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Influence of preoperative anatomy and functional status on outcomes after total temporomandibular joint replacement with patient-specific endoprostheses: A retrospective cohort study

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Abstract

Background. Temporomandibular joint (TMJ) replacement may be indicated for various pathological conditions, and the type of condition can affect the surgical procedure and outcomes. The causes of limited range of motion after alloplastic TMJ replacement have not been extensively studied.

Objectives. The present study aimed to evaluate the impact of preoperative jaw anatomy and functional status on the immediate and long-term outcomes of total TMJ replacement using a two-component patient-specific TMJ endoprosthesis.

Material and methods. This retrospective study included 31 patients who underwent total TMJ replacement surgery between 2016 and 2020. The main outcome variable was the maximal incisal opening (MIO) after treatment. Secondary outcome variables included MIO improvement and the presence and type of postoperative complications. The primary predictive variable was the preoperative initial MIO. Secondary predictive variables included sex, age, indications for TMJ replacement, preoperative occlusion, condition of the glenoid fossa and/or condyle, shortening of the mandibular ramus, sagittal mandible position, lateral chin deviation, shape of the coronoid process, and type of surgery.

Results. The mean preoperative MIO was 13.0 ±8.0 mm, while the mean MIO 1 month after surgery was 20.6 ±5.5 mm, which was not statistically significant. However, at a later follow-up, functional parameters showed a significant improvement ($p = 0.003$), with a mean MIO of 32.5 ±5.0 mm 3 years after surgery. Statistical analysis indicated that the initial mouth opening is the strongest predictor of long-term functional recovery after TMJ replacement. Postoperative complications occurred in 4 cases (12.9%) following patient-specific endoprosthesis (PSE) placement.

Conclusions. The use of PSEs for TMJ replacement has enabled the restoration of anatomical relationships in complex clinical cases and an improvement in mouth opening. The preoperative MIO was the only factor that significantly influenced long-term functional outcomes.

Keywords: patient-specific implants, alloplastic temporomandibular joint replacements, maximal mouth opening, TMJ scarification

Introduction

Alloplastic temporomandibular joint (TMJ) replacement is a widely accepted therapy for end-stage TMJ disease and a routine procedure for TMJ reconstruction after mandible resection in patients with malignant or benign tumors. Numerous publications have shown that TMJ replacement leads to significant improvements in quality of life, decreased pain scores, and increased mouth opening and food intake.[1–3]

Alloplastic TMJ prostheses, whether stock or patient-specific, typically consist of a polymeric fossa component and metallic condyle. These prostheses are fixed to adjacent bony structures using traditional preauricular and submandibular/periangular approaches.[4,5] However, a considerable variety of pathological conditions may indicate the need for TMJ replacement. Customized patient-specific endoprostheses (PSEs) have many advantages in complex cases where the anatomy is abnormal, or the patient has a history of multiple joint surgeries.

A patient-specific design promotes a good fit between the prosthetic components and bone surfaces, as well as adaptation to the patient's jaw anatomy, even in cases of severe deformity. This design type increases the precision of alloplastic TMJ placement, particularly when used in combination with cutting and positioning guides. Additionally, it simplifies the surgical procedure and reduces operation time. According to a study by Mercuri, PSEs provided significantly better outcomes than stock implants.[6] When using PSEs, the design of the artificial joint components can be adjusted to conform to the patient's preoperative anatomy.[6,7] However, in these cases, the ability to compensate for individual topographical changes and functional disorders caused by existing pathological processes may be overestimated and require further investigation.

