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Original Article

Impact of orthognathic surgery on emotional expression and smile aesthetics in Chinese patients as measured by FaceReader: a before-and-after study

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Background: The attractiveness of a person's smile is influenced by several factors, including gingival display, incisor show, and facial asymmetries. Malocclusion has long been recognized as having a significant negative impact on smile aesthetics. Addressing dentofacial deformities is a major treatment goal in orthodontic and orthognathic interventions, aiming to improve both functional and aesthetic outcomes. We sought to quantify and assess the impact of orthognathic surgery on a patient's expression of happiness within their smile, thereby addressing the current research gap in this highly subjective field.
Methods: We utilized FaceReader, a commercially available and previously validated artificial intelligence (AI) system, to analyze preoperative and postoperative facial photographs of 216 Chinese patients who underwent orthognathic surgery between January 1, 2021, and December 31, 2022. The AI software measures seven cardinal emotions and associated facial action units, providing an objective evaluation of emotional outcomes.
Results: Our findings indicated a significant postoperative increase in patients' expression of "happiness" while smiling, accompanied by a concurrent decrease in their estimated age. Patients with insufficient incisor show and open bite exhibited notable improvements in emotional expression, while those with a gummy smile showed no significant change. Additionally, stratification based on malocclusion classification (class I, II, III) revealed consistent improvements in emotional outcome scores among class II and III patients.
Conclusion: Our findings underscore the potential of AI in providing objective insights into emotional changes following orthognathic surgery.

Abbreviations: AI, artificial intelligence; AU, action unit

Keywords: Artificial intelligence / Dental esthetics / Happiness / Orthognathic surgery / Smiling

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INTRODUCTION

Background

Smile attractiveness is influenced by a variety of factors including gingival display, incisor exposure, arch width, and facial asymmetries. Malocclusion has long been recognized as a significant negative factor affecting facial and smile attractiveness,

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making it a critical consideration in orthodontic treatment planning [1,2]. Orthognathic surgery has emerged as a pivotal intervention for correcting dentofacial deformities, addressing both functional and aesthetic impairments [3].

Despite increasing research focused on aesthetic outcomes following orthognathic treatment, a significant limitation remains in the over-reliance on subjective assessments [4-6]. Most studies rely on patient-reported measures or surgeon evaluations, which lack the objectivity needed for an unbiased understanding of treatment efficacy. Recent advancements in artificial intelligence (AI) have shown promise in producing objective outcomes for aesthetic surgery. Patcas et al. [6] applied AI to quantify facial attractiveness and apparent age in orthognathic patients, demonstrating positive effects.

FaceReader (Noldus Information Technology BV; https://www.noldus.com/facereader) is a commercially available AI system developed and validated using the Amsterdam Dynamic Facial Expression Set—a standardized collection of images portraying various emotional expressions. FaceReader employs machine learning to analyze video data [7,8] and provides an objective measure of facial expressions by breaking down the seven basic emotions [9]. We have previously utilized this software to quantify emotional outcomes for various aesthetic and reconstructive interventions [2,10-17].

Objectives

Our study focuses on using this advanced software to measure the impact of orthognathic surgery on a patient's expression of happiness within their smile through quantitative analysis. By employing this innovative AI tool, we aim to provide objective and nuanced insights into the aesthetic outcomes of orthognathic interventions, thereby addressing a critical gap in the current research on dentofacial deformities.

METHODS

Study design

This is a before-and-after study described in accordance with the TRENDS statement (https://www.equator-network.org/reporting-guidelines/improving-the-reporting-quality-of-non-randomized-evaluations-of-behavioral-and-public-health-interventions-the-trend-statement/) (Fig. 1).

Setting

We retrospectively identified all patients who underwent orthognathic surgery by the senior author between January 1, 2021, and December 31, 2022, at Chang Gung Memorial Hospital, Taiwan.

