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Did temporomandibular gap arthroplasty with temporalis interpositional flap improve function and pain in patients with end-stage joint disease? A 5-year retrospective follow-up

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ABSTRACT

The primary aim of this study was to investigate whether patients with end-stage temporomandibular joint (TMJ) disease treated with gap arthroplasty with temporalis interpositional flap (GAT) had improved maximal interincisal opening (MIO) and TMJ pain in a long-term perspective.

All patients with severe osteoarthritis, or fibrous or bony ankyloses, and subjected to GAT between 2008 and 2015 were included. The criteria of treatment success were TMJ pain VAS score $\leq$4 and MIO $\geq$30 mm. Reoperation was considered as a failure.

Forty-four patients (mean age 47 years) were included in this retrospective descriptive case series and followed up for up to 7 years (mean 4.5). Comorbidities were frequent ($n = 34$) and most commonly rheumatic disease ($n = 17$). The indications for surgery were ankylosis ($n = 32$) or severe osteoarthritis ($n = 12$). Of the 44 included patients, 84% ($n = 37$) had a history of earlier TMJ surgery. The preoperative mean values for TMJ pain and MIO (VAS 7 and 23 mm, respectively) changed significantly ($p < 0.001$) to postoperative means of VAS 3 and 34 mm, respecitvely. The success rate was 59% ($n = 26$). When compared with a previous 2-year follow-up, the success rate was found to have decreased over time ($p = 0.0097$). The rate of successful treatment outcome in terms of MIO alone was 82% ($n = 36$). The most common reason for treatment failure was residual pain.

In conclusion, the success-rate after GAT did not show long-term stability and continued to drop over time in this patient cohort. TMJ pain seems to be the main reason for failure.

1. Introduction

Temporomandibular joint (TMJ) disorders are common, affecting 31% of the adult population, with a strong, unexplained female predominance (Johansson et al., 2003; Valesan et al., 2021). In a small proportion of patients, severe TMJ pathology, including ankylosis, develops. Severe pathology of the TMJ causes grave functional impairment. If ankylosis develops, the condylar process of the mandible is fused to the glenoid fossa by fibrotic or bony tissue, with possible life-threatening consequences (Bhatt et al., 2013; Movahed and Mercuri, 2015).

In developing countries, TMJ ankylosis usually develops during early childhood as a complication of otitis media (Bhatt et al., 2013; Karamese et al., 2013; Al-Moraissi et al., 2015). The factors suggested as causing severe TMJ disease, including ankylosis, are local or systemic infection and rheumatic disease (Al-Moraissi et al., 2015; Movahed and Mercuri, 2015; Upadya et al., 2021). According to some studies, a common etiological factor is trauma, through intraarticular hematoma, tissue scarring, and excessive bone formation (Bhatt et al., 2013; Karamese et al., 2013). Since most TMJ trauma resolves uneventfully, this does not explain individual susceptibility to developing severe pathology of the TMJ. Thus, the etiology and epidemiology of these conditions are largely unknown.

Most patients with TMJ ankylosis or severe osteoarthritis require open TMJ surgery. There are different choices of surgical procedure, including gap osteotomy, gap arthroplasty with temporalis

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interpositional flap (GAT), and joint reconstruction using alloplastic materials or autogenous grafts (Holmlund et al., 2013; Al-Moraissi et al., 2015). Although surgery has a good outcome in short-term follow-ups, some patients can experience re-ankylosis or postoperative occlusal changes (Roychoudhury et al., 1999; Bayat et al., 2009; Ma et al., 2015b). The choice of surgical method may differ between different settings, as exemplified by the Swedish national recommendations, according to which the first surgical method of choice is GAT or gap osteotomy without interposition of muscle tissue (National Board of Health and Welfare, 2022). According to a previous systematic review, GAT appears to be slightly more effective than gap osteotomy (Al-Moraissi et al., 2015). However, no long-term studies were available at the time of this publication. Therefore, studies need to investigate whether this conclusion is valid in a more long-term perspective (Österberg et al., 2017).

The primary aim of our study was to evaluate long-term outcomes after treatment of fibrous or bony ankyloses, or severe osteoarthritis of the TMJ, with GAT. The hypothesis was that patients treated with this method might deteriorate over time. The secondary aim was to evaluate treatment outcomes in relation to diagnosis, surgical procedure, preoperative status, and general health. A tertiary aim was to compare the temporal muscle flap cohort with a historical cohort comprising patients who had undergone TMJ gap osteotomy without muscle interpositioning.