The primary goal of total joint replacement is the restoration of appropriate anatomical relationships of the jaw and masticatory functions, including a normal physiological range of mouth opening and normal lateral and protrusive mandibular movement. Several authors have reported improved short- and long-term mouth opening following PSE placement.[7] However, data on improvements in protrusion and laterotrusion of the mandible remains controversial. It is evident that individuals who have undergone alloplastic reconstructions typically exhibit reduced jaw mobility, even in cases of the most successful procedures, when compared to those with normal jaw function.[8]

The existing literature lacks sufficient research on the causes of limited range of motion following alloplastic TMJ replacement. At the same time, there is an overestimation of the impact of patient-specific solutions on functional outcomes after TMJ replacement. Potential explanations of this finding include muscular detachment during surgery, irregularities in prosthesis design, and soft tissue changes such as scarring, muscular contraction, calcification, and ectopic bone formation.[9] It is also possible that the initial anatomy and functional status resulting from the etiology of TMJ pathology (ankylosis, tumors, condylar head fractures, severe arthritis, or secondary reconstructions) may significantly influence the immediate and long-term outcomes of TMJ replacement.[3] In addition, the literature suggests that additional factors associated with an increased surgical risk and procedural complexity include shortening of the ramus and attached musculature, malocclusion, marked asymmetry of the jaw, scarring from previous surgeries, and limited space for the PSE components.[10] However, the impact of these factors on long-term functional outcomes is not well defined. Novel data could provide clear indications for patient-specific TMJ replacement. Based on the aforementioned background, we hypothesized that the type of condition may influence the surgical procedure, the design of the alloplastic endoprosthesis, and the outcomes of the intervention.

The present study aimed to evaluate the impact of preoperative jaw anatomy and functional status on the immediate and long-term outcomes of total TMJ replacement using two-component PSEs.

Material and methods

This retrospective cohort study analyzed data from patients who underwent total TMJ replacement surgery at the Department of Maxillofacial Surgery and Innovative Dentistry in Kyiv, Ukraine, and the Head and Neck Surgery Clinic for Children and Youth in Olsztyn, Poland, between 2016 and 2020. The inclusion criteria were as follows: individuals who underwent total joint replacement with an alloplastic two-component PSE for primary or secondary TMJ reconstruction and had complete documentation of their clinical case with a post-surgical follow-up of at least 3 years. Patients were excluded if they were under 16 years of age, had neurological or muscular diseases that affected mandibular movements and mouth opening, mental illness, active malignancy, or a history of radiation or chemotherapy, were non-adherent to medical recommendations, had no interaction with a physician during the postoperative period, or refused to participate in the study. The study was approved by the Ethics Committee of the Bogomolets National Medical University, Kyiv, Ukraine (approval No. 153; November 29, 2021).

Case histories of all patients were retrospectively reviewed, and the preoperative status, treatment outcomes and any complications were recorded. The main outcome variable was the maximal incisal opening (MIO) after treatment. Secondary outcome variables included MIO improvement (expressed as the difference between the postoperative and preoperative MIO) and the presence and type of postoperative complications.

The study's primary predictive variable was the preoperative initial MIO. Secondary predictive variables included the patient's sex, age, indications for TMJ replacement, preoperative occlusion, condition of the glenoid fossa and/or condyle, shortening of the mandibular ramus, sagittal mandible position, lateral chin deviation, shape of the coronoid process (normal, elongated or deformed), and type of surgery (primary or secondary, unilateral or bilateral TMJ replacement, and coronoid process preservation or resection).

The preoperative anatomy was evaluated and categorized by 2 experienced and independent observers based on presurgical multi-slice spiral computed tomography (CT) data. The length of the ramus was measured on separate 3D images of the mandible as the distance between the most superior point of the condyle and the most inferior point of the gonion. The shortening of the affected ramus in cases of unilateral TMJ pathology was determined by comparing its length with the unaffected side. In bilateral cases, the lengths were compared to the average statistical data found in the literature.[11,12] If the glenoid fossa and/or condyle were clearly visible with no pathological signs, they were considered to be preserved. Conversely, cases where the anatomy and interrelations of the bony structures were severely deformed were considered to be affected. The coronoid process was recorded as elongated or not according to previously described criteria.[13]

