

Research Article

Application of Artificial Intelligence in Predicting Soft-Tissue Aesthetics and Patient Satisfaction after Maxillofacial Surgery

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ABSTRACT

Background: Predicting the postoperative facial appearance is an important issue to consider in the planning of maxillofacial surgery as the soft-tissue changes may impact aesthetics and patient satisfaction. Although artificial intelligence (AI) shows promise in predicting facial morphology after surgery, more research is needed to correlate objectively documented soft-tissue changes, with patients' satisfaction.

Objective: The purpose of this study was to assess the accuracy of this AI model in predicting aesthetic soft tissue changes after surgery and to establish the correlation between the prediction accuracy and patient satisfaction after maxillofacial surgery.

Methods: A prospective observational study was carried out on 220 patients between 20-40 years of age who were scheduled for maxillofacial surgery that involved a soft tissue or facial aesthetic component. Participants were recruited by consecutive sampling, based on predetermined criteria. A face-based AI prediction model was trained with pre-operative standardized facial photos and 3D facial scans and various other demographic and surgical parameters. Postoperative facial predictions using AI were compared with the standard postoperative three-dimensional facial scans after the specified healing period. After the specified healing period, AI-generated postoperative facial predictions were compared to standard postoperative three-dimensional facial scans. The mean absolute error (MAE), root mean square error (RMSE), landmark displacement error and intraclass correlation coefficients (ICC) were used to assess the accuracy of predictions for selected soft-tissue landmarks: lower-lip projection, upper-lip position, chin projection, facial midline, nasal projection, facial width and lower-face proportions. The FACE-Q domains of facial appraisal and a global satisfaction score were used to evaluate patient-reported aesthetic outcomes. Subsequently, associations between the accuracy of the AI predictions and patients' satisfaction were investigated.

Results: The AI-based model achieved significant correlation between predicted and postoperative soft-tissue morphology. The accuracy of the prediction was evaluated for each facial landmark and each regional aesthetic characteristic, with a lower prediction error resulting in greater similarity between the facial outcome predicted by the AI and the actual postoperative facial outcome. Major changes in the shape of the profile and contour were found to be very consistent and those of the soft tissue somewhat more variable. Patient reported outcomes showed better facial appearance, satisfaction with lower-face and jawline, satisfaction with lips and overall aesthetic satisfaction. The analysis also examined whether patients with smaller AI prediction errors had higher satisfaction scores, to determine the relationship between the objective accuracy of the prediction by the AI and the subjective aesthetic perception by the patient.

Conclusion: The results of the study indicated that the use of AI-assisted prediction could enable individualized assessment of the aesthetic outcomes of the soft tissues after maxillofacial surgery. Three-dimensional prediction-error measurements were integrated with patient-reported aesthetic outcomes to create a patient-centred evaluation of the performance of AI-based facial prediction. This could help to provide better individualised counselling and evaluation during the postoperative phase, by associating predicted facial alterations with the patient's aesthetic experience.

Keywords: Maxillofacial, Artificial Intelligence, Aesthetics, Post Operative.

INTRODUCTION

Maxillofacial surgery is used to correct dentofacial deformities, restore facial function and enhance facial harmony. But the ultimate shape and form of the bones is not all that matters; so does the reaction of the overlying soft tissues. The position of the lips, the projection of the chin, lower face shape, or symmetry of the face can impact patient's perception of their surgical outcomes. So, it is essential to predict facial appearance reliably preoperatively as part of treatment planning and patient counselling(1).

Traditional prediction methods and virtual surgical planning systems have helped to better illustrate the expected postoperative facial changes. However, differences between simulated and actual results could occur due to the non-homogeneity of soft tissues' response to the movement of the skeleton. Three-dimensional facial assessment is more complete than two-dimensional assessment in measuring regional changes and assessing postoperative morphology(2).

Artificial Intelligence (AI), notably machine learning and deep learning, has given rise to novel opportunities for personal outcome prediction for facial outcomes. These techniques are able to recognize intricate association between pre-operative facial shapes, skeletal movement and post-operative soft tissue changes. AI systems could use clinical imaging information to make predictions that help surgeons assess the likely aesthetic outcomes prior to surgery (3).

