.

Regarding the time span between initial surgery and miniplate removal, the majority of cases involved removal within one year. According to existing literature, most miniplate removals took place between 6 months and 1 year post-fixation, with some cases being removed even within less than 3 months following fixation. It is generally advised that miniplates be removed after confirming bone healing, typically within 6 months to a year. The broad spectrum of miniplate removal times identified in this study can be attributed to a complex interplay of patient-specific elements, fracture characteristics, surgical techniques, healing rates, and potential complications. Tailored patient care, clinical discretion, and continuous evaluation are crucial for determining the optimal timing of plate removal to ensure optimal results.

The mandible was the predominant site for miniplate removal, accounting for the majority (72.8%) of cases, particularly in the mandibular body and symphysis region. In a study by Park et al. [29], they found the mandibular angle region to be the primary location for miniplate removal (39.5%), while Islamoglu et al. [13] reported that the mandible was involved in 62.85% of hardware removal cases in the maxillofacial region. The increased tendency to remove miniplates from the mandible, as observed in our study and other research, may be linked to the mandible's denser cortical bone structure relative to other facial bones. Additionally, the main blood supply to the mandible originates from the inferior alveolar artery and periosteum, both of which are susceptible to damage during trauma and surgical procedures [15,27]. Furthermore, the relatively thicker intraoral mucosa during surgical approaches heightens the risk of plate exposure.

Matthew and colleagues [37] conducted an assessment of Champy titanium and stainless steel miniplates and screws used to stabilize mandibular fractures in an animal model. They retrieved these miniplates and screws at 4, 12, and 24 weeks after the surgery and concluded that there is no conclusive evidence supporting the routine removal of either titanium or stainless steel miniplates within six months following insertion. However, titanium tends to degrade over time due to wear and the release of particles. The resulting corrosion and wear byproducts, including metal ions or particles, can lead to tissue changes, ranging from fibrosis to infection and necrosis [38].

Given its superior corrosion resistance, non-carcinogenic nature, hypoallergenicity, non-toxicity, and excellent tissue compatibility, titanium hardware can be safely retained in the maxillofacial region [39]. However, the metallic composition (stainless steel or titanium) played a negligible role in the number of miniplates removed, as the removal count was equivalent for both materials [40].

Initially, Champy [2] recommended miniplate removal after three months of fixation, which became the established practice. Subsequently, authors leaned toward retaining Vitallium miniplates, which exhibited greater inertness. Frost et al. [41] determined that approximately 18% of Vitallium miniplates necessitated removal for clinical reasons. Titanium emerged as a successful material in numerous surgical procedures, with nearly 100% of it being released at the site during osteosynthesis, remaining stable and clinically inert within surrounding tissues. Hence, routine removal of titanium miniplates, except in cases of infection, dehiscence, or hypersensitivity, was not deemed necessary. Miniplate removal should primarily address miniplate-related symptoms. While some authors advocate routinely removing miniplates to avert interference with jaw function and osteoporosis, most studies suggest removal only when symptoms manifest and discourage the routine removal of asymptomatic miniplates [12,41–49].

Amidst the ongoing discourse and implications concerning metal plates, researchers have developed novel bioresorbable and bioactive materials as alternatives. These materials, such as polyglycolic acid, polylactic acid, and copolymers of polyglycolic acid and polylactic acid, incorporated with hydroxyapatite in polylactic acid, stimulate the formation of new bone tissue without inducing mutagenic effects. Despite the appealing biodegradation characteristic of these materials, there are currently insufficient follow-up data from comparative studies between metallic alloys and bioresorbable substances [50,51].

The question of whether to remove miniplates after fracture healing remains a subject of debate within the medical community. One major influence in this decision is the cost associated with miniplate removal, which can substantially vary among different countries. The cost of miniplate removal for jawbone fracture fixation is a multifaceted issue shaped by a range of factors. While procedural costs are relatively consistent, discrepancies in hospitalization expenses and potential complications can lead to significant cost disparities. Healthcare providers and policymakers should consider these economic factors while strategizing for jawbone fracture management and subsequent implant removal.

The limitations of this study encompass the lack of injury specifics due to the predominantly retrospective nature of the studies, as well as the challenge of tracking patient's post-treatment wellbeing for assessing post-operative complications.

5. Conclusions

In conclusion, our meta-analysis underscores the necessity for miniplate removal in cases where hardware leads to diverse complications and physical discomfort. The primary factors prompting plate removal were request by the patient and infections. Typically, plate removal occurred within a timeframe of 6 to 12 months, with the mandible being the most common site for removal. These findings emphasize the importance of prolonged monitoring to assess the fate of miniplates in maxillofacial surgery and provide valuable insights for future clinical decision-making. To solidify these conclusions and delve deeper into the factors influencing plate removal in maxillofacial surgery, further research with larger participant pools and standardized outcome reporting is imperative.

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