The surgical procedures were performed under general anesthesia following standard surgical protocols. Patient-specific endoprostheses from 3 different manufacturers (KLS Martin, Tuttlingen, Germany; ChM, Juchnowiec Kościelny, Poland; and Imatech Medical, Kyiv, Ukraine) were used. The PSEs were selected based on computer modeling and manufactured stereolithographic models and surgical guides. The fossa component was installed using a preauricular approach, while the condyle component was positioned using a periangular approach. Conventional physiotherapy and self-training were used in all cases to prevent postoperative decreases in mouth opening. After TMJ replacement, all patients were clinically evaluated at 1 week, 1 month, 6 months, 12 months, and 36 months, with a special focus on facial symmetry, occlusion, mouth opening, lateral and anterior movements, as well as complaints and the development of complications. All patients underwent a CT or orthopantomogram within 1 week of TMJ replacement and again 1 year after surgery to evaluate the position of the TMJ components and the condition of the adjacent anatomy.

To prevent bias, our study was conducted in accordance with rigorous inclusion criteria. Twenty-one patients were excluded from the study, including adolescents in various stages of mandible growth or those who had undergone previous mandibular distractions. These conditions can influence primary outcome variables compared to the rest of the evaluated patients.

The primary outcome variable used to determine statistical power was the MIO at 36 months. The level of significance was set at a p-value of <0.05. A power analysis indicated that 31 patients were required to achieve 81% power to detect a 50% difference from the initial mouth opening.

Statistical analysis

The obtained data was initially described qualitatively, using absolute and percentage frequencies. For quantitative variables, mean and standard deviation ($M \pm SD$) were calculated for normally distributed data, and median (*Me*) and the interquartile range (*IQR*) were calculated for non-normally distributed data. Statistical analysis was performed using the Wilcoxon signed-rank test for non-parametric values and Student's t-test for parametric values. Fisher's test was used for the remaining values. Correlations between qualitative and quantitative variables were assessed using analysis of variance (ANOVA) and logistic regression models, built using the Akaike information criterion (AIC). Sample power and size calculations were performed using Pillai's trace test. The calculations were conducted using the R v. 4.2.2 software (https://cran.r-project.org/bin/windows/base/old/4.2.2/). A p-value <0.05 was considered statistically significant.

Results

Fifty-two patients who underwent total TMJ replacement surgery were evaluated for compliance with the inclusion criteria. Seven adolescents under the age of 16 and 2 adults were excluded due to a lack of data, making it impossible to further evaluate correlations between the variables. Of the remaining 6 patients under the age of 16, 4 had previously undergone mandibular distraction. Six patients did not reach the follow-up period of 36 months due to complications or malignant recurrence. A total of 31 patients met the inclusion criteria and were enrolled in the study. Of these patients, 71% were female, and the mean age was 28.4 ±13.5 years. The indications for TMJ replacement are presented in Fig. 1.

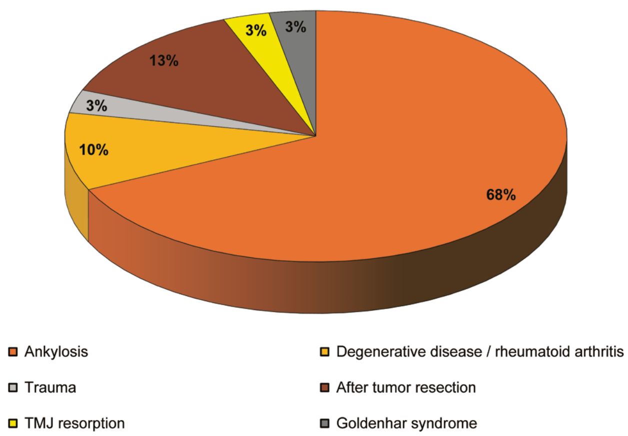

Fig. 1. Indications for temporomandibular joint (TMJ) replacement

Ankylosis was the most common TMJ pathology requiring alloplastic joint replacement, accounting for 68% of cases. Twenty-five patients (80.6%) had undergone surgery before the final alloplastic reconstruction. The mean number of surgical procedures per case was 1.68 ±0.64. In 15 patients, TMJ replacement was performed alongside orthognathic surgery or mandibular reconstructions following hemimandibulectomy (Table 1).

