REVIEW PAPER

COMPARISON OF STRAIGHT MINI-PLATES VS. TRAPEZOIDAL PLATES FOR INTERNAL FIXATION IN CONDYLAR FRACTURES: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: The advancement of technology has introduced various fixation methods to ensure optimal bone healing in open treatment and internal fixation of maxillofacial fractures. Trapezoidal plates are specifically developed for the condyle region to resist forces and stresses in 3 dimensions: bending, shearing, and torsion.

Objectives: This systematic review aimed to evaluate the clinical outcomes of open treatment and internal fixation in the treatment of condylar fractures using trapezoidal plates, and compared with the usage of straight mini-plates.

Material and methods: A systematic search using PRISMA framework was conducted in five online databases (PubMed, Medline, Scopus, Embase, and Cochrane Library) in December 2022 to obtain relevant comparative studies reporting trapezoidal and straight mini-plates in condylar fracture patients within the last 10 years. Inclusion criteria were adult patients, minimum follow-up duration of 3 months, and outcomes, including mouth opening, duration of operation, and any notable post-operative complications.

Results: A total of 8 studies with 224 patients were considered, which compared the efficacy of trapezoidal plates and straight mini-plates in the treatment of condylar fracture. All of them mentioned the superiority of trapezoidal plates, especially in terms of duration and ease of insertion; however, most studies also mentioned their results insignificance. Nevertheless, 5 studies found that complications still occur post-surgery, even with trapezoidal plates as the fixator.

Conclusions: Trapezoidal plates can serve as alternative fixator for the open treatment of condylar fractures. Considerations of degree of severity and operator factors are needed in the decision of using trapezoidal plates.

Key words: mini-plate, trapezoidal plate, condylar fracture.

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INTRODUCTION

Condylar fracture is known to be one of the most commonly encountered cranio-maxillofacial fractures, with prevalence rates varying from 29 to 52% of all mandibular fractures [1]. This type of fracture may be caused by either a direct or indirect trauma, and depending on the degree of severity, directions, occlusion, and the point of application of fracture force since condylar fractures have a varying degree of displacement [2].

Generally, the management of condylar fracture include a more conservative treatment using intermaxillary fixation (IMF) methods, or a surgical approach involving open reduction with internal fixation

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(ORIF) [3]. With the development of better diagnostic and surgical tools, surgical management has become more preferable in the treatment of condylar fractures in current days compared with those of the 20th century, emphasizing the recognized complexity of fractures in the region [3-6]. Therefore, it is important to utilize a fixation tool that can adequately adapt to anatomical and functional properties of the region, and resist tensions, compressions, bending, or shearing upon loading, ensuring better clinical outcomes post-surgery [7, 8].

Throughout the years, various tools have been introduced as fixators in the surgical management of condylar fractures, including mini-plates, resorbable pins, and most recently developed and researched, three-dimensional plates (3D plate) [9, 10]. The use of 3D plates in condylar fractures was first mentioned by Meyer *et al.* [11, 12] in 2002, who proposed the ideal lines of osteosynthesis for the condylar region to ensure a more predictable outcome, modifying the 3D plate to form a trapezoidal shape, thus often called trapezoidal condylar plates (TCPs) or trapezoidal plates in short.

The use of trapezoidal plates in condylar fractures have been reported in various studies [7, 12-15]. However, differences in study design and relatively small sample size were reported to be some of the factors, which did not permit for significant and definite conclusion regarding the efficacy of its usage. In addition, few studies have been done to directly compare the results of surgical approach in condylar fractures using trapezoidal plates and standard mini-plates, which are the current gold standard of fixators in ORIF procedures.

OBJECTIVES

This paper aimed to summarize the results of previously conducted studies to evaluate the efficacy of trapezoidal plate utilization compared with the currently most used approach, mini-plates, for the internal fixation of condylar fractures.

MATERIAL AND METHODS

A systematic review was carried out according to the preferred reporting items for systematic review and meta-analysis (PRISMA) statement. The protocol for this review was established and registered in PROSPERO database, with an ID No.: CRD42022378108.

INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria were analyzed using the PICO (population, intervention, comparison, outcome) framework (Table 1).

STUDY SELECTION

A preliminary search was conducted in PubMed on surgical management tools for mandibular condylar fractures to identify relevant key words. The terms were then analyzed, and a list of key words on variables of condylar fractures, mini-plate, and trapezoidal plate was developed. Next, a more comprehensive electronic search was performed in the following databases: PubMed, Medline, Embase, Cochrane Database of Systematic Reviews, and Scopus using the established key words. Only clinical studies conducted on humans, published in English, and comparing trapezoidal plate and straight mini-plate efficacy for internal fixation in condylar fracture cases within the last 10 years were deemed eligible for screening. Results were screened by title and abstract to exclude duplicate or irrelevant articles. Full text of the screened articles were further read and exclusions were done according to the criteria established.

DATA EXTRACTION

From all of the articles finalized from the screening process, variables were recorded in the form of a table and presented in the Results Section, including general demographics (author(s), year of publication, study design, number of patients, sex distribution, age range, number of fractures, location of fractures, and method of fixation), pre-operative variables (mouth opening), intra-operative variables (duration of operation/ insertion time), and post-operative variables (post-operative mouth opening, complication(s), and need for re-operation).

ASSESSMENT OF STUDY QUALITY

Bias risk assessments were performed to the finalized articles used in this review with a modified version of Newcastle-Ottawa scale [16]. Aspects applied in the evaluation included study selections, comparability, and study outcomes. Studies with less than 5 points according to the evaluation results were not included in

TABLE 1. PICO framework of the review

Population (P)	Condylar fracture patients within the age range of 15-60 years, with a minimum follow-up period of 3 months
Intervention (I)	Internal fixation of condylar fracture using 3D plate or trapezoidal condylar plate
Comparison (C)	Internal fixation of condylar fracture using straight mini-plate
Outcome (O)	Occlusion, mouth opening, length of operating time, and post-operative complications

TABLE 2. Quality assessment of the included studies using modified Newcastle-Ottawa scale (NOS)

First author, year [Ref.]	Study selection			Comparability	Outcome			Total
	Representativeness of exposed cohort	Selection of non-exposed	Ascertainment of exposure		Assessment of outcome	Adequate follow-up time	Adequacy of follow-up	
Ahuja, 2018 [18]	*	*	*	**	*	*	*	8/8
Sukegawa, 2019 [19]	*	*	*	**	–	*	–	6/8
El-Mahdy, 2020 [20]	*	*	*	**	*	*	*	8/8
Scott, 2021 [21]	*	*	*	**	*	*	*	8/8
Adhikari, 2021 [22]	*	*	*	*–	*	*	*	7/8
Ganguly, 2021 [23]	*	*	*	*–	–	*	*	6/8
Oraby, 2022 [24]	*	*	*	*–	*	*	*	7/8
Lajpat, 2022 [17]	*	*	*	**	–	–	*	6/8

Based on the information, a general consensus can be made that sex tendency for condylar fractures is male sex, and some of the studies noted to be in relation with the etiology of traumas, most often cited as road traffic accidents. There is a varying sample size between each study, a total of 224 patients with 226 fractures. As the follow-up period of each study differed from one another, we decided to establish 3 months as the post-operative marker for the current review.