The accuracy of three-dimensional soft-tissue prediction remains an important consideration when applying AI to clinical practice. Previous studies have shown that prediction performance can vary from one part of the face to another, with the lips and chin being particularly difficult due to the complex nature of the soft-tissue movements in these areas. The differences highlight that the overall prediction accuracy is not enough to fully reflect the clinical value of an AI model (4).

More recently, studies have emerged that have shown the promise of AI in predicting post-orthognathic surgery facial changes. Yet it is difficult to directly compare models due to methodological variations in study design, prediction methods, imaging protocol, and outcome assessments. Such restrictions reinforce the necessity of standardisation

through quantitative prediction errors and comparing the prediction of the AI with actual measurement of the patient's face after surgery (5).

Patient satisfaction is a critical part of assessing surgical success as well as objective measurements of facial dimensions. Even if the surgery is technically successful, patients may not be happy with their physical results. The postoperative results can be influenced by the expectations, facial harmony, and satisfaction with certain features like lips, chin, and jaw-line. Therefore, patient-reported outcome measures can be used in conjunction with objective clinical evaluation (6).

The FACE-Q is a validated patient-reported tool for measuring satisfaction with facial appearance and specific facial aesthetics. It has been used in facial bone contouring research and shown to be applicable to understanding patients' perceptions as well as clinical results. Predictive research with AI can be enriched with appropriate FACE-Q domains to help identify if objectively accurate predictions align with patient outcome that is deemed acceptable (7). Recent advances in AI have been made around the accuracy of the prediction, its speed, and the incorporation of 3D facial data to make the predictions. In a 2025 study, researchers looked at a deep learning model to automatically predict postoperative soft-tissue changes in various orthognathic surgeries, using 458 patients. These advancements suggest that the use of AI in predicting faces is moving towards making increasingly useful and clinically relevant facial simulations, which, however, needs to be appropriately validated (8).

While these progressions have been made, clinical usefulness of AI is not solely determined by prediction accuracy. It is also important to research if the changes being predicted do correspond with the appearance of the patients post surgery and their satisfaction after surgery. Patient-reported outcomes could be used in conjunction with objective measures, such as mean absolute error and landmark displacement, to give a more holistic view of AI-aided facial prediction (9).

Thus, the present study aimed to assess the use of AI in predicting the postoperative soft tissue aesthetic outcome in 220 patients ranging in age between 20 and 40 years who were undergoing maxillofacial surgery. It

explored the correlation between the three dimensional facial measurements predicted by the AI and those measured by the patient, and explored the correlation between prediction accuracy and patient satisfaction. The study aimed to evaluate the feasibility of using AI to assist in patient-specific surgical planning and more accurate patient expectations of aesthetic outcomes, by combining two quantitative facial assessment techniques with patient-reported outcomes. The study set out to determine the potential of using AI to aid in patient-specific surgical planning and patient expectations of aesthetic outcomes more accurately, using two quantitative facial assessment techniques combined with patient-reported outcomes (10).

METHODOLOGY

A prospective observation study was performed to evaluate the use of artificial intelligence (AI) to predict soft-tissue aesthetic changes and determine their association with the patient's satisfaction after maxillofacial surgery. This study involved 220 patients (aged 20–40 years) who had undergone maxillofacial surgical procedures with the expectation of altering the facial soft-tissue form. Consecutive sampling was done to obtain subjects for the period designated for the study. Patients were included if they were 20 to 40 years of age and had undergone facial-profile or aesthetic-based maxillofacial surgery and had adequate original facial records and were able to be followed up after the stated healing period. Patients who had undergone prior major facial reconstructive surgery, extensive facial scarring or facial deformity that prevented identification of facial landmarks, craniofacial syndromes, or incomplete pre- or post-operative facial records were excluded.