Initial preoperative mouth opening was measured and analyzed as a potential risk factor for inadequate rehabilitation. Seventeen patients (54.8%) had an MIO of less than 15 mm before surgery, while only 1 patient had an MIO greater than 30 mm. The median preoperative MIO was 13 ±8 mm (Table 2). An MIO of ≥40 mm was achieved during surgery in all cases. However, only 4 patients (12.9%) showed fairly good functional results (MIO > 40 mm) 1 month after surgery. At that time,

Table 1. Distribution of demographic and clinicopathological characteristics of the patients

Patient No.	Sex	Age [years]	Diagnosis	Occlusion	Glenoid fossa	Coronoid process (shape)	Ramus size	Endoprosthesis	Timing of surgery	MIO before treatment [mm]	MIO 3 years after surgery [mm]
1	F	17	ankylosis	normal	affected	affected	shortened	unilateral	delayed	14	28
2	F	60	after tumor resection	malocclusion	intact	affected	normal	unilateral	immediate	25	35
3	F	18	ankylosis	normal	affected	affected	shortened	bilateral	delayed	7	22
4	F	35	ankylosis	malocclusion	affected	affected	shortened	bilateral	delayed	1	25
5	F	25	ankylosis	normal	affected	affected	shortened	unilateral	delayed	8	26
6	F	41	rheumatoid arthritis	normal	affected	intact	normal	unilateral	delayed	4	21
7	F	18	ankylosis	malocclusion	intact	affected	shortened	bilateral	delayed	10	25
8	M	55	ankylosis	normal	affected	intact	normal	bilateral	immediate	1	35
9	M	27	ankylosis	normal	affected	affected	shortened	unilateral	delayed	13	25
10	F	31	Goldenhar syndrome	malocclusion	affected	affected	shortened	unilateral	immediate	20	35
11	F	64	ankylosis	malocclusion	affected	affected	normal	bilateral	delayed	7	29
12	F	40	TMJ resorption	normal	intact	affected	normal	bilateral	immediate	16	35
13	F	33	degenerative disease	malocclusion	affected	affected	normal	unilateral	delayed	5	32
14	F	50	trauma	malocclusion	intact	affected	normal	unilateral	delayed	6	25
15	F	37	ankylosis	normal	intact	intact	normal	unilateral	delayed	20	27
16	F	20	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	1	24
17	F	26	after tumor resection	malocclusion	intact	affected	normal	unilateral	delayed	10	22
18	F	23	after tumor resection	normal	intact	intact	normal	unilateral	delayed	25	35
19	M	38	after tumor resection	normal	intact	intact	normal	unilateral	immediate	30	37
20	F	17	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	20	40
21	M	21	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	5	40
22	F	17	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	20	30
23	F	17	ankylosis	malocclusion	affected	intact	shortened	bilateral	delayed	10	40
24	F	17	ankylosis	malocclusion	intact	affected	normal	bilateral	immediate	20	30
25	F	18	TMJ resorption	malocclusion	affected	affected	shortened	unilateral	delayed	20	40
26	M	20	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	15	35
27	M	18	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	20	40
28	M	23	ankylosis	malocclusion	affected	affected	shortened	bilateral	delayed	20	40
29	M	17	ankylosis	malocclusion	affected	affected	shortened	bilateral	delayed	0	30
30	F	19	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	20	40
31	M	18	ankylosis	malocclusion	affected	affected	shortened	unilateral	delayed	10	30

M – male; F – female; MIO – maximal incisal opening.

the mean MIO was 20.6 ±5.5 mm, which was not significantly different from the preoperative values. However, at a later follow-up, significant improvements in functional parameters were observed (p = 0.003), with a median MIO of 32.5 ±5 mm 3 years after surgery. Subsequent follow-up showed only moderate functional improvements, which were not statistically significant (Fig. 2). Further statistical analysis indicated that initial mouth opening was the most significant predictor of long-term functional recovery after TMJ replacement (Table 3).