TABLE 3. Demographic data of each study

First author, year [Ref.]	Study design	Patients (*n*)	Sex		Age range, years (mean)	Fracture (*n*)	Fracture location	Fixation method	Follow-up period
			M	F					
Ahuja, 2018 [18]	PA	20	17	3	15-55 (31)	20	Right (*n* = 9) Left (*n* = 10) Bilateral (*n* = 1)	TCP (*n* = 10) Mini-plate (*n* = 10)	10 days 4 weeks 12 weeks 24 weeks
Sukegawa, 2019 [19]	RA	26	15	11	20-70 (54)	28	Right (*n* = 11) Left (*n* = 17)	TCP (*n* = 13) Mini-plate (*n* = 15)	12 weeks 24 weeks
El-Mahdy, 2020 [20]	RCT	18	10	8	18-40 (29)	18	No information	TCP (*n* = 9) Mini-plate (*n* = 9)	1 week 2 weeks 4 weeks 8 weeks 12 weeks 24 weeks
Scott, 2021 [21]	RCT	44	40	4	18-53 (25)	44	Right (*n* = 26) Left (*n* = 18)	TCP (*n* = 22) Mini-plate (*n* = 22)	10 days 4 weeks 12 weeks 24 weeks
Adhikari, 2021 [22]	RCT	52	46	6	18-32 (25)	52	Right (*n* = 26) Left (*n* = 22) Bilateral (*n* = 4)	TCP (*n* = 26) Mini-plate (*n* = 26)	1 week 4 weeks 12 weeks 24 weeks
Ganguly, 2021 [23]	RCT	20	18	2	31-40 (31)	20	No information	TCP (*n* = 20) Mini-plate (*n* = 20)	1 week 4 weeks 12 weeks
Oraby, 2022 [24]	RCT	20	20	0	23-40 (30)	20	No information	TCP (*n* = 10) Mini-plate (*n* = 10)	1 week 4 weeks 12 weeks 24 weeks
Lajpat, 2022 [17]	CS	34	27	7	20-41 (30)	34	No information	TCP (*n* = 17) Mini-plate (*n* = 17)	3 days 1 week 2 weeks 3 weeks

PA – prospective analysis, RA – retrospective analysis, RCT – randomized controlled trial, CS – comparative cross-sectional, M – male, F – female, TCP – trapezoidal condylar plate

the review due to high-risk of bias. The process of assessment of study quality is shown in Table 2.

RESULTS

During preliminary search, a total of 434 records were identified. The screening phase excluded 426 studies (roughly 98% of the records), and the final 8 studies were included in the current review. PRISMA flowchart summarizing screening process is presented in Figure 1. The selected studies were further assessed for quality and risk of bias using a modified Newcastle-Ottawa scale, where each category was checked in 0-1 point, except for comparability with maximum of 2 points. All of the studies showed intermediate- to low-risk of bias (Table 1). However, since the authors established 3 months as an adequate follow-up time, a study by Lajpat (2022) that provided data of follow-up at the longest 21 days was deemed insufficient for post-operative evaluations [17]. Nevertheless, all the studies were included for intra-operative variables. A summary of demographic data of the studies is presented in Table 3. Based on the information, a general consensus can be made that sex tendency for condylar fractures is male sex, and some of the studies reported to be in relation with the etiology of traumas, most often cited as road traffic accidents.

There was a varying sample size between each study, with a total of 224 patients and 226 fractures. As follow-up period of each study differed from one another, we decided to establish 3 months as the post-operative marker for this review. We categorized the comparisons between TCPs and standard mini-plates into pre-operative variable (mouth opening), intra-operative variable (duration of operation/ insertion time), and post-operative variables (post-operative mouth opening, complications, and need for re-operation). A summary of data extracted from the literature reviewed is presented in Table 4.

DISCUSSION

The trends in using surgical approach to treat maxillofacial fractures are expanding, especially when it comes to significantly displaced injuries that may need a restoration of pre-traumatic anatomical relations [25]. This becomes crucial in the condylar region, which has a complex anatomy combined with unique healing potentials and biomechanical properties. Schneider [26] recommended that in a case, where a fracture with a deviation of more than 10 degrees or with a ramus shortening of more than 5 mm is encountered, ORIF would be the treatment of choice, regardless of its degree of severity.

