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Meta-Analysis
TMJ Disorders

Temporomandibular joint prosthesis as treatment option for mandibular condyle fractures: a systematic review and meta-analysis

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Abstract. The aim of this study was to perform a systematic review of the literature on the temporomandibular joint (TMJ) prosthesis as a treatment option after mandibular condyle fracture. Three databases were searched (PubMed, Embase, Cochrane Library) and 2670 unique papers were identified. A total of 337 studies were included (121 case reports, 89 case series, and 127 cohort/clinical studies). In total 14,396 patients and 21,560 prostheses were described. Of the 127 cohort or clinical studies, 100 (79%) reported inclusion criteria, 54 (43%) reported exclusion criteria, and 96 (76%) reported the inclusion period. The base population from which patients were recruited was reported in 57 studies (45%). The reason for TMJ prosthesis implantation was reported for 4177 patients (29.0%). A history of condylar fracture was present in 83 patients (2.0%); a history of mandibular trauma was present in 580 patients (13.9%). The meta-analysis showed a pooled prevalence of condylar fracture of 1.6% (95% confidence interval 0.9–2.4%) and a pooled prevalence of trauma or condylar fracture of 11.3% (95% confidence interval 7.1–16.0%). Heterogeneity was highly significant ($P < 0.001$). The TMJ prosthesis appears to be reserved for patients with persistent pain, bony or fibrous ankylosis, or osteomyelitis after primary closed or open treatment of fractures of the mandibular condyle.

Keywords: Mandibular condyle; Bone fractures; Temporomandibular joint; Systematic review; Meta-analysis; Joint prosthesis; Arthroplasty; Mandibular fractures.

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After the treatment of a fracture of the mandibular condyle, the patient may experience complications including restricted mouth opening, persistent pain, loss of function (e.g. chewing, biting, yawning), and damage to the facial or trigeminal nerve.[1–5] A fracture of the mandibular condyle may develop into fibrous or bony ankylosis of the

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temporomandibular joint (TMJ), severely limiting its function. Fibrous or bony ankylosis may occur if the fracture remains undetected, in severe comminuted fractures of the mandibular condylar head, if patients have prolonged immobilization of the mandible, or when treatment is delayed, particularly in young children.[6] Ankylosis may also develop due to avascular necrosis of the condylar head of the mandible.[7,8] In the case of post-condylar fracture TMJ disorders, treatment options such as physical therapy, arthrocentesis, arthroscopy, orthognathic surgery, or open joint surgery may alleviate the complaints and improve function. If complaints persist, a TMJ prosthesis may be helpful in reducing these complaints and may improve mandibular function.[9,10]

Several systematic reviews on TMJ prostheses have been published. These reviews have described the historical background of the TMJ prosthesis, designs and materials, indications for use, functional efficiency of the prosthesis, and recommendations for developments in TMJ prosthesis design.[11–15] However, an overview of how often a TMJ prosthesis is applied following a history of fracture of the mandibular condyle appears to be lacking in the published literature. Such an overview would inform surgeons about how often a TMJ prosthesis has been used for the treatment of the sequelae of a fracture of the mandibular condyle and may provide indications and outcomes. Additionally it could also help surgeons in decision-making regarding the treatment of fractures of the mandibular condyle.

The aim of this review was to systematically analyse the literature on the frequency of use and indications of the TMJ prosthesis as a treatment modality after a fracture of the mandibular condyle.

Materials and methods

This systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[16] The protocol for this systematic review was registered in the PROSPERO database (CRD42020158164).[17]

A literature search was conducted in the PubMed, Embase, and Cochrane Library databases, from inception to December 12, 2020, using the following terms and their synonyms: temporomandibular joint, temporomandibular joint disorders, prostheses and implants, prosthesis failure, prosthesis design, and prosthesis fitting. The search strategy was developed together with an information specialist and was adapted for each database (Supplementary Material Appendix 1). Two reviewers (ETN, PUD) independently assessed the titles and abstracts using a standardized screening form of inclusion and exclusion criteria (Supplementary Material Appendix 2). In the case of disagreement between the reviewers, the record was included for full-text assessment. Thereafter a full-text assessment was performed by the same reviewers using the same criteria for inclusion and exclusion. In the case of disagreement at this stage, a discussion was continued until consensus was reached. In the case of persistent disagreement, an independent reviewer (RRMB) made the binding decision.

Abstracts were included for full-text assessment if they described patients with one or two TMJ prostheses, if the TMJ prosthesis included a fossa component, a condylar component, or both, and if the study design was a case report or case series, a case–control study, a cohort study, a cross-sectional study, or a randomized controlled trial. Abstracts were excluded if they concerned an animal study, a laboratory study, a systematic review, material development study, a finite element analysis (material testing), an expert opinion or a letter to the editor, a study protocol, a disc implant only, if no patient data were reported, or if the full text was not available. No language or time restrictions were applied. Studies written in languages other than English, German, French, and Dutch were translated into English. Reference lists of the included studies were checked for relevant studies missed in the database search.