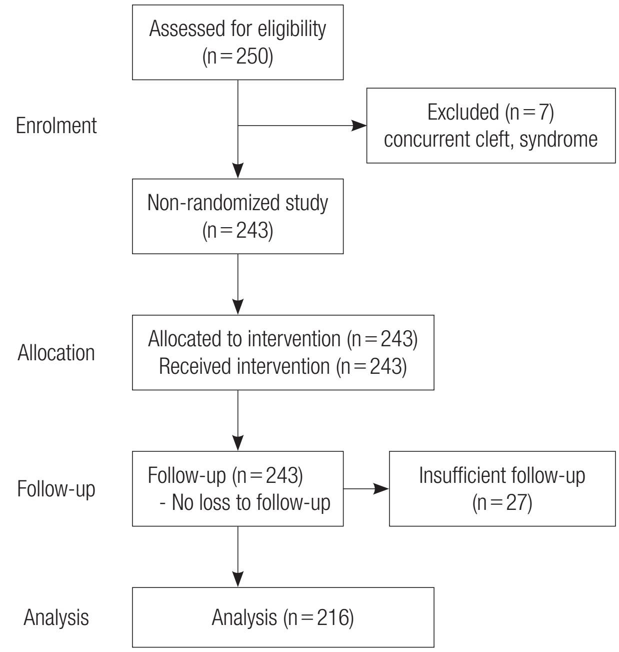

Fig. 1. Flowchart of current study.

Participants

Preoperative and postoperative facial photographs and patient variables, including age, sex, and type of malocclusion, were collected. A total of 216 patients were included, providing 864 images for analysis (preoperative and postoperative, smile and repose). All patients were Chinese. Standardized photographs were taken in a studio by a professional medical photographer using consistent lighting and background. Patients were instructed to smile naturally, and for repose images, to maintain a neutral expression. Malocclusion was classified as class I, II, or III based on skeletal criteria. Insufficient teeth show was defined as less than 2 mm of tooth exposure when smiling. Patients without postoperative photos, those with less than 6 months of follow-up, those with an underlying cleft or other syndromic diagnoses, and patients with post-trauma conditions were excluded.

Intervention

Bimaxillary surgery was performed using a conventional Le Fort I osteotomy and bilateral sagittal split osteotomy with rigid non-resorbable plate fixation. Patients without postoperative photos, with less than 6 months of follow-up, with underlying cleft or syndromic diagnoses, and those with post-traumatic conditions were excluded.

Outcomes

We aimed to quantify the impact of orthognathic surgery on a patient's expression of happiness within their smile by quantitatively analyzing preoperative and postoperative photographs using FaceReader.

Data sources/measurement

Images were analyzed using a commercially available facial expression recognition software package (FaceReader; Noldus Information Technology BV) [8,9]. The data generated reflected the proportion of each of the seven cardinal emotions expressed, along with the associated facial AUs. Classification was achieved by training an artificial neural network with over 10,000 manually annotated images by trained experts. The system evaluated movements of more than 500 facial landmarks on each face for classification. Research data are available in Supplementary Materials 1 and 2.

Bias

The entire target population was selected to avoid selection bias.

Study size

Sample size estimation was not done. The entire target population was included.

Assignment method

Only one group was followed up.

Blinding (masking)

No blinding was done.

Unit of analysis

The unit of analysis was the single group.

Statistical methods

Differences between paired continuous variables were assessed using the nonparametric Wilcoxon signed-rank test to compare facial emotions detected by the facial expression recognition technology preoperatively and postoperatively. All statistical analyses were performed using JMP (SAS Institute Inc.). A p-value of less than 0.05 was considered statistically significant.