2. Materials and methods

2.1. Study design and study population

The study design was a retrospective descriptive case series including all patients subjected to GAT between 2008 and 2015 in the Department of Oral and Maxillofacial Surgery, Karolinska University Hospital, Stockholm, Sweden. The patients eligible for inclusion were identified by searching the medical records for the nationally defined surgical codes potentially describing GAT (Nomesco, 2009) (Supplementary Table 1). All those patients identified as having had had GAT were included if they fulfilled criteria for severe osteoarthritis, or fibrous or bony ankylosis. Severe osteoarthritis was defined as Wilkes stage 5 with progression, responding to neither non-invasive nor invasive treatment (Wilkes, 1989). Ankylosis was defined in accordance with Lund et al. (2020). The exclusion criteria were missing patient records or other surgical interventions aside from GAT. Ethical approval was obtained from the regional ethical committee prior to commencement of the study (Dnr, 2015/1608–31) and the Helsinki Declaration was followed accordingly. Any uncertainty regarding interpretation of information in the patient records was resolved by discussion between all authors. Since the study design was a descriptive case series, power analysis was not applicable.

In addition, a historical group consisting of patients subjected to TMJ gap osteotomy in the Department of Oral and Maxillofacial Surgery, Karolinska University Hospital, Stockholm, Sweden was used for comparison. These patients had also been diagnosed with severe osteoarthritis, or fibrous or bony ankylosis, in the same manner as the GAT patients.

2.2. Surgical intervention and main outcome variables

The surgical procedure, previously described in detail (Holmlund et al., 2013), was as follows. A preauricular approach with a temporal extension was used and a gap arthroplasty was performed. The severely affected bone was removed, creating a gap of about 10 mm. A temporal muscle flap was raised, with its basis attached to the zygomatic arch, and was transferred laterally over the arch and then fixated into the gap. Fixation was achieved using resorbable sutures, passing through drilled holes in the arch to the soft tissue within the created joint space. All patients were given one dose of 600 mg clindamycin intravenously as antibiotic prophylaxis at the start of incision. No further antibiotics were prescribed.

The main outcome variables were TMJ pain and maximal interincisal opening (MIO), which are further specified below.

2.3. Subjective measures

Several subjective clinical variables were collected from the medical charts. TMJ pain was assessed by asking the patient to estimate the pain in the affected TMJ during mandibular movements on a 0–10-graded visual analogue scale (VAS), where 0 denoted no pain and 10 the worst imaginable pain. Similarly, patients were asked to estimate their TMJ function by VAS-grading their ability to chew and move the mandible. Zero represented no functional disability and 10 the worst imaginable functional disability.

Global pain referred to the patient's assessment of pain in the rest of their body, apart from TMJ pain. TMJ psychosocial was defined as the patient's perception of how the TMJ problems affected their psychosocial situation. Both global pain and TMJ psychosocial were recorded on a VAS, were 0 reflected no pain or psychosocial impact and 10 denoted the worst imaginable global pain/psychosocial impact.

2.4. Objective measures

Data on MIO and horizontal mandibular movements (lateral excursion and protrusion) recorded in millimetres were collected. Findings of lateral joint and/or masticatory muscle tenderness upon palpation were recorded. Any notes in the patient's medical records of pre- and postoperative malocclusion, and any treatment to correct the occlusion after the surgery, were registered. Indications for surgery, previous surgical interventions and corticosteroid joint injections, and surgical complications, such as infection, bleeding, and nerve injury, were also recorded. Grading of complications according to the Clavien–Dindo classification was performed (Dindo et al., 2004). The absence of fully standardized phrasings in patient records necessitated text interpretation for indications for surgery and occlusal changes. To ensure the best possible accuracy, all recordings from the patient records were carried out by two oral and maxillofacial surgeons subspecialized in TMJ surgery (BL and MU). In cases of unclarity, applicable text sections were read by all authors and then discussed as a group until consensus was reached.

2.5. Criteria for evaluation of treatment outcomes

Criteria for success were defined as MIO $\geq$30 mm or $\geq$40% improvement compared with preoperative MIO, and TMJ pain VAS $\leq$4 or $\geq$40% improvements. Reoperation in the form of major TMJ surgery, such as alloplastic total joint replacement or repeated arthroplasty surgery, was considered as a failure.