Data extraction and analyses

Data were extracted from the included studies by the same reviewers, independently, using a predesigned extraction sheet. Data on the study design, reasons for implantation of the TMJ prosthesis, number of patients, number of implanted prostheses, number of unilateral and bilateral prostheses, number of implanted fossa prostheses, and number of condylar prostheses were extracted. The cohort studies, clinical trials, and cross-sectional studies were subsequently analysed regarding the reporting of inclusion criteria, exclusion criteria, specification of the institute where the study was performed, specification of the time frame during which patients were recruited, number of reported patients, number of patients eligible for a TMJ prosthesis, patients meeting the inclusion criteria of the study, and number of excluded patients.

The reasons for implanting a TMJ prosthesis were divided into the following categories: trauma not specified, trauma specified as condylar fracture, low-grade inflammation, high-grade inflammation, malignant neoplasm, benign neoplasm, growth problems in the case of hypoplasia or hyperplasia, congenital disorders, ankylosis not specified, resorption, other reason, or no reason provided (Supplementary Material Appendix 2).

If insufficient data were provided or numbers regarding patients and/or prostheses did not add up, the corresponding author was contacted by email and asked for additional information or data. In the case of doubt regarding data, the corresponding author was also contacted by email. If no reply was received, a reminder was sent a few weeks after the first email.

If the same study population was described in more than one paper – which was assumed based on similarities in patients being treated in the same institution during the same time frame, with similar diagnoses, reported by the same authors, or when a follow-up of the same population was presented – the study including the most patients and with the most well-documented causes was included. If this was not clear, the corresponding authors of the studies were contacted.

Extracted data were entered into an SPSS file (IBM SPSS Statistics version 23; IBM Corp., Armonk, NY, USA) for the calculation of descriptive statistics. Disagreements between observers were resolved by discussion until consensus was reached. If disagreement persisted, an independent observer (RRMB) made a binding decision. Inter-observer reliability, i.e. agreement on the title and abstract assessment and the full text assessment, was examined by calculating the percentage agreement, Cohen's kappa, and Gwet's AC1.

The pooled prevalence of a history of condylar fracture and of a history of condylar fracture or trauma was analysed in Excel (Microsoft Excel; Microsoft Corp., Redmond, WA, USA). MetaXL 5.3, a free but copyrighted