Table 2. MIO values in different time periods

MIO [mm]	*Me*	*IQR*
Before surgery	13	6–20
During surgery*	41	37–45
1 month after surgery	20.6	15–25
1 year after surgery*	30.8	25–35
3 years after surgery*	32.5	27–37

Me – median; *IQR* – interquartile range; * significant difference observed between preoperative results and group results (p < 0.05, analysis of variance (ANOVA)).

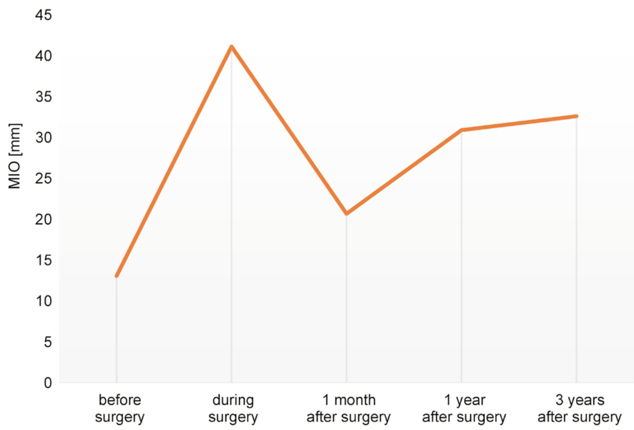

Fig. 2. Changes in maximal incisal opening (MIO) in patients who underwent TMJ replacement

Postoperative complications occurred in 4 cases (12.9%) following PSE replacement. These included 2 cases of artificial condylar head displacement (treated with closed reduction and prolonged immobilization) and 3 cases of auditory canal perforation (2 of which were successfully treated conservatively).

Table 3. Influence of various factors on long-term functional outcomes in patients after total TMJ replacement (after 3 years)

Factors		Patients with MIO > 30 mm (*n* = 20)	Patients with MIO < 30 mm (*n* = 11)	*p*-value
Age [years]	*M*	28.7	28.4	0.45^{W}
	Me	23	33	
	SD	13.6	14.4	
MIO before treatment [mm]	*M*	15.45	8.55	0.023^{t*}
	SD	1.89	1.73	
Sex *n* (%)	male	8 (88.8)	1 (11.2)	0.106^{F}
	female	12 (54.5)	10 (45.5)	
Occlusion *n* (%)	normal	4 (40.0)	6 (60.0)	0.105^{F}
	malocclusion	16 (76.2)	5 (23.8)	
Chin dislocation *n* (%)	yes	13 (65.0)	7 (35.0)	1.000^{F}
	no	7 (63.6)	4 (36.4)	
Ramus size *n* (%)	shortened	12 (63.1)	7 (36.9)	1.000^{F}
	normal	8 (66.6)	4 (33.4)	
Timing of surgery *n* (%)	immediate	6 (100.0)	0 (0.0)	0.066^{F}
	delayed	14 (56.0)	11 (44.0)	
Coronoid process (shape) *n* (%)	affected	16 (64.0)	9 (36.0)	1.000^{F}
	intact	4 (66.6)	2 (33.4)	
Glenoid fossa *n* (%)	affected	15 (68.2)	7 (31.8)	0.683^{F}
	intact	5 (55.5)	4 (44.5)	
Retrusion of the mandible (sagittal mandible position) *n* (%)	yes	14 (66.6)	7 (33.4)	1.000^{F}
	no	6 (60.0)	4 (40.0)	
Endoprosthesis *n* (%)	unilateral	13 (61.9)	8 (38.1)	0.712^{F}
	bilateral	7 (70.0)	3 (30.0)	

M – mean; *SD* – standard deviation; TMJ – temporomandibular joint; * statistically significant (p < 0.05); ^{W} Wilcoxon signed-rank test; ^{t} Student's *t*-test; ^{F} Fisher's test.