2.6. Statistical analyses

Mean values, ranges, and standard deviation (SD) were calculated for the descriptive statistics. When comparing successful and unsuccessful outcomes, Fisher's exact test was used for binary variables, chi-squared for nominal categorical variables, and Fisher's permutation test for numerical variables. When changes between pre- and post-TMJ pain VAS and MIO were investigated, Fisher's test for pairwise comparison was used. All three tests are non-parametric. A two-sided p-value was used for all analyses, with $p < 0.05$ considered statistically significant. Odds ratio (OR) was calculated using logistic regression analysis (parametric). Missing data were handled by analyzing missing data mechanisms and if applicable imputations were made (Heymans and Twisk, 2022). All the statistical analyses were performed by a statistician in close collaboration with the researchers.

3. Results

3.1. Patients' characteristics

In total, 44 patients previously treated with GAT were included. No patients were excluded based on the predefined criteria. Most patients were women ($n = 34$). The mean age was 47 years (SD = 14.8), ranging from 14 to 73 years. A majority of the patients ($n = 34$) had reported a comorbidity — most commonly a rheumatic disease, followed by cardiovascular disease (Table 1). The indication for surgery was either ankylosis ($n = 32$) — mostly fibrotic ankylosis — or severe osteoarthritis ($n = 12$). Based on possible etiologies of ankylosis or severe osteoarthritis, the patients were grossly divided into the following groups: chronic inflammatory arthritis, osteoarthritis, trauma, and unknown etiology. Osteoarthritis was the most common etiology, followed by chronic inflammatory arthritis (Fig. 1).

The mean follow-up time was 4.5 years, ranging up to 7 years (SD = 1.1). Some missing data posts were found randomly distributed among all variables, and were categorized as randomly missing, and therefore no imputations were made regarding these (Heymans and Twisk, 2022). The variables global pain, TMJ psychosocial, and lateral TMJ and masticatory muscle palpation pain, showed extensive missing data, which were regarded as non-randomly missing. This made valid analysis impossible, and the variables were not statistically analyzed. Patient characteristics are shown in Table 1.

Table 1
Demographic data of the included patients previously subjected to temporomandibular joint osteoarthrectomy with transfer of the temporalis muscle.

Characteristics	All patients n = 44	Successful cases n = 26	Failed cases n = 18	Successful vs Failed P-value OR (95% CI)
Patient gender, n (%)				
Male	10 (23)	6 (23)	4 (22)	>0.30 1.05
Female	34 (77)	20 (77)	14 (78)	(0.25–4.42)
Patient age, years, n (%)				
0–19	2 (5)	1 (4)	1 (6)	>0.30 0.99
20–39	11 (25)	6 (23)	5 (28)	(0.95–1.03)
40–59	22 (50)	14 (54)	8 (44)	
>60	9 (20)	5 (19)	4 (22)	
Mean age (SD)	47.2 (14.8)	48.4 (14.2)	45.6 (15.9)	
Medical condition[a], n				
Healthy	9	7	2	>0.30 0.34
Psychiatric	3	1	2	(0.06–1.87)
Neuropsychiatric	0	0	0	
Autoimmune	17	8	9	
Metabolic	4	3	1	
Cardiovascular	8	5	3	
Cancer	0	0	0	
Other[b]	22	12	11	
Pre-operative, mean (SD)				
TMJ pain (VAS 0–10)	6.7 (2.1)	6.4 (2.3)	7.2 (1.8)	>0.30 1.20 (0.81–1.78)
MIO (mm)	23.4 (7.1)	24.8 (7.7)	21.2 (5.6)	0.15 0.92 (0.84–1.02)
Operated side (%)				
Right	19 (43)	13 (50)	6 (33)	>0.30 0.50 (0.14–1.74)
Left	17 (39)	8 (31)	9 (50)	right vs left + bilateral
Bilateral	8 (18)	5 (19)	3 (17)	
Follow-up year				
Mean year (SD)	4.5 (1.1)	4.7 (1.1)	4.5 (1.2)	>0.30 0.85 (0.48–1.48)

Abbreviations: MIO, maximal interincisal opening; n, number of patients; pat, patients; SD, standard deviation; VAS, visual analogue scale; OR, odds ratio; CI, confidence interval.
Criteria of success was defined as maximal interincisal opening ≥30 mm or ≥40% improvement and TMJ pain VAS ≤4 or ≥40% improvement. Patients' appreciation of treatment outcome was not evaluated.
[a] Note, an individual patient can have several diagnoses, explaining the distributed number exceeding total patient population size.
[b] Other: knee prosthesis, gall surgery, herniated spine disc, Bartholin's cyst, hiatus hernia etc.