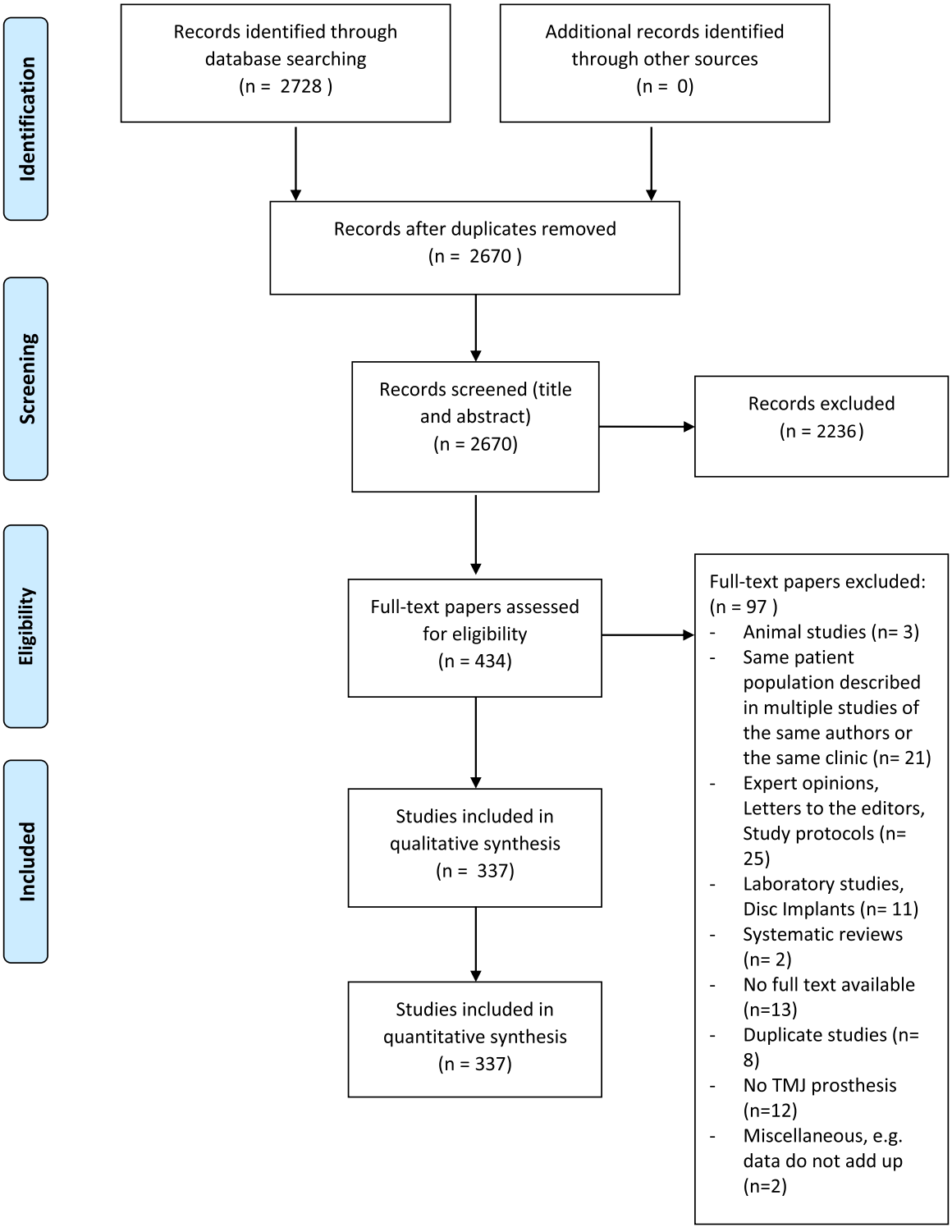

Fig. 1. Flowchart showing the inclusion process.

software program (EpiGear International Pty Ltd, Sunrise Beach, Queensland, Australia; www.epigear.com) was used for the meta-analysis. The inverse variance heterogeneity method was applied because of clinical and methodological heterogeneity between the studies. A double-arcsine transformation was applied, as this controls better for extreme prevalence and sample sizes. A sensitivity analysis was performed based on the assumption that all recipients of a TMJ prosthesis with a history of mandibular trauma would have had a mandibular condyle fracture. In a second sensitivity analysis, data from the study by Elledge et al.[18] were entered to verify the robustness of the outcomes.

Results

In total, 2728 records were identified. After removing duplicates, 2670 records

Table 1. Characteristics of the included studies (N = 337).

	Total studies (n = 337)	Case reports (n = 121)	Case series (n = 89)	Cohort/clinical studies[a] (n = 127)
	n (%)[b]	n (%)[c]	n (%)[c]	n (%)[c]
Study design (268 valid observations)				
Retrospective	222 (82.8%)	121 (54.5%)	31 (14.0%)	70 (31.5%)
Cross-sectional	7 (2.6%)	0 (0%)	3 (42.9%)	4 (57.1%)
Prospective	39 (14.6%)	0 (0%)	8 (20.5%)	31 (79.5%)
Design unclear	69	0	47	22
Patients in studies	14,396	121 (0.8%)	405 (2.8%)	13,870 (96.3%)
Patients with implant reason reported	4177	121 (2.9%)	377 (9.0%)	3679 (88.1%)
Fracture of the mandibular condyle	83 (2.0%)	19 (22.9%)	37 (44.6%)	27 (32.5%)
Trauma not specified	580 (13.9%)	11 (1.9%)	38 (6.6%)	531 (91.6%)
Low-grade inflammatory arthritis	1507 (36.1%)	9 (0.6%)	51 (3.4%)	1447 (96.0%)
High-grade inflammatory arthritis	379 (9.1%)	17 (4.5%)	62 (16.4%)	300 (79.2%)
Neoplasm, malignant	153 (3.7%)	6 (3.9%)	20 (13.1%)	127 (83.0%)
Neoplasm, benign	215 (5.1%)	25 (11.6%)	40 (18.6%)	150 (69.8%)
Neoplasm not specified	110 (2.6%)	0 (0%)	7 (6.4%)	103 (93.6%)
Growth problems: hypo- or hyperplasia of condyle	10 (0.2%)	0 (0%)	5 (50%)	5 (50%)
Congenital	78 (1.9%)	10 (12.8%)	33 (42.3%)	35 (44.9%)
Ankylosis, not specified	591 (14.1%)	4 (0.7%)	50 (8.5%)	537 (90.9%)
Resorption	124 (3.0%)	8 (6.5%)	15 (12.1%)	101 (81.5%)
Other[d]	347 (8.3%)	12 (3.5%)	19 (5.5%)	316 (91.1%)
Implant reason not reported	10,219	0	28	10,191
Prostheses				
Patients with a unilateral prosthesis	3802 (17.6%)	71 (1.9%)	228 (6.0%)	3503 (92.1%)
Patients with a bilateral prosthesis	8676 (40.2%)[e]	50 (0.6%)	150 (1.7%)	8476 (97.7%)
Unknown unilateral or bilateral	406	0	6	400
Number of implanted prostheses	21,560 (100%)	171 (0.8%)	534 (2.5%)	20,855 (96.7%)
Fossa prostheses	6085 (29.5%)	4 (0.1%)	8 (0.1%)	6073 (99.8%)
Condyle prostheses	1060 (5.1%)	30 (2.8%)	113 (10.7%)	917 (86.5%)
Total TMJ prostheses (fossa + condyle)	13,513 (65.4%)	137 (1.0%)	411 (3.0%)	12,965 (95.9%)
Unknown fossa/condyle/total TMJ prosthesis	902	0	2	900
Types of prosthesis implanted within studies				
Custom	121 (38.1%)	57 (47.1%)	28 (23.1%)	36 (29.8%)
Stock	137 (43.17%)	47 (34.3%)	43 (31.4%)	47 (34.3%)
Other[f]	25 (7.9%)	9 (36%)	5 (20%)	11 (44%)
Combinations (custom/stock, custom/other or stock/other)	35 (11.0%)	0 (0%)	10 (28.6%)	25 (71.4%)
Not reported	19	8	3	8