With the increasing trend of ORIF in the treatment of condylar fracture, osteosynthesis line becomes another subject of discussion, and was first described by Champy *et al.* (1976) for the regions' body, symphysis, and angle of mandible. Meyer [11] was the first to in-

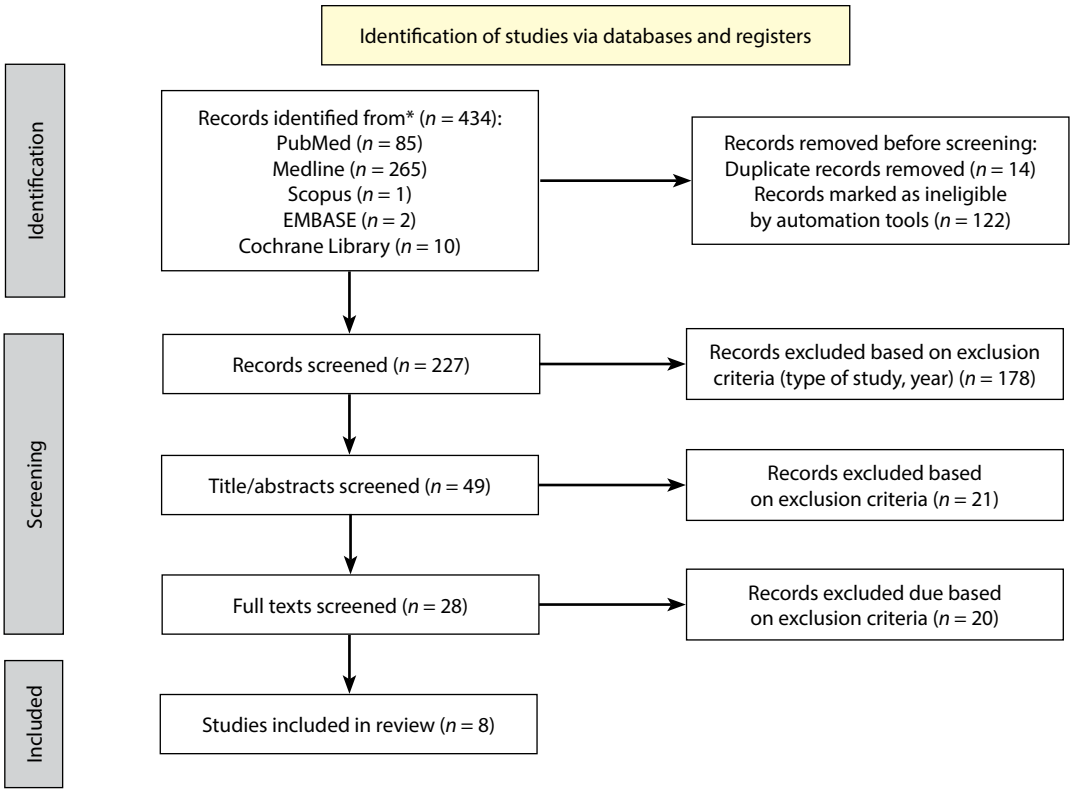

FIGURE 1. PRISMA chart showing the screening flow of the studies included in this review

TABLE 4. Differences in pre-operative, intra-operative, and post-operative (12 weeks) outcomes between TCP and standard mini-plates