RESULTS

Participants

The initial cohort comprised 250 patients. Seven patients were excluded due to concurrent cleft or syndromic pathologies, and an additional 27 were excluded because of insufficient follow-up (less than 6 months). This resulted in a final sample of 216 patients (Table 1). The median preoperative age was 25.2 years (range, 16.8–58.0 years), with 73 (33.8%) being male. By the end of the study, 96 patients (44.4%) had been debonded from their braces. One patient underwent a mandible-only bilateral sagittal split osteotomy, while the remainder underwent bimaxillary surgery. A total of 129 patients (59.7%) underwent concurrent genioplasty, and 40 (18.5%) had concurrent chin shaving/mandible contouring. Preoperatively, five patients (4.6%) presented with a gummy smile, and 54 (25.0%) had insufficient incisor show. Additionally, 37 patients (17.1%) had an open bite. There were 21 (9.7%), 35 (16.2%), and 160 (74.1%) patients with Angle class I, II, and III occlusion, respectively. The median follow-up time was 12 months (range, 6–31 months).

Table 1. Patient demographics

Variable	No. (%) (n = 216)
Median age (yr)	25.2
Male sex	73 (33.8)
Debonded	96 (44.4)
Presence of open bite	37 (17.1)
Insufficient incisor show preoperatively	54 (25.0)
Angle class	
1	21 (9.7)
2	35 (16.2)
3	160 (74.1)
Median follow-up time (mo)	12
Procedure details	
Bimaxillary surgery	215 (99.5)
Mandible-only BSSO	1 (0.5)
Genioplasty	129 (59.7)
Chin shaving/mandible contouring	40 (18.5)

BSSO, bilateral sagittal split osteotomy.

Main results

When comparing preoperative and postoperative emotional outputs using FaceReader, several significant differences emerged. A representative patient case is illustrated in Fig. 2. Overall, patients expressed less "happiness" in repose ($p \leq 0.01$) and more "happiness" while smiling ($p \leq 0.01$) postoperatively (Fig. 3). For facial action unit analysis, there was a decrease in the output of action unit (AU) 12 (lip corner puller) during smiling postoperatively. In repose, no significant differences were observed for AU 6 (cheek raiser), AU 12, AU 20 (lip stretcher), or AU 25 (lips part) (Table 2, Fig. 4).

Patients were stratified based on the presence of a gummy smile, and no significant differences were found in emotional outputs between pre- and postoperative photos for either smiling or repose (Table 3). In patients without a gummy smile, "happiness" decreased in repose ($p \leq 0.01$) and increased when