TMJ, temporomandibular joint.

[a]The paper by Christensen et al. (Christensen RW, Alexander R, Curry JT, Christensen MS, Dollar JV. Hemi and total TMJ reconstruction using the Christensen prostheses: a retrospective and prospective evaluation. Surg Technol Int 2004: 12: 292–303) described a prospective and a retrospective study.

[b]Column percentages of the total (only valid observations).

[c]Row percentages.

[d]For example, foreign body response, osteomyelitis, removal of Proplast/Teflon prosthesis.

[e]Number of pairs.

[f]For example, prosthesis made out of acrylic, silicone, bone cement, aluminium oxide ceramics, gold, carbon, composite.

remained (Fig. 1). Finally 337 studies, published between 1951 and 2021, were included for qualitative synthesis (Table 1, Supplementary Material Appendix 3).

Inter-observer agreement for the title and abstract selection was 95.1%; kappa = 0.847 and AC1 = 0.927.

Not all data from these studies were available for analysis; the data most frequently missing were reasons for implantation, study design, and type of prosthesis implanted. Case reports and case series were the most completely documented study types.

Of the 337 studies selected, 127 (37.7%) were cohort studies or clinical trials (Table 1). The studies described a total of 14,396 patients and 21,560 implanted prostheses. Reasons for receiving a TMJ prosthesis differed among the case reports, case series, and cohort studies and clinical trials. In the case reports, a benign neoplasm and a fracture of the mandibular condyle were the most common reasons. In the case series, high-grade inflammation and low-grade osteoarthritis were the most common. In the cohort studies and clinical trials, the reason for receiving a TMJ prosthesis was predominantly low-grade inflammatory arthritis, ankylosis (not specified), and trauma (not specified) (Table 1). Condylar fractures were present in 2.0% and trauma (not specified) in 13.9% of all patients receiving a TMJ prosthesis for whom the reason for a TMJ prosthesis was reported.

The implanted prostheses were predominantly total TMJ prostheses (both fossa and condyle components): of the 21,560 implanted prostheses, 13,513

(65.4%) were total TMJ prostheses. Patients in case reports and case series received a unilateral prosthesis more often than a bilateral prosthesis, while patients reported in cohort studies and clinical trials more frequently received a bilateral prosthesis. Custom TMJ prostheses were used more often than stock prostheses in case report patients, whereas the use of stock prostheses was reported more commonly in patients in the case series and cohort studies or clinical trials (Table 1).

The majority of cohort studies and clinical trials reported inclusion criteria for patients (78.7%), while exclusion criteria were less frequently reported (42.5%). Patients eligible for a TMJ prosthesis, as in the base population from which patients were selected based on inclusion and exclusion criteria for the studies, were not always described. The base population from which patients were recruited was not reported in 70 of the 127 cohort studies and clinical trials (55.1%). Patients eligible for receiving a TMJ prosthesis were described in 57 of the 127 cohort studies and clinical trials (44.9%), with 5021 eligible patients (36.2% of all cohort and clinical trials patients, Table 2).