3.1.1. Preoperative treatment

Most of the included patients had undergone different types of treatment before being subjected to surgery (Fig. 2). One patient had not been subjected to any pretreatment, while in another case notes on presurgical treatments were missing. Presurgical conservative treatments, such as medication, bite guard, corticosteroid injection, or physical therapy in terms of jaw movement exercises, were reported for 73% ($n = 32$) of the patients. Most of the patients (84%; $n = 37$) had a history of earlier TMJ surgical treatment, such as arthroscopy, discectomy, gap osteotomy, and arthroplasty before GAT (Fig. 3). The number of surgical procedures preceding GAT ranged from one to four, and included arthroscopy and/or open joint surgery.

3.2. Surgical outcome

The preoperative mean values for TMJ pain and MIO were VAS 6.7 (SD = 2.1) and 23.7 mm (SD = 7.1), respectively, while the postoperative values were VAS 3.4 (SD = 3.0) and 33.8 mm (SD = 9.5), respectively. Both of these improvements were statistically significant ($p < 0.001$). When taking both criteria for success — TMJ pain and MIO — into account, the overall success rate was 59% ($n = 26$). In comparison with an earlier published report, where the study population comprised a subset of the patients in the current study, the success rate had dropped by 18% (Holmlund et al., 2013). The rate of successful treatment outcome in terms of MIO alone was 82% ($n = 36$). Thus, the most common reason for treatment failure was residual moderate-to-severe pain ($n = 14$). During the follow-up period, four patients were subjected to major revision surgery, and therefore considered as treatment failures (Table 2).

Although ankylosis was the predominant indication for surgery in the failed cases (14 out of 18 failed cases) there was no significant difference ($p > 0.30$) between the successful and failed group in terms of indication for surgery (Fig. 1). There was a higher success rate (75%; 6/8) in the group without any preoperative surgical treatment in comparison with those who had undergone previous open-joint surgery with or without arthroscopy (52%; 17/33) (Fig. 3). However, this difference was not statistically significant ($p = 0.21$).

The group with a successful treatment result ($n = 26$) and the unsuccessful group ($n = 18$) were compared with regard to subjective and objective preoperative parameters — gender, age, comorbidity, diagnosis indicative for surgery, preoperative conservative treatment, prior TMJ surgery, surgical side, MIO, and preoperative VAS-graded TMJ pain — to find possible predictors for treatment outcome. None of the investigated parameters was significantly different between the groups. However, it can be noted that in the patients without any comorbidities the success rate was 78% (7/9), while in the group with autoimmune disease the corresponding figure was 47% (8/17) (Table 1).

In the successful group, the mean postoperative MIO was 38.3 mm (SD = 5.6) and mean postoperative TMJ pain was VAS 1.5 (SD = 1.5). In this group there were notes in the patient records for 16 patients regarding self-graded postoperative global pain, with a mean of VAS 2.5 (SD = 2.6), and self-graded postoperative TMJ psychosocial influence, with a mean of VAS 2.3 (SD = 2.8). For the remaining 10 successful cases, information regarding these parameters was missing. In the unsuccessful group, the mean postoperative MIO was 27.1 mm (SD = 10.2) and mean postoperative TMJ pain was VAS 6.3 (SD = 2.1). In this group there were data from 14 patients reporting postoperative global pain (mean VAS 6.1, SD = 3.0) and postoperative TMJ psychosocial influence (mean VAS 4.6, SD = 3.0).