Discussion

Managing destructive and degenerative TMJ pathologies that require total joint replacement is a challenging task for maxillofacial surgeons.[6,14,15] The primary goal of total TMJ replacement is to achieve appropriate functional and aesthetic rehabilitation while minimizing the risk of complications.[16,17] However, replacement procedures can be challenging, both technically and surgically, due to the presence of complex conditions with underlying pathology, anatomical deformities, small joint size, and high expectations for functional and aesthetic outcomes.

Over the last decade, numerous publications have demonstrated the advantages of custom-made, patient-specific TMJ endoprostheses in comparison with standard prostheses.[18,19] According to the literature, PSEs provide better adaptation to the initial preoperative anatomy and have the potential to restore the height and shape of the ramus while correcting the position of the chin. They also facilitate reconstruction procedures for complex mandibular or zygomatic defects that require simultaneous TMJ replacement. Some authors have implanted PSEs of the TMJ simultaneously with orthognathic procedures to correct severe anatomical deformities and anomalies.[19–21]

The design of a modern PSE involves technical solutions to ensure that its predetermined positioning is correct. This can be achieved through the use of complex implant geometry, intraoperative navigation, or pre-drill guides. Incorrect positioning of the fossa component may cause inflammation of the auditory system or a dislocation of the condyle component, which in turn could lead to limited mouth opening and/or malocclusion.[9]

These advantages of PSEs provide significant anatomical benefits, including the correction of ramus height, occlusion, and facial proportions and symmetry. Numerous studies have suggested that patient-specific solutions are the optimal choice for TMJ reconstruction.[8,22,23] However, the extent to which functional outcomes improve with PSEs compared to stock TMJ replacement remains controversial. Kozakiewicz et al. and Zheng et al. achieved the average MIOs of 36.7 ±7.4 mm and 39.25 ±5.17 mm, respectively, after using PSEs to replace the TMJ.[18,24] Comparable results were reported by authors who found that the average MIO increased from 21.0 mm before surgery to 34.7 mm after 10 years of follow-up in patients who received stock TMJ Concepts replacements.[17] Other researchers have reported similar results with stock TMJ endoprostheses.[2,25,26] However, due to the limited number of patients in the series, heterogeneous study groups and different approaches to the evaluation of functional outcomes, it is challenging to make direct comparisons between the results achieved by different authors. Additionally, different underlying pathologies and respective indications for total joint replacement must be considered as a major source of heterogeneity in the results.

In our study, preoperative mouth opening was limited, with a median of only 13 ±8 mm. At one-year postoperative follow-up, it had improved by 2.37-fold. Although the intraoperative MIO was ≥40 mm in all cases, the functional outcome was partially lost at the end of the 1st month. There were no statistically significant differences between the mean preoperative MIO and MIO 1 month after surgery. Over the following months, the MIO increased significantly, reaching its maximum by the end of the 1st year. Subsequently, only minor improvements were observed in some patients, but these changes were not statistically significant. Aagaard and Thygesen reported comparable functional recovery timings following the implantation of stock TMJ endoprostheses.[27] In our study, we observed a more than 2.5-fold increase in MIO after long-term follow-up (3 years after surgery), which falls within the range reported in the literature. However, PSE implantation allowed for the procedure to be simplified and performed as a 'one-stage surgery' with highly acceptable anatomical outcomes in cases where orthognathic surgery or mandible reconstructions were indicated.