After informed consent, the demographic and clinical data was collected as baseline. Facial photographs and 3D facial scans were taken in a standard setting. All of the photos were taken in a standard head position, standard distance from the camera, in front light, with the right and left profile and in an oblique view of the face, with a standard facial expression. Reproducible anatomical landmarks were set with three dimensional surface data obtained from the face using a facial scanning system. Other details relevant to the surgery, such as the type of maxillofacial surgery and the main skeletal and soft-tissue changes to be performed during the actual surgery were also recorded.

The predictive part of the AI was created with the preoperative facial records and relevant clinical and surgical parameters as the input to the model. The custom system produced personalised predictions for the postoperative facial morphology, especially that of the nose, upper and lower lips, chin, face width, lower facial height and facial symmetry. AI predictions were made prior to the postoperative evaluation, and then compared with the 3D facial scans of the patients after their surgery. This method enabled to evaluate the prediction performance without interference from the postoperative observations.

Assessment of postoperative facial morphology was assessed after the indicated healing period, when the postoperative soft-tissue morphology was thought to be stable enough for comparison. Postoperative photographs and 3D scans of the faces were acquired with the same acquisition protocol as at baseline. A 3D facial record was taken before and after surgery, with stable anatomical reference areas registered, and soft-tissue landmarks identified. The assessment points encompassed: nasal projection, position of upper-lip line, lower-lip line projection, chin projection, facial width, lower facial height, and facial symmetry. The discrepancy between the postoperative measurements and the ones predicted by AI was computed for every facial parameter.

The mean absolute error (MAE), root mean square error (RMSE), landmark displacement error, and intraclass correlation coefficient (ICC) were used to assess the accuracy of prediction by AI. The difference between actual and predicted measurements after the procedure is represented by MAE, whereas RMSE reflected the size of prediction error with a higher emphasis on the larger errors. The difference in position of the predicted and actual postoperative soft-tissue landmarks was determined using landmark displacement error. ICC was calculated to check the agreement between the AI-predicted and observed measurements.

Patient-reported aesthetic outcomes were measured using the FACE-Q patient-reported outcome framework created by Klassen et al. (2010) on which relevant domains included satisfaction with facial appearance and facial features. They were evaluated on satisfaction with overall facial appearance, lower face/jawline, lips, and overall postoperative aesthetic satisfaction. The higher scores indicated higher satisfaction with postoperative

facial appearance. To reduce potential influence of the participants' responses, the questionnaire was given post surgical evaluation and prior to the participants being told the quantitative results of the AI prediction-errors.

The main results were the accuracy of the AI prediction of the postoperative soft-tissue morphology and the matching of the predicted to the actual facial measurements. Secondary outcomes comprised patient satisfaction with the appearance of the face, satisfaction with individual facial regions, and relationship between the accuracy of the AI prediction and patient-reported satisfaction. Correlation between prediction error and satisfaction score was evaluated to assess whether there was a correlation between predictions of facial morphology by AI and patient-reported aesthetic outcomes.

The IBM SPSS Statistics was used to enter data and analysis. Continuous variables were reported as mean and standard deviation and categorical variables were reported as frequencies and percentages. Before inferential analysis the normality of continuous variables was determined. The agreement between AI-predicted and observed measurements after surgery was assessed through ICC and the MAE and RMSE were computed for each facial parameter. For patient satisfaction, where assumptions for parametric analysis were

satisfied, Pearson's correlation coefficient was used to explore the association between AI prediction error and patient satisfaction. Multiple linear regression model was used to see if prediction error with the use of AI and selected clinical and demographic parameters are independent contributors to overall postoperative satisfaction. A p value of less than 0.05 was regarded as a statistical significance and 95% confidence intervals were provided as appropriate.

Standardized imaging conditions, defined anatomical landmarks and a predefined postoperative assessment protocol were used to assure consistency of measurements. The predictions generated by the AI have been made prior to making comparison with the postoperative observation. All participants were measured using the same anatomical landmarks and measurements. Confidentiality of participants was ensured throughout the study and data were coded and kept securely. All participants were informed about the aim of the study, the procedures to be followed, the potential benefits and the confidentiality of the study and written informed consent was obtained. The study was voluntary and participants were made aware that they could withdraw from the study at any time without it impacting their care. All of the data gathered and facial imaging documentation was kept confidential and strictly for research purposes.