Patients who either sustained a trauma not further specified or a fracture of the mandibular condyle were described in 112 studies. Three studies were not included in Table 1 since there were discrepancies in the numbers reported in the studies. In the study by Sidebottom et al.,[19] a total of 77 patients were mentioned, of whom only two were described in the paper. Details of the other 75 were not provided and were not obtained after contacting the authors. Another two publications, by Elledge et al.[18] and Idle et al.,[20] which described a database of patients who received a TMJ prosthesis in the United Kingdom, were also not included in Table 1. There were discrepancies in the numbers of patients, numbers of prostheses (the number of unilateral and bilateral prostheses), and numbers of causes described in both of these studies. The authors were contacted about the discrepancies but no additional information was received.

In 20 of the 127 cohort studies and clinical trials (15.7%), the authors reported that only patients who received a TMJ prosthesis from one surgeon were selected for the study.

Case reports and case series provided the most details regarding patient characteristics, trauma characteristics, treatment of the fractured mandibular condyle, time between trauma and placement of the TMJ prosthesis, and the indication for placement of the TMJ prosthesis after fracture of the mandibular condyle. The time between trauma and placement of the TMJ prosthesis varied between studies and ranged from 3 days to 30 years (data reported for 29 of the 83 patients with condylar fractures, Table 3).

Patients in whom direct TMJ replacement after trauma was performed ($n = 4$) all had severe dislocation and/or comminution with no real options to reduce the fracture. In one case report, reduction of a condylar fracture was not possible due to severe dislocation, and the entire condylar head was removed and replaced with an acrylic condylar head as a prosthesis.[21] One case series reported on a patient who had attempted suicide with a shotgun in the mouth. This patient had severe soft tissue damage and a comminuted fracture of the mandibular condyle, ramus, and angle, which was then reconstructed with a condylar reconstruction plate from the glenoid fossa to the symphysis region.[22] Another case series described two cases in which respectively a Teflon and a Silastic block was placed.[23] In the first case, an edentulous patient suffered from a comminuted fracture of the mandibular condyle after a car accident. The comminuted condyle was removed and a block of Teflon was carved and placed in the glenoid fossa. Function remained good with dentures. In the second case, the condylar head was severely displaced. While attempting to reduce the fragment, the surgeons observed that the articular surface was completely sheared off. They then removed the condylar head and placed a Silastic block in the joint space.

Meta-analysis

Considerable statistical heterogeneity was found in the meta-analyses ($P < 0.001$) (Table 4). The pooled prevalence of condylar fractures was 1.6% (95% confidence interval (CI) 0.9–2.4%, $I^2 = 38.49$). The pooled prevalence of condylar fractures or trauma was 11.3% (95% CI 7.1–16.0%, $I^2 = 81.43$). In the sensitivity analysis, the data of Elledge et al.[18] were entered into the meta-analysis (768 joint replacements, of which 48 were related to a trauma) and the pooled prevalence of a condylar fracture or trauma was 10.5% (95% CI 5.3–16.5%, $I^2 = 81.61$). Hence a small change (0.8%) in pooled prevalence of condylar fractures or trauma was found.

Discussion

Main findings

This systematic review included 14,396 recipients of a TMJ prosthesis described in 337 studies, of whom only 83 recipients of a TMJ prosthesis (approximately 2%) had a history of a fracture of the mandibular condyle (pooled prevalence, 1.6%). Another 580 recipients of a TMJ prosthesis (approximately 14%) had a trauma, not further specified, in their history (pooled prevalence, 11.3%). Not all studies were sufficiently documented to arrive at a more precise estimation of these percentages.

Table 2. Summary of reporting in cohort/clinical studies ($N = 127$).

Studies reporting	
Inclusion criteria	100 (78.7%)
Exclusion criteria	54 (42.5%)
Research institute	52 (40.9%)
Timeframe of the inclusion	96 (75.6%)
Base population from which patients were recruited	57 (44.9%)
Patients	
Receiving a TMJ prosthesis	13,870
Reported to be eligible for receiving a TMJ prosthesis	5021
Meeting inclusion criteria of the study	4797

TMJ, temporomandibular joint.

Table 3. Overview of the 83 mandibular condyle fractures in 48 studies.