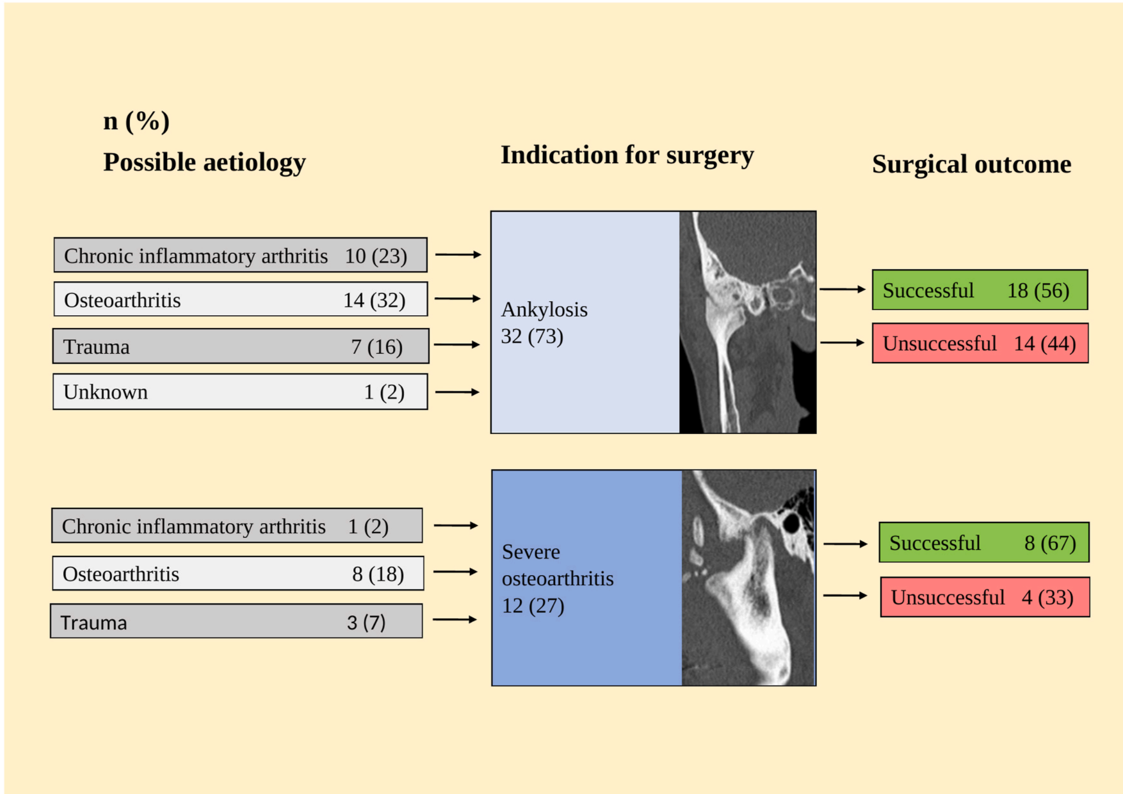

Fig. 1. Illustration of possible etiology in relation to indication for surgery and outcome. The CT images show typical examples of the radiographic degree of severity for the two diagnostic groups into which the patients were divided. Abbreviation: *n*, number of patients. Criteria for success: maximal interincisal opening ≥30 mm or ≥40% improvement and TMJ pain VAS ≤4 or ≥40% improvement. Reoperation in the form of major surgery was considered a failure.

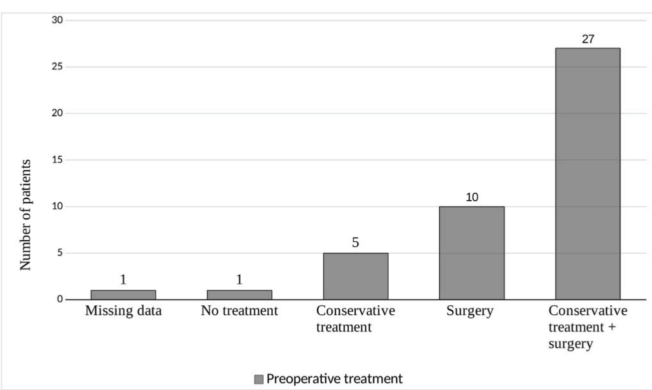

Fig. 2. Distribution of preoperative treatments before the surgery at issue — osteoarthrectomy with transfer of temporalis muscle (GAT). The figure over each bar represents the number of patients subjected to the stated treatment. Conservative treatment refers to physiotherapy, medication, bite guard, corticosteroid injection, physiotherapy, awareness raising, and information. Surgery refers to arthroscopy and open TMJ surgery.