RESULTS

Table 1. Sociodemographic Characteristics of Participants (N = 220)

Variable	Frequency (n)	Percentage (%)
Age (years)		
20–24	62	28.2
25–29	71	32.3
30–34	49	22.3
35–40	38	17.3
Gender		
Male	118	53.6
Female	102	46.4
Type of Maxillofacial Surgery		
Orthognathic surgery	82	37.3
Facial trauma/reconstructive surgery	56	25.5
Jaw corrective surgery	47	21.4
Other aesthetic/functional maxillofacial procedures	35	15.9

Table 2. Descriptive Statistics of Preoperative and Postoperative Facial Measurements

Soft-Tissue Measure	Preoperative Mean $\pm$ SD	Postoperative Mean $\pm$ SD	Mean Change
Nasal projection (mm)	24.18 $\pm$ 3.42	25.36 $\pm$ 3.51	1.18
Upper-lip position (mm)	14.62 $\pm$ 2.85	13.47 $\pm$ 2.71	-1.15

Lower-lip projection (mm)	16.84 ± 3.12	15.39 ± 2.98	-1.45
Chin projection (mm)	19.27 ± 4.06	21.08 ± 4.18	1.81
Facial width (mm)	128.45 ± 8.73	126.92 ± 8.61	-1.53
Lower facial height (mm)	70.26 ± 6.84	68.74 ± 6.57	-1.52

Table 3. Agreement Between AI-Predicted and Actual Postoperative Soft-Tissue Measurements

Measurement	MAE (mm)	RMSE (mm)	ICC	95% CI
Nasal projection	1.42	1.86	0.91	0.88–0.93
Upper-lip position	1.28	1.71	0.89	0.86–0.92
Lower-lip projection	1.51	1.98	0.87	0.83–0.90
Chin projection	1.36	1.79	0.92	0.89–0.94
Facial width	1.63	2.14	0.86	0.82–0.89
Lower facial height	1.47	1.91	0.88	0.84–0.91

Table 4. Patient-Reported Aesthetic Satisfaction After Surgery

FACE-Q/Aesthetic Outcome	Mean ± SD	Interpretation
Satisfaction with facial appearance	72.84 ± 12.46	Moderate-to-high
Satisfaction with lower face/jawline	74.16 ± 11.83	Moderate-to-high
Satisfaction with lips	70.52 ± 13.21	Moderate-to-high
Overall postoperative satisfaction	73.18 ± 11.95	Moderate-to-high

Table 5. Relationship Between AI Prediction Error and Patient Satisfaction

Variable	Pearson's r	p-value
Overall AI prediction error vs. facial appearance satisfaction	-0.46	<0.001
AI prediction error vs. lower-face/jawline satisfaction	-0.41	<0.001
AI prediction error vs. lip satisfaction	-0.35	<0.001
AI prediction error vs. overall postoperative satisfaction	-0.44	<0.001

Table 6. Multiple Linear Regression Predicting Overall Patient Satisfaction

Predictor	β	SE	t	p-value
AI prediction error	-0.31	0.07	-4.43	<0.001
Age	-0.06	0.08	-0.79	0.431
Gender	0.05	0.08	0.68	0.498
Change in chin projection	0.19	0.08	2.51	0.013
Change in upper-lip position	0.16	0.07	2.21	0.028
Facial symmetry improvement	0.27	0.08	3.48	<0.001

Table 7. Association Between Prediction Accuracy and Satisfaction Categories

AI Prediction Accuracy	Low Satisfaction n (%)	Moderate Satisfaction n (%)	High Satisfaction n (%)
High accuracy	8 (8.2)	28 (28.9)	61 (62.9)
Moderate accuracy	18 (19.8)	40 (44.0)	33 (36.3)
Lower accuracy	28 (50.9)	20 (36.4)	7 (12.7)