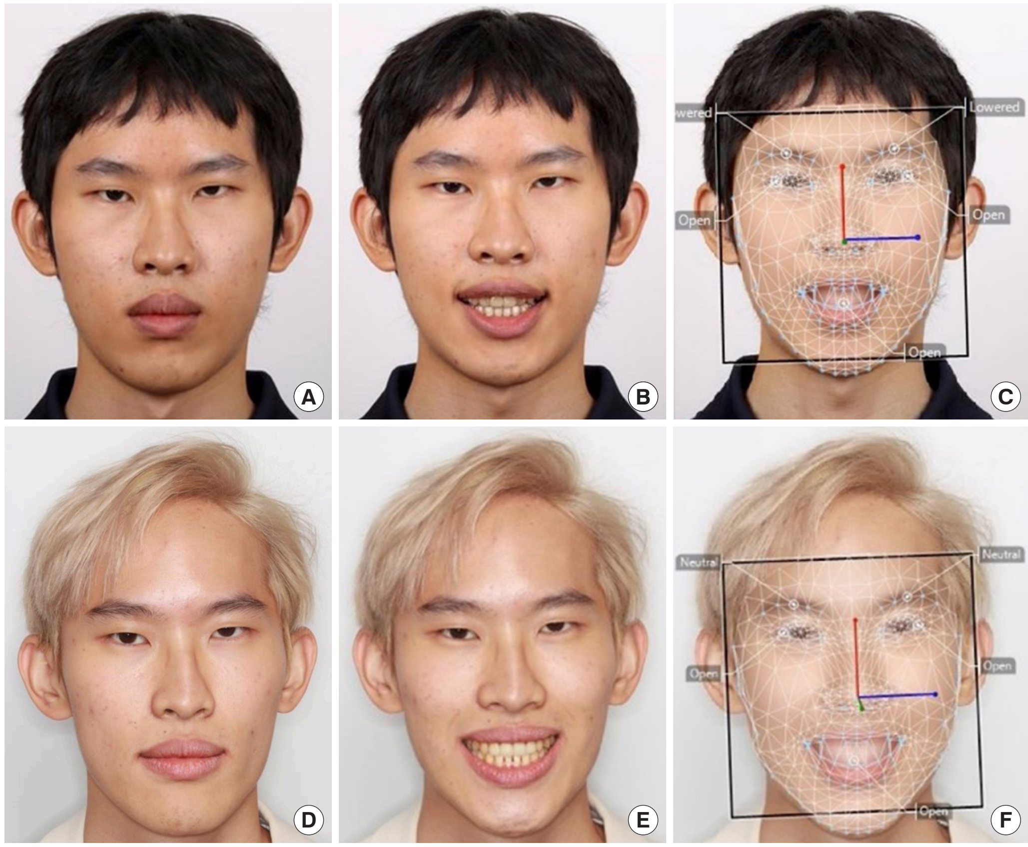

Fig. 2. Case example. A 24-year-old man underwent bimaxillary orthognathic surgery for class III malocclusion, with maxillary advancement, clockwise rotation, and mandibular setback. No genioplasty or additional procedures were performed. The photos, taken at 27 months postoperatively, show preoperative and postoperative results with the patient in repose (A, D), smiling (B, E), and FaceReader software (Noldus Information Technology BV) face detection during smiling (C, F). Informed consent was obtained from the patient for publishing this photo.

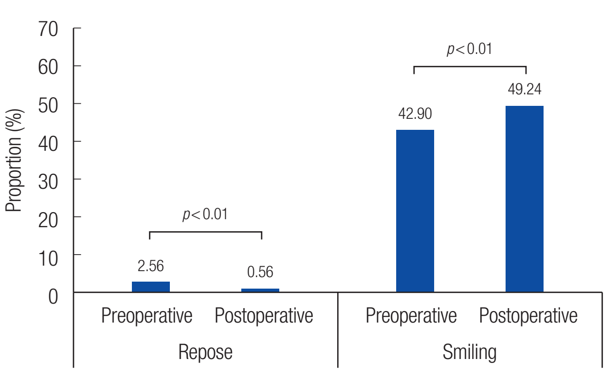

Fig. 3. Graph depicting the average percentage of happiness before-and-after orthognathic surgery (in repose and while smiling) in patients with dentofacial deformities. Emotion analysis was conducted using FaceReader software (Noldus Information Technology BV).

smiling ($p \leq 0.005$). The lip corner puller AU output also increased during smiling postoperatively ($p < 0.01$).

Further analysis based on the bonded status of patients' braces revealed that debonded patients showed no significant differences in repose; however, during smiling, both "happiness" and lip corner puller AU output increased significantly postoperatively. Conversely, in patients who were still bonded, "happiness" decreased in repose ($p \leq 0.05$).

When stratifying patients by preoperative insufficient incisor show, those with sufficient incisor show experienced a significant postoperative decrease in "happiness" in repose. In contrast, patients with insufficient incisor show had increased "happiness" and lip corner puller AU output during smiling ($p \leq 0.01$), while patients with sufficient incisor show exhibited only an increase in lip corner puller AU output ($p \leq 0.05$).

Among patients with an open bite, no differences in FaceReader output were observed in repose; however, when smiling, there was a significant increase in both "happiness" ($p \leq 0.05$) and lip corner puller AU output ($p \leq 0.05$). In patients without an open bite, "happiness" decreased in repose ($p \leq 0.01$), while the lip corner puller AU output increased during smiling ($p \leq 0.05$).

When examining patients by Angle class, class II patients exhibited increased lip corner AU output during smiling ($p < 0.01$), and class III patients showed a significant increase in "happiness" during smiling ($p < 0.05$).