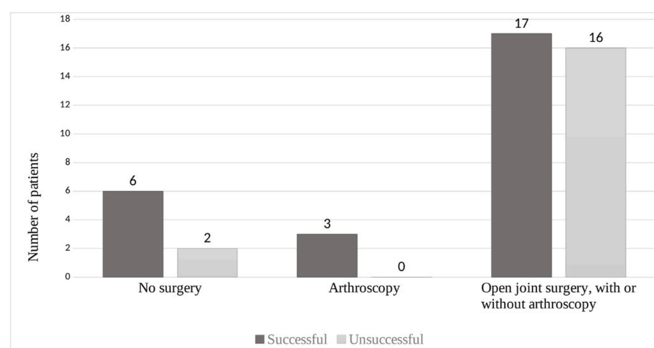

Fig. 3. Surgical treatment performed before GAT and outcome in relation to previous surgery. Open-joint surgical procedures included discectomy, gap osteotomy, or TMJ arthroplasty. The graph shows number of patients in each category. Criteria for success: maximal interincisal opening ≥30 mm or ≥40% improvement and TMJ pain VAS ≤4 or ≥40% improvement. Reoperation in the form of major surgery was considered a failure.

3.2.1. Comparison with the historical cohort

When comparing the success rate of the historical TMJ gap osteotomy group (60%; 12/20) with that of the present study's GAT cohort, there was no significant difference ($p > 0.30$) (Table 3). All the failed gap osteotomy cases reported a postoperative TMJ pain of VAS ≥4 and seven patients had an MIO ≤30 mm (Table 3). Thus, a combination of poor MIO and TMJ pain was seen in seven of the eight failed cases in this historical cohort.

3.3. Complications

A postoperative superficial and localized skin infection at the site of incision occurred in two of the GAT cases (Clavien–Dindo grade II). Both infections were treated with a 7-day course of clindamycin and healed uneventfully. These two patients belonged to the successful group.

Twelve patients (27%) had a temporary facial nerve palsy that recovered spontaneously within 6 months postoperatively (Clavien–Dindo grade I). In two cases (5%) there was a permanent weakness of the temporal branch of the facial nerve at follow-up (Clavien–Dindo grade I). There were no bleeding complications during or after surgery.

Table 2
Treatment outcome for different success criteria and for all criteria in concert.

Treatment outcome (n = 44)	n (%)
Pain, n (%)	
VAS ≤ 4 or VAS improved > 40%	30 (68)
VAS > 4	14 (32)
Maximum interincisal opening (MIO)	
MIO ≥ 30 mm or MIO improved > 40%	36 (82)
MIO < 30 mm	8 (18)
Major revision surgery, n (%)	
Yes	4 (9)
No	40 (91)
All criteria, n (%)	
Success	26 (59)
Failure	18 (41)

Abbreviations: n, number of patients; VAS, visual analogue scale; MIO, maximal interincisal opening.
Criteria of success was defined as maximal interincisal opening ≥30 mm or ≥40% improvement and TMJ pain VAS ≤4 or ≥40% improvement. Patients' appreciation of treatment outcome was not evaluated.

Table 3
Demographic data of control group subjected to temporomandibular joint osteoarthrectomy without transfer of the temporalis muscle (i.e. gaposteotomy).

Characteristics	All cases n = 20	Successful cases n = 12	Failed cases n = 8	Successful vs Failed P-value OR (95% CI)
Patient gender, n (%)				
Male	1 (5)	1	0 (0)	>0.30 2.22 (0.08–61.41)
Female	19 (95)	11	8 (100)	
Patient age, years, n (%)				
0–19	0 (0)	0	0 (0)	
20–39	5 (25)	2 (17)	3 (38)	
40–59	11 (55)	7 (58)	4 (50)	
>60	4 (20)	3 (25)	1 (12)	
Mean age (SD)	50.0 (14.9)	52.8 (15.2)	45.6 (14.1)	>0.30 0.96 (0.90–1.03)
Follow-up, years				
Mean (SD)	3.9 (2.5)	4.6 (2.9)	2.7 (1.1)	0.082 0.96 (0.90–1.03)
TMJ pain, VAS (0–10)				
Pre-operative, mean (SD)	7.9 (2.4)	7.4 (2.8)	8.7 (1.2)	>0.30 1.53 (0.65–3.63)
Last follow-up, mean (SD)	3.6 (3.6)	0.7 (1.1)	7.4 (1.4)	<0.001 -
MIO (mm)				
Pre-operative, mean (SD)	17.3 (9.9)	15.8 (10.6)	19.6 (9.0)	>0.30 1.04 (0.95–1.15)
Last follow-up, mean (SD)	28.1 (8.6)	31.8 (6.4)	22.4 (8.6)	<0.001 0.85 (0.74–0.98)

Abbreviations: n, number of patients; SD, standard deviation; VAS, visual analogue scale; OR, Odds ratio; CI, confidence interval (CI).
Criteria of success was defined as maximal interincisal opening ≥30 mm or ≥40% improvement and TMJ pain VAS ≤4 or ≥40% improvement. Patients' appreciation of treatment outcome was not evaluated.