Table 8. Comparison of AI-Predicted and Actual Postoperative Soft-Tissue Changes

Outcome	Mean Absolute Difference (mm)	95% CI	p-value
Nasal projection	1.42	1.26–1.58	<0.001
Upper-lip position	1.28	1.14–1.42	<0.001
Lower-lip projection	1.51	1.34–1.68	<0.001
Chin projection	1.36	1.20–1.52	<0.001
Facial width	1.63	1.44–1.82	<0.001

Lower facial height	1.47	1.31–1.63	<0.001
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Model summary: $R^2 = 0.34$; Adjusted $R^2 = 0.32$; $F(6, 213) = 18.27$, $p < 0.001$.

DISCUSSION

The aim of the present study was to investigate the possibility of using artificial intelligence to predict the postoperative aesthetics of soft tissues and its correlation with the patients' satisfaction levels after maxillofacial surgery. One key part of this strategy is that the measurements taken are three dimensional and objective as well as taking into account patient reported outcomes. AI-driven prediction could enhance the visualization of facial changes before surgery and facilitate more accurate communication with patients about what to expect. With the aid of AI, predictions can aid in preoperative visualization and better communicate expected facial outcomes. The clinical value of these systems relies on the accuracy of these systems in various facial areas and patient categories (11).

Research that has been conducted on the prediction of soft tissues using AI can be used to interpret the results of the proposed study. In a 2025 scoping review, authors noted the use of AI in various applications, such as diagnosis, surgical planning, soft tissue prediction, and postoperative outcome evaluation. However, potential issues in translating model performance to the consistent clinical outcomes were also noted in the review. This reinforces the significance of measuring prediction error at each facial landmark as opposed to just using a general model accuracy measure (12).

Patient satisfaction can also vary between different areas of the face even if the overall result of the surgery is successful. Research performed to evaluate the satisfaction of patients after facial feminization surgery showed that several facial traits were improved after facemening surgery. Though the procedure is not the other maxillofacial procedures, the findings show how important it is to consider particular facial elements along with total satisfaction when exploring the aesthetic outcomes when it comes to maxillofacial procedures (13).

An additional factor is the difference in the expectations of patients when they are first admitted and their assessment of appearance after surgery. In a study on social appearance of patients who underwent orthognathic surgery, it was found that patient-surgeon communication and expectation management were important. Discussions can also be

enhanced by AI-generated simulations that create realistic images of what the face might look like afterward, though it's important to note that the results are predictions and not promises of the final outcome (14).

Results must also be seen in the context of the multi-faceted nature of postoperative outcome. Studies on postoperative life satisfaction after orthognathic surgery have focused on the evaluation of patient-reported outcomes as well as anatomical and functional changes. Therefore, the accuracy of AI predictions should be used as a part of the broader assessment of outcomes, not as a replacement for clinical or functional evaluation or the patient's experience of surgery (15).

CONCLUSION

AI could prove to be a helpful tool in predicting postoperative soft tissue changes and individual aesthetic assessment following maxillofacial surgery. The use of 3D facial measurements together with patient satisfaction gives a more holistic assessment of surgical outcomes. The utility of AI in the medical field relies greatly on reliable predictions, suitable validation, and realistic communication of expected results.

Future Suggestions

In future studies, AI prediction models should be tested in larger populations with more centres and varying facial shapes and surgeries. Longer follow-up periods, standardized three-dimensional imaging protocol and validated patient reported outcome measures should be included. This would further elucidate the clinical utility of AI-assisted planning by comparing AI predictions with traditional simulation approaches and real-world postoperative outcomes.

Limitations of Study

Limitations of the study could include the information from a particular clinical setting, the differences in surgical techniques, and the difference in response to the soft tissues in each individual. The accuracy of AI predictions could also be influenced by the image quality and the model's training data, as well as the post-operative assessment time. Patient satisfaction is an individual and subjective issue and sometimes it can be affected by social and psychological factors and expectations which may not be solely reflected by facial

measurements. Results obtained should be taken with a pinch of salt until confirmed by independent research.

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