Table 2. Complete FaceReader output in patients with dentofacial deformities who underwent orthognathic surgery treatment

Facial action unit	Repose			Smiling		
	Preoperative	Postoperative	*p*-value	Preoperative	Postoperative	*p*-value
Happy (%)	2.56	0.56	0.005	42.90	49.24	0.030
AU6	0.014	0.032	0.590	0.662	0.741	0.442
AU12 (left)	0.046	0.037	0.716	2.014	2.407	< 0.001
AU12 (right)	0.060	0.037	0.468	2.083	2.505	< 0.001
AU12	0.032	0.037	0.951	1.810	2.176	0.002
AU20 (left)	0.028	0.014	0.480	0.287	0.398	0.109
AU20 (right)	0.028	0.014	0.480	0.324	0.435	0.120
AU20	0.028	0.014	0.480	0.264	0.375	0.096
AU25	0.236	0.139	0.087	3.852	3.703	0.119

AU, action unit.

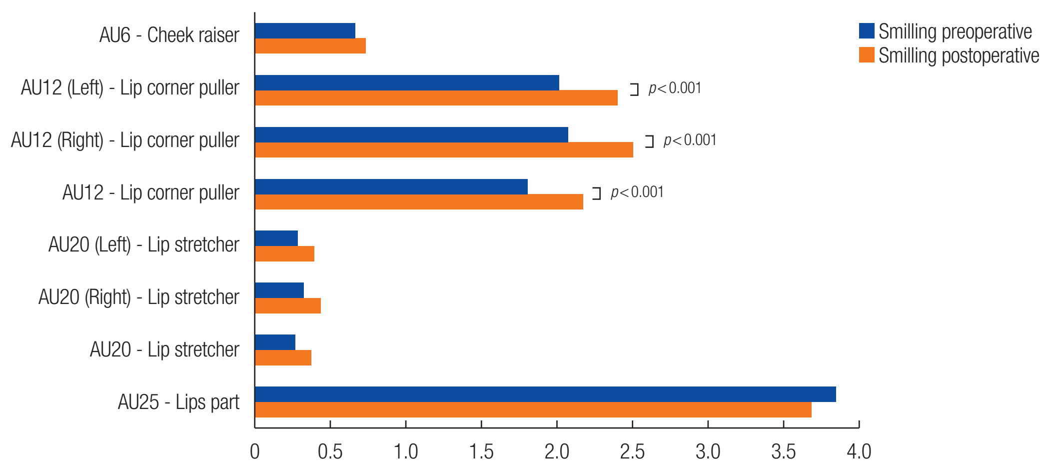

Fig. 4. Graph showing the mean output of action units (AUs) associated with happiness preoperatively versus postoperatively during smiling. Patients with dentofacial deformities who underwent orthognathic surgery were evaluated using FaceReader software (Noldus Information Technology BV), which detects facial AUs.

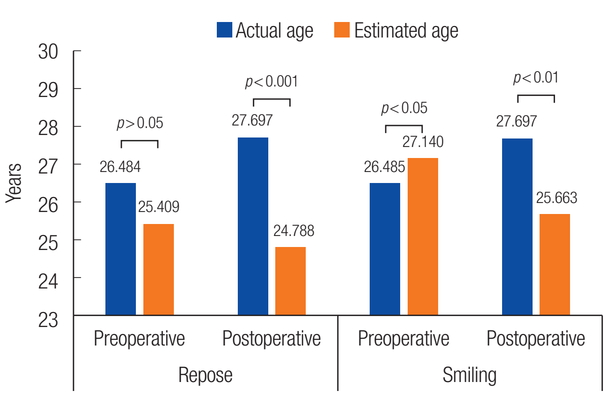

Fig. 5. Comparison of actual age at the time of photography versus estimated age by FaceReader software (Noldus Information Technology BV) in the same group of patients with dentofacial deformities who underwent orthognathic surgery.