There were almost no data on preoperative occlusal status. This prevented analyses of eventual occlusal changes due to GAT in relation to pre-existing ones due to earlier surgery or TMJ pathology. However, when interpreting postoperative occlusal status in the cohort, the patients were divided into three groups: (1) no or minimal occlusal changes, 68% ($n = 30$); (2) moderate or severe occlusal changes, 30% ($n = 13$); and (3) missing data. In one patient, a previous gap osteotomy was identified with certainty as the cause of severe occlusal change. All patients with moderate or severe occlusal changes needed prosthetic treatment ($n = 9$, Clavien–Dindo grade IIIa) or orthognathic surgery ($n = 4$, Clavien–Dindo grade IIIb).

4. Discussion

The aim of this study was to evaluate the long-term outcomes after treatment of fibrous or bony ankyloses, or severe osteoarthritis, of the TMJ with GAT. The hypothesis was that the treatment success with GAT would decline over time. This hypothesis was based on the clinical observation that, over time, some operated patients seemed to deteriorate. The results showed that the overall success rate of GAT decreased over time, where pain was the main reason for failure.

TMJ surgery is a much debated issue with regard to algorithms for diagnostic classification and to treatment alternatives. Eventual choice of therapy is likely based on a combination of many factors, such as economic resources, surgeons' skills and preferences, healthcare trends, available medical equipment, and authority policies.

Often results after TMJ surgery are illustrated by showing mean values of various parameters, without considering cut-off levels for success or compiling different outcome measures when interpreting the results of surgery. In the evaluation of treatment outcomes, it is important to align with predefined criteria of success; if possible, these should include at least one objective and one subjective measure. Furthermore, it is the evaluated factors in concert that should define the treatment outcome. This was applied in the current study, using similar criteria for success to those in a previous 2-year follow-up study (Holmlund et al., 2013). However, it should be kept in mind that the currently chosen criteria for success —MIO and TMJ pain — are not necessarily correlated with patient satisfaction.

In Sweden, according to national guidelines, the recommended first choice of treatment for advanced TMJ pathology is GAT (Socialstyrelsen, 2021). However, to date the evidence supporting GAT is limited, and long-term follow-ups are sparse. A study from India on 15 ankylosis patients treated with GAT and followed for 1–6 years (mean 3 years and 4 months) reported good outcome regarding MIO (Rajurkar et al., 2017). The etiology was trauma or ear infection, in contrast with our study, in which the predominant etiology was of chronic inflammatory origin, and where many patients had been subjected to several operations prior to GAT. To our knowledge, this was the first attempt to carry out a long-term follow-up on this type of patient population.

Our results showed that the success rate after GAT in the studied population was 59% (26/44) after a mean follow-up of 4.5 years. This was significantly lower ($p = 0.0097$) than that for a previous 2-year follow-up (77% success), which might indicate that this patient group deteriorates with time (Holmlund et al., 2013). A possible explanation could be that about one third of included patients had an autoimmune joint disease, which is a chronic condition with a life-long risk of exacerbation, even after surgery. In the group with autoimmune disease the success rate was 47% (8/17), compared with a success rate of 78% (7/9) in the otherwise healthy group (Table 1).

A significant proportion of the included patients had been subjected to open TMJ surgery prior to GAT, and in around half of the patients repeated open-joint procedures had been performed. This is a previously acknowledged risk factor for adverse outcome after TMJ surgery (Mercuri, 2012; Aagaard and Thygesen, 2014). Today it is therefore advocated that extensive reconstructive TMJ surgery should be considered at an earlier stage, instead of subjecting the patient to repeated minor interventions that might worsen the prognosis, which is also indicated by our study (Johnson et al., 2017; Bach et al., 2022).