The main limitations of our study included the enrollment of a relatively small group of patients with heterogeneous pathologies, restricted inclusion criteria, and the use of implants from multiple PSE manufacturers. Despite these limitations, the study found no significant correlations between functional outcomes and initial anatomy (Table 4). In particular, the state of the glenoid fossa, occlusion, chin dislocation, ramus size, and coronoid process had no significant effect on the integral functional outcomes. Our study included patients with various pathologies and previous surgeries, and none of these factors had a significant influence on functional recovery. However, in contrast to Kozakiewicz et al., who found only weak correlations between the preoperative MIO and outcomes,[18] our study demonstrated a significant impact of the preoperative MIO on the postoperative MIO ($p < 0.05$). Even after eliminating

Table 4. Univariate logistic regression model predicting mouth opening after TMJ reconstruction

Variable	*OR*	95% *CI*	*p*-value
Age	0.99	0.95–1.05	0.960
Sex	6.67	0.71–62.7	0.0972
Malocclusion	0.21	0.041–1.05	0.057
Chin dislocation	1.06	0.23–4.92	0.939
Shortened ramus size	0.86	0.19–3.92	0.842
Timing of reconstruction	N/A	N/A	N/A
Coronoid process	1.12	0.17–7.4	0.902
Glenoid fossa	0.58	0.12–2.97	0.507
Retrusion of the mandible	1.33	0.28–6.33	0.717
TMJ replacement	0.696	0.139–3.50	0.660
MIO before treatment	1.13	1.01–1.26	0.032*

OR – odds ratio; *CI* – confidence interval; N/A – not applicable; * statistically significant ($p < 0.05$, multivariate logistic regression analysis).

bony defects and achieving appropriate mandibular length and position, reduced preoperative mouth opening was associated with worse functional recovery. This finding suggests that the condition of the soft tissues responsible for jaw function should also be considered, in addition to the clear importance of correct anatomical reconstruction. The main findings of our study are in agreement with the study by Mercuri, which highlighted the importance of the condition and functional training of masticatory muscles for functional recovery.[6]

In our study, we observed 3 cases of auditory canal perforation due to the surgical plan. The perforation resulted from sharp edges of the personalized fossa component being closely adjacent to the auditory canal. Two of these cases were managed conservatively (secondary healing using aseptic keratoplastic agent coverage and preventative antibiotics) without negative consequences for the TMJ endoprosthesis (i.e., no persistent infection). Additionally, we observed 2 cases of dislocation of the ramus and condyle components during the 1st week after surgery. Both cases were successfully treated with closed reduction and immobilization of the mandible for 2 weeks. The overall complication rate was 12.9% (4 cases), and it did not affect the final outcomes in the patient group. This rate is comparable to the results achieved by Rajkumar and Sidebottom in a larger group of patients.[17]

Personalized joint replacement enables the simultaneous reconstruction of the TMJ, mandible, temporal bone, and zygoma. This approach requires close interaction between the surgeon and the bioengineer during the modeling and design process, while also considering manufacturing and treatment strategies. However, our results suggest that despite the possibility of the precise determination of mandible length and position using different patient-specific solutions, TMJ-related soft tissue conditions are still being underestimated.[28,29]

Conclusions

The use of PSEs for TMJ replacement has enabled the restoration of anatomical relationships in complex clinical cases and has improved mouth opening from 13 ±8 mm preoperatively to 32.5 ±5 mm after 3 years of follow-up. The intraoperative MIO was greater than the postoperative MIO in all cases. Maximal incisal opening at 1 month did not significantly differ from preoperative values. It significantly increased 1 year after surgery following physiotherapy and remained stable during 3 years of follow-up.

The preoperative MIO was the only factor that significantly influenced long-term functional outcomes. None of the other variables examined, including age, indications for TMJ replacement, preoperative occlusion, state of the coronoid process, glenoid fossa and/or condyle, shortening of the mandibular ramus, sagittal mandible position, jaw asymmetry, as well as the type of surgery (primary or secondary, unilateral or bilateral TMJ replacement, and coronoid process preservation or resection) had a significant impact on treatment outcomes.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the Bogomolets National Medical University, Kyiv, Ukraine (approval No. 153; November 29, 2021).

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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