	Total	Case reports	Case series	Cohort/ clinical studies
	n (%)[a]	*n* (%)[b]	*n* (%)[b]	*n* (%)[b]
Studies with mandibular condyle fractures	48	19	21	8
Number of patients with mandibular condyle fractures	83	19	37	27
Description of fractures (59 valid observations)				
Left	13 (22.0%)	6 (46.2%)	7 (53.8%)	0 (0%)
Right	11 (18.6%)	5 (45.5%)	4 (36.4%)	2 (18.2%)
Bilateral	35 (59.3%)	8 (22.9%)	19 (54.3%)	8 (22.9%)
Side not reported	24	–	7	17
Sex (59 valid observations)				
Male	36 (61.0%)	9 (25%)	20 (55.6%)	7 (19.4%)
Female	23 (39.0%)	10 (43.5%)	6 (26.1%)	7 (30.4%)
Not reported	24	0	11	13
Mean age at TMJ replacement (± SD), where data available (number of patients with age reported)		32.2 (± 17.4) ($n = 18$)	39.2 (± 17.8) ($n = 18$)	45.2 (± 12.8) ($n = 6$)
Trauma mechanism (29 valid observations)				
Fall	10 (34.5%)	3 (30%)	7 (70%)	–
Motor vehicle accident	8 (27.6%)	5 (62.5%)	3 (37.5%)	–
Traffic accident	7 (24.1%)	2 (28.6%)	5 (71.4%)	–
Gunshot	1 (3.4%)	–	1 (100%)	–
Horseback riding	1 (3.4%)	–	1 (100%)	–
Miscellaneous	2 (6.9%)	1 (50%)	1 (50%)	–
Not reported	54	8	19	27
Interval between trauma and TMJ prosthesis placement (number of patients for which interval was reported)		3 d – 26 y ($n = 15$)	1 w – 30 y ($n = 13$)	4 y ($n = 1$)
Indication for TMJ placement (68 valid observations)				
Ankylosis	34 (50%)	12 (35.3%)	17 (50%)	5 (14.7%)
Condylar resorption	1 (1.5%)	1 (100%)	–	–
Osteoarthritis	3 (4.4%)	1 (33.3%)	1 (33.3%)	1 (33.3%)
Inflammation	1 (1.5%)	1 (100%)	–	–
Malunion of the condylar fracture	6 (8.8%)	–	6 (100%)	–
Fractured osteosynthesis materials	1 (1.5%)	1 (100%)	–	–
Reconstruction/fractured condyle	21 (30.9%)	2 (9.5%)	9 (42.9%)	10 (47.6%)
Heterotopic calcification	1 (1.5%)	1 (100%)	–	–
Not reported or unclear	15	–	4	11
Treatment received for the condylar fracture before TMJ replacement (36 valid observations)				
ORIF	13 (36.1%)	3 (23.1%)	6 (46.2%)	4 (30.8%)
Conservative treatment with/without IMF	12 (33.3%)	6 (50%)	6 (50%)	–
Closed reduction with/without IMF	4 (11.1%)	3 (75%)	1 (25%)	–
Untreated fracture	3 (8.3%)	3 (100%)	–	–
Direct TMJ replacement after fracture of the mandibular condyle	4 (11.1%)	1 (25%)	3 (75%)	–
Not reported or unclear	47	3	21	23
Other treatments before TMJ replacement (40 valid observations)				
Gap arthroplasty	5 (12.5%)	3 (60%)	2 (40%)	–
Costochondral graft	2 (5%)	2 (100%)	–	–
Multiple surgeries not further specified	3 (7.5%)	–	2 (66.7%)	1 (33.3%)
Condylectomy	1 (2.5%)	–	1 (100%)	–
None	24 (60%)	14 (58.3%)	10 (41.7%)	–
Other (silicone implants, place holders or splints)	5 (12.5%)	–	5 (100%)	–
Not reported	43	0	17	26

IMF, intermaxillary fixation; ORIF, open reduction and internal fixation; SD, standard deviation; TMJ, temporomandibular joint; d, day; w, week; y, year.

[a]Column percentages of the total (only valid observations).

[b]Row percentages.

Low-grade osteoarthritis, ankylosis (not specified), and trauma (not specified) were the most common indications for implanting a TMJ prosthesis. High-grade inflammatory arthritis and miscellaneous were the fourth and fifth most common causes for implanting a TMJ prosthesis. Thus, of all patients who received a TMJ prosthesis, only a minority had a history of a mandibular condyle fracture. However, as all patients in this review received a TMJ prosthesis, for cases in which a trauma was not specified, a condylar fracture was likely the cause. That would suggest a higher percentage, but this could not be deduced directly from the studies. For patients with a reported indication for implanting a TMJ prosthesis, this was most often low-grade osteoarthritis. Therefore it is

Table 4. Results of the meta-analysis.

	Pooled prevalence (95% CI)	I^2 (95% CI)	Cochran Q	P-value
Condylar fractures	0.016 (0.009–0.024)	38.492 (29.098–46.641)	479.613	< 0.001
Condylar fractures or trauma	0.113 (0.071–0.160)	81.427 (79.423–83.236)	1599.083	< 0.001
Condylar fractures or trauma[a]	0.105 (0.053–0.165)	81.608 (79.633–83.392)	1620.307	< 0.001

CI, confidence interval.