The main reason for failure in this patient cohort was residual pain after the surgery. If only MIO had been considered, the success rate would have been 82%, indicating that the functional improvement after GAT is high, even in the longer term. Although pain is complex and not always easy to manage, the result highlights the importance of addressing pain before surgery (Machoň et al., 2020). This includes pain management and coping strategies, but also thorough preoperative efforts to ensure realistic patient expectations. In the current study, most of the patients had undergone conservative treatment before GAT, which also included addressing pain. Postsurgical residual pain does not necessarily mean low patient satisfaction, since a reduction in pain, although still over the currently applied cut off (≤ VAS 4 or ≥ 40% improvement), can be very valuable for patients with chronic pain. Importantly, pain should not be a sole indication for surgery (Dolwick, 2007; Song and Yap, 2018). Moreover, one cannot ignore the fact that the surgical method is an inherent risk factor for pain. A putative risk could be interpositioning of viable muscle tissue into a space that is inevitably subjected to pressure. However, postoperative MRI indicates that the muscle flap is transformed into fibrotic tissue (authors' observation), analogous to pseudo-disc formation of the posterior disc attachment after long-term disc displacement without reduction (Thyne et al., 1992; Zhuo and Cai, 2016; Bristela et al., 2017).

Occlusal changes are often mentioned as one of the negative aspects of the studied surgical treatment (Holmlund et al., 2013; Ma et al., 2015a, 2015b). Since information on preoperative occlusal status was often lacking in the patient records, along with the fact that many patients had undergone repeated surgical interventions and also had TMJ pathologies known to cause occlusal changes, the true effect of GAT on occlusion could not be determined. However, 13 patients (30%) had occlusal changes that were addressed postoperatively as part of the rehabilitation. This could indicate that GAT does increase the risk for occlusal changes.

On this basis, alternative TMJ surgical methods that restore condylar height should be considered if the patient has a preoperative occlusal change, or when the gap osteotomy is expected to result in a pronounced vertical discrepancy. Furthermore, the experience from these patients suggests that occlusal changes can be difficult to predict based on resection extent, since the adaptability of the joint and adjacent soft-tissue structures seems to vary considerably between different individuals (authors' clinical observation). There was no major difference in success rates between patients subjected to GAT and the historical group treated with gap osteotomy. Although conclusions cannot be drawn, this could indicate that gap osteotomy without temporal muscle insertion could be a comparable alternative to GAT. However, impaired mouth opening capacity was more common in the failed patients in the historic control group compared with the GAT group.

Our study had some limitations. One drawback of a retrospective medical record-based study is the possibility that mainly deviant findings are recorded. For this study, the approach to this was to consider everything not mentioned as missing data, thus reducing the power and giving an inherent uncertainty to the data analyses and conclusions. The advantage of this approach is a reduced risk of affecting data by interpretation. The time-points for follow-up visits at our centre varied substantially, partly due to different outcomes of surgery (those with good outcomes had fewer recalls) and the fact that patients from other regions in Sweden most often had their check-ups at their primary referral centres. This caused the frequency of longitudinal data to fluctuate significantly over time, which is why the last follow-up recorded were used as the primary analyzable point. The study size was another limitation, impeding solid statistical analyses. To be able to take this a step further and make a valid statement regarding GAT, it will be necessary to conduct larger prospective studies comparing the same categories of patients randomized to different treatments, which should include total joint replacement in combination with long-term follow-up. Because of the difficulty in conducting well-designed studies on rare conditions within a reasonable timeframe, the results of this study can be considered as having value, but should be interpreted with great caution.

5. Conclusion

This study showed that the success rate in the patient cohort treated with GAT appeared to decrease with time. In addition, TMJ pain seemed to be the main reason for failure in this patient category. This highlights the importance of properly addressing preoperative pain prior to surgery, but also calls for further studies on risk factors for failure and alternative treatments. Although total alloplastic joint replacement is a commonly used and accepted surgical method in these patients, GAT may have its applications in some settings, and therefore the method needs to be further evaluated.

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Declarations of interest

None.

CRediT author statement

Nikoo Bazsefidpay: conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; resources; visualization; writing — original draft, review, and editing. Mattias Ulmner: conceptualization; data curation; formal analysis; investigation; methodology; resources; supervision; visualization; writing — original draft, review, and editing. Bodil Lund: conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; visualization; writing — original draft, review, and editing.

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Appendix A. Supplementary data

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