No.	Study, year [Ref.]	Trapezoidal condylar plate					Standard mini-plate					Additional notes
		Pre-operative	Intra-operative	Post-operative			Pre-operative	Intra-operative	Post-operative			
		Mouth opening (*n*)	Duration of insertion (*n*)	Mouth opening (*n*)	Complication (*n*)	Re-operation (*n*)	Mouth opening (*n*)	Duration of insertion (*n*)	Mouth opening (*n*)	Complication (*n*)	Re-operation (*n*)	
1	Ahuja, 2018 [18]	> 30 mm (1), < 30 mm (9)	< 5 minutes (9), 5-10 minutes (1)	> 30 mm (8), < 30 mm (2)	Altered occlusion (2)	–	30-39 mm (4), < 30 mm (6)	5-10 minutes (1), 10-15 minutes (3), > 15 minutes (6)	> 30 mm (8), < 30 mm (2)	Altered occlusion (4)	Yes (1)	In terms of adaptations, TCPs were considered simpler compared with straight mini-plates
2	Sukegawa, 2019 [19]	No information	No information	> 30 mm (12)	Plate breakage (2), pain (3)	–	No information	No information	> 30 mm (14)	Pain (4), paralysis (2)	–	TCP plate strength was adequate to accommodate typical simple fractures
3	El-Mahdy, 2020 [20]	13.0 ± 4.1 mm	141 minutes*	43.44 mm	–	–	15.1 ± 4.2 mm	157 minutes*	46.44 mm	–	–	No malocclusions, lateral deviation during mouth opening, nor pain at 8 weeks post-operative follow-up in both groups
4	Scott, 2021 [21]	24.50 ± 3.8 mm	9.6 ± 0.9 minutes	34.50 ± 2.3 mm	Altered occlusion (1)	–	23.70 ± 5.6 mm	17.5 ± 1.4 minutes	33.60 ± 2.8 mm	Altered occlusion (4)	–	Number of patients with post-operative occlusal derangement was higher in standard mini-plate group ($n = 4$) compared with TCP group ($n = 1$)
5	Adhikari, 2021 [22]	15 mm	6 minutes	45 mm	Sialocele (1), hypertrophic sear (1)	–	15 mm	15 minutes	40 mm	Sialocele (3), hypertrophic sear (1), plate breakage (4)	–	–
6	Ganguly, 2021 [23]	23.40 ± 6.19 mm	117.2 minutes*	42.40 ± 1.82 mm	No information	–	21.60 ± 3.21 mm	141.2 minutes*	35.80 ± 1.30 mm	No information	–	Mean bite efficiency score in TCP group (3.0) was better than standard mini-plate group (1.8)
7	Oraby, 2022 [24]	No information	< 5 minutes (8), 5-10 minutes (2)	No information	Altered occlusion (4)	–	No information	10-15 minutes (3), > 15 minutes (7)	No information	Altered occlusion (2)	Yes (1)	TMJ functions according to Helkimo index showed higher rate of good score (D0) in TCP group (30%) compared with standard mini-plate group (10%); however, statistically insignificant
8	Lajpat, 2022 [17]	< 30 mm (17)	No information	> 30 mm (17)	–	No information	< 30 mm (17)	No information	> 30 mm (17)	Altered occlusion (1)	No information	The use of TCPs generated better stability and lower morbidity compared with the use of standard mini-plates

TCP – trapezoidal condylar plate

**Mean length of cumulative operating time was recorded rather than specific plate insertion time.*

troduce the osteosynthesis line in the condylar region. Since then, the use of standard mini-plates for the fixation of condylar fracture has become the gold standard. A study mentioned that a failure rate of 35% as well as reports of inadequate fixation were seen in the use of single mini-plates; the use of two standard mini-plates became more widely used [27]. Despite this, another study presented difficulties in using multiple mini-plates for condylar fragments, mainly due to the small fragment sizes [23]. Since then, the concept of 3D fixation, referring to the function of a fixator in resisting forces from three directions, such as bending, shearing, and torsion, in the form of a geometrical, closed quadrangular mini-plate fixed onto the bone, is known as TCP [7]. With the emphasis on resistance against the forces, the use of TCPs conceptually became more potential compared with standard mini-plates. Nevertheless, the potentials of TCPs' concept have only been proven through finite element analyses [28], and more data is needed to ensure clinical evidences of their potentials.

Multiple studies have compared the abilities of TCPs and standard mini-plates in numerous variables, but limitations reported by the authors included differences in standardizing measurements for every variable recorded, especially in terms of mouth opening and duration of insertion. This can be seen in Table 4, where some studies used mean and standard deviations in measuring mouth openings, while others used a grouped range. Notwithstanding, most of the studies provided similar or comparable results with one another.

In the current review, the authors found that the duration of insertion of TCPs as fixation method in condylar fractures, generally, is faster compared with the duration of insertion of standard mini-plates, especially when based on specific plate insertion duration and cumulatively with total operating time. Additionally, Ahuja *et al.* [18] described that other than faster insertion time, the adaptation of TCPs was subjectively easier compared with standard mini-plates, mainly due to its prefabricated shape.

In terms of mouth opening, even though most studies described that TCP patients showed better post-operative mouth opening compared with standard mini-plate patients, a study by El-Mahdy *et al.* [20] presented a contradictory result. Nevertheless, other studies also noted that the differences between the two fixation methods in post-operative mouth openings were not significant [21]. Nys *et al.* [29] mentioned that there was an 8-10% risk of sub-optimal mouth opening out of all condylar fracture cases, irrespective of a fixation method used.