[a]Including data from the paper by Elledge et al.,[18] based on numbers presented in Fig. 2 of that paper (768 joint replacements of which 48 were related to a trauma).

unlikely that all 10,219 patients with unreported causes had a fracture of the mandibular condyle. Since not all studies reported the number of patients in a particular time period who were eligible to receive a TMJ prosthesis, it is possible that at the time of the studies more patients could have met the criteria for a TMJ prosthesis. More patients could also have sustained a fracture of the mandibular condyle than was reported in the studies.

Relevance

According to the meta-analysis, the estimated prevalence of patients receiving a TMJ prosthesis with a history of a fracture of the mandibular condyle is 1.6%, but this prevalence may range from 0.9% to 2.4%. Similarly, the estimated prevalence of patients receiving a TMJ prosthesis with a history of a fracture of the mandibular condyle or a trauma is 11.3%, but may range from 7.1% to 16.0% (Table 4). This estimate is probably a very small percentage of the total number of mandibular condyle fractures, as facial fractures are common, and a fracture of the mandibular condyle occurs in approximately 17.5–52.0% of all mandibular fractures.[1,4,24,25] From the data reviewed, it remains unclear what the exact indications for TMJ prostheses were. Regarding trauma, in cases involving a comminuted condyle, immediate implantation of a TMJ prosthesis is probably an option,[9] as illustrated in the four patients with a condylar fracture in whom the condyle was directly replaced since there was no real option for reduction of the condyle because of comminution. However, it should be pointed out that in these four historic cases presented in Table 3, the surgeon's experience and the availability of a prosthesis or osteosynthesis materials may have led to immediate TMJ prosthesis implantation. In the case of the gunshot wound patient, it could be assumed that a highly skilled surgeon was needed for the reconstruction. The materials available changed over time. The acrylic condyle in the study of Terracol[21] was placed in 1954. Currently this type of material would not be used anymore. Data from the included studies showed that most trauma patients received a TMJ prosthesis because of failed closed or open treatment, ankylosis, resorption, or non-union (Table 3).

Other studies

In the United Kingdom, oral and maxillofacial surgeons have been given guidelines for TMJ prosthesis implantation. According to these guidelines, one indication is post-traumatic condylar loss or damage. Other indications are the presence of degenerative or inflammatory joint disease or severe congenital deformities.[26] A case study reported on the implantation of a TMJ prosthesis after surgical treatment of a fracture of the mandibular condyle.[27] In that case, progressive condylar resorption occurred that was attributed to the fractured and dislocated osteosynthesis material. The authors pointed out that condylar resorption in relation to failure of osteosynthesis material is a seldom-reported complication.[27]

In the case of resorption or ankylosis in patients with TMJ dysfunction after a fracture of the mandibular condyle, the United Kingdom guidelines mentioned above recommend implantation of a custom or stock total joint prosthesis.[26] Reconstruction decisions should be based on several factors including the amount of resorption, malposition/malunion, ankylosis, salvageability of the proximal segment of the mandibular condyle, and the anatomy of the fossa and ramus. If the proximal segment of the condyle is not salvageable, implantation of a TMJ prosthesis is advised.[27]

Quality of the studies

Many of the studies included in this review lacked systematic documentation. Data were often missing or were not reported, as shown in the tables. The reasons for implanting the prosthesis were not reported for about two-thirds of all patients. In the case of a non-specified trauma history, these data were possibly missing because the trauma occurred many years previously and was initially treated at another institution, in another city, or even in another country.

Multiple studies ($n = 21$) presented the same population in more than one publication. In publications with overlapping populations, only the study with the most complete information was included in the analysis (Fig. 1). In studies where overlap was not clear, the corresponding authors were contacted and asked for additional information. However, only a few authors replied, despite several emails being sent. These studies were then excluded. Including multiple publications reporting the same populations in this systematic review would have led to an overestimation of the number of patients who received a TMJ prosthesis.

In some studies, the reported number of patients and implanted TMJ prostheses did not add up. Two database studies did not clearly state in their articles that not all data were present at the time of publication.[18,20] It could have been that some data were missing, or that patients received multiple prostheses (more than two) sequentially over time because of retreatment, but this was not reported in the article. It is probable that part of the patient data in the study by Elledge et al.[18] had been published previously in the study by Idle et al.[20] The study by Elledge et al.[18] was published after the study by Idle et al.[20] and described the same database at a later moment in time, with larger numbers of patients and TMJ replacements.

An analysis was performed to determine whether the cases from these studies would have influenced the outcome of the research question of this review. In the study by Elledge et al.,[18] 48 TMJ replacements due to non-specified trauma were reported. It was

unclear whether this number referred to patients or to implanted joints. Condylar fractures were not specifically mentioned. In the study by Idle et al.,[20] 35 total joint replacements due to trauma were reported. Here again the authors did not specify whether this number referred to patients or joints. Also condylar fractures were not mentioned. In the sensitivity analysis, the data from the study by Elledge et al.[18] were entered into the meta-analysis. The effect was small (Table 4). Therefore the influence of the exclusion of this study with regards to the research question was small.

Multiple studies selected only some of the participants for reporting findings. In 20 of the 127 cohort studies and clinical trials (15.7%), the authors stated that only patients who received a TMJ prosthesis from one surgeon were selected to participate in the study. As specific skills are needed to implant a TMJ prosthesis, it was assumed that the authors preferred to report the outcomes of only an experienced surgeon instead of a mixed group that included novice surgeons as well, but this prevents a precise estimate of the total number of patients who received a prosthesis from being made. Based on the data presented, it is impossible to estimate how many prostheses were actually implanted and what the exact reasons were for implantation. Some studies reported selecting patients based on their patient history: only patients who were operated on by one surgeon were included. This type of selection was reported in the studies by Dela Coleta et al.,[28] Goncalves et al.,[29] Loveless et al.,[30] Perez et al.,[31] Yoon et al.,[32] Yuen et al.,[33] Wolford et al.,[34–36] and Zou et al.[37,38] This selection could have resulted in bias.

Additionally, some studies included only records with complete follow-up of at least 1 year. Although this enabled the reporting of longer-term outcomes, it did not allow the assessment of the total number of patients receiving a prosthesis and the reasons for implanting a TMJ prosthesis. Furthermore it was unclear how many patients dropped out, for example due to poor outcomes. It was attempted to estimate the number of excluded patients to determine the source population, which could then be a more accurate estimate of the total number of patients who received a TMJ prosthesis. However, this estimation was not always possible because the number of eligible patients was described in only 44.9% of all cohort studies and clinical trials. As a result, the institution in which the study was performed could have treated more patients in that same timeframe who received a TMJ prosthesis from a different surgeon. This could have led to an underestimation of the number of patients who received a TMJ prosthesis after a fracture of the mandibular condyle in this systematic review. In short, no studies were found that systematically reported the reasons for implanting a TMJ prosthesis.

Strengths and limitations

The strengths of this review were the following. The lack of language and time restrictions in the selection process enabled a broader search. Also, the search strategy was designed with the help of an information specialist, and inter-observer agreement was good.[39] Although the quality of the studies was not assessed with a formal assessment tool, potential sources of selection bias were assessed by studying the source population and the patient inclusion and exclusion criteria described in the cohort studies and clinical trials.

Regarding limitations, none of the included studies was specifically designed as a prevalence study, which prevented an accurate estimate of the percentage of patients with a condylar fracture in their history to be made. Another limitation of this systematic review is that the source studies lacked systematic data about patient history and diagnosis leading up to the implantation of the TMJ prosthesis. Additionally, in a many studies, a long time period had passed between the trauma and TMJ prosthesis implantation, which prevented a description of the precise damage that occurred during the trauma.

Future research

Future studies should report specifically on the total number of patients who received a TMJ prosthesis and what the indications for implantation were. It should also be clear how many prostheses were implanted and what the causes and reasons for implantation of the TMJ prosthesis were. A clarification regarding the inclusion and exclusion criteria for patients receiving a TMJ prosthesis would also be helpful and would enable a good overview of indications and contraindications for implantation of a TMJ prosthesis.

Furthermore, future studies should also report on the outcomes (mandibular function impairment, range of mouth opening, and complications) of patients receiving a TMJ prosthesis after a condylar fracture and whether these outcomes differ from those of patients receiving a prosthesis for other reasons. Studies should specify the time between fracture of the mandibular condyle and implantation of the TMJ prosthesis, as well as other treatments that the patient received prior to TMJ prosthesis implantation. These data are needed to determine whether treatment optimization is possible. The results could benefit the discussion regarding the best type of treatment after a fracture of the mandibular condyle.

Conclusions

In conclusion, the pooled prevalence of condylar fractures was calculated to be 1.6% (95% CI 0.9–2.4%). The pooled prevalence of condylar fractures or trauma was calculated to be 11.3% (95% CI 7.1–16.0%). However, these results should be considered with caution since they are based on studies with clinical, methodological, and statistical heterogeneity.

Although this review shows that the TMJ prosthesis is used as a treatment option after fracture of the mandibular condyle, the absolute or relative indications and when it should be used as primary or secondary treatment remain unclear. The TMJ prosthesis appears to be reserved for patients with a comminuted condyle and patients with persistent pain, bony or fibrous ankylosis, or osteomyelitis after primary closed or open treatment of fractures of the mandibular condyle.

Ethics approval and consent to participate

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Competing interests

None.

Patient consent

Not applicable.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijom.2022.05.014.

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