An interesting result from a study by Sukegawa *et al.* [19] showed a plate breakage encountered in the TCP patient group. Theoretically, TCPs or 3D plates were crafted to achieve a fixator that was able to withstand destructions caused by forces in the condylar region, including bending, shearing, and torsion. The finding gave rise to a question, as the same complication did not happen in the standard mini-plate patient group. According to our literature search, a few studies reported plate stiffness as a factor in plate breakage. Firstly, the event of plate breakage and/or screw loosening can be associated with the lack of stiffness of the plate material used, or associated with insufficient fracture reduction. A study by Murakami *et al.* [30] noted that in the open surgery treatment of mandible fractures, the occlusal forces are affected by stress placed on the plate that may cause plate breakage and failure. This is especially important in the condylar region, which constantly receives various forces and stress due to its biomechanical functions. Notwithstanding, this does not mean that the stiffer the plate, the better the outcomes. Ganesh *et al.* [31] mentioned that extreme stiffness may cause excessive stress-shielding to the bone, where an excessive compressive stress-shielding may delay the formation of callus and bone healing, while tensile stress-shielding may increase the risk of osteoporosis. Other studies emphasized that the position of screws during the plate insertion is an important factor that may affect its stiffness, strain of the plate, and its cyclic fatigue [32-34]. Therefore, the experience and expertise of the operating surgeon in correct plate and screw insertion determine the outcomes of the treatment. Kozakiewicz *et al.* [35] reported that an A-shaped plate for open rigid internal fixation of condylar neck fracture can be used for stabilization of condyle neck fractures. This is an innovation in the management of condyle fractures. The use of A-plate was analyzed with a finite element analysis compared with trapezoidal plates to determine the weakest point of using trapezoidal plates in condyle fractures. As a result, a part of the trapezoidal plate at the fracture line was shown as the weakest part and caused plate breakage. It might be one of the reasons that Sukegawa presented plate breakage complications.

A total of three studies found post-operative altered occlusion in both patient groups. Specifically, studies conducted by Ahuja and Scott [18, 21] found that the number of post-operative altered occlusion complications was higher in the straight mini-plate group compared with the TCP group. One thing that may contextualize such difference in both plates' ability to stabilize an occlusion, was the inter-fragmentary strength of 3D plates that is generally better compared with straight mini-plates, and noted in several studies comparing the two plates in other regions in the mandible [36-39]. Moreover, studies by Ahuja [18] and Oraby [24] reported a need for re-operation in one case each. In both the studies, the main reason for re-operation was the event of altered occlusion or malocclusion, which could not be restored even with the application of elastics, IMF, nor other non-invasive approaches during follow-ups after more than 2 weeks. Mendonca and Kankere [40] proposed several strategies that can be applied to prevent unfavorable occlusions in maxillofacial fracture treatments, irrespec-

tive of the method of fixation and region of fracture. These strategies include adequate evaluation and analysis of the fracture line, pre-operative incision planning, optimal dissection with a preservation of the mucosal cuff, accurate IMF pre-fracture fixation, rigid internal fixation, re-suspension of soft tissues, and early follow-up to quickly detect any abnormalities.

CONCLUSIONS

The treatment of condylar fracture requires a crucial understanding of the contexts of anatomical location and biomechanics of the region. The most commonly accepted method of fixation in the treatment of the condylar fracture is the use of two standard mini-plates, but as the development in the trend of fixation methods progresses, 3D plates and TCPs are alternatives that ensure faster time of insertion and resilience against forces in the condylar region as well as minimizing complications, especially in simple condylar fractures. TCPs are also superior when it comes to cost efficiency, thus increasing patient accessibility to treatment options. Nevertheless, operator's consideration in terms of understanding the degree of severity of a condylar fracture as well as personal preference and experience should be emphasized in the choice of a fixation method in the treatment of condylar fractures.

CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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