Finally, analysis of the effect of orthognathic surgery on estimated age based on FaceReader outputs (Table 4, Fig. 5) revealed that preoperatively in repose, the estimated and actual ages did not differ significantly, although the estimated age was significantly higher than the actual age when smiling. Postoperatively, the estimated age was significantly lower than the actual age in both repose ($p \leq 0.001$) and smiling ($p \leq 0.01$).

DISCUSSION

Key results

We observed a substantial enhancement in the expression of happiness associated with smiling and a reduction in the average estimated age following orthognathic surgery for dentofacial deformities. To our knowledge, this is the first large-scale application of AI software to analyze the effects of orthognathic surgery on emotional expression in patients with dentofacial deformities.

Interpretation/comparison with previous studies

Our previous publications have demonstrated the efficacy of

Table 3. FaceReader output stratified by the presence of gummy smile, status of debondedness, preoperative incisor show, open bite, and Angle classification

Patient characteristic	Facial action unit	Repose			Smiling		
		Preoperative	Postoperative	*p*-value	Preoperative	Postoperative	*p*-value
Presence of gummy smile (n = 6)	Happy	0.000	4.020	1.000	74.680	78.820	0.223
	AU12	0.000	0.200	1.000	1.800	3.600	0.174
	AU6	0.000	0.200	1.000	2.200	1.800	0.346
No gummy smile (n = 242)	Happy	2.623	0.481	0.002	42.149	48.536	0.035
	AU12	0.033	0.033	1.000	1.810	2.142	0.005
	AU6	0.014	0.028	0.784	0.626	0.716	0.368
Debonded – yes (n = 104)	Happy	2.885	0.016	0.100	42.265	54.946	< 0.001
	AU12	0.021	0.052	0.572	1.698	2.323	0.002
	AU6	0.000	0.021	0.346	0.729	0.917	0.172
Debonded – no (n = 144)	Happy	2.343	0.203	0.014	43.408	44.827	0.944
	AU12	0.042	0.025	0.710	1.898	2.068	0.229
	AU6	0.025	0.042	1.000	0.610	0.602	0.854
Insufficient incisor show preoperatively (n = 31)	Happy	3.272	0.109	0.059	28.165	42.324	0.011
	AU12	0.019	0.000	1.000	0.981	1.630	0.007
	AU6	0.000	0.000	NA	0.296	0.481	0.116
Sufficient incisor show preoperatively (n = 215)	Happy	2.326	0.714	0.036	47.814	51.541	0.348
	AU12	0.037	0.049	0.774	2.086	2.358	0.039
	AU6	0.019	0.043	0.590	0.784	0.827	0.891
Open bite present (n = 88)	Happy	3.965	1.932	0.584	36.459	55.432	0.013
	AU12	0.000	0.108	0.371	1.730	2.432	0.046
	AU6	0.000	0.000	NA	00.865	0.973	0.751
Open bite absent (n = 160)	Happy	2.273	0.279	0.004	44.234	47.956	0.250
	AU12	0.039	0.022	0.482	0.827	2.123	0.018
	AU6	0.017	0.039	0.590	0.620	0.693	0.479
Angle class 2 (n = 33)	Happy	4.406	0.000	0.059	40.571	49.374	0.395
	AU12	0.057	0.000	0.346	1.629	2.486	0.002
	AU6	0.057	0.114	1.000	0.543	0.886	0.090
Angle class 3 (n = 183)	Happy	2.339	0.706	0.038	44.163	49.763	0.090
	AU12	0.031	0.031	1.000	1.850	2.063	0.121
	AU6	0.006	0.013	0.773	0.719	0.725	0.778

AU, action unit; NA, not available.

Table 4. Comparison between the patient's actual age at the time of preoperative and postoperative photography and estimated age by FaceReader[a)]

	Repose			Smiling		
	Actual age	Estimated age	*p*-value	Actual age	Estimated age	*p*-value
Preoperative	26.484	25.409	0.120	26.485	27.14	0.041
Postoperative	27.697	24.788	< 0.001	27.697	25.663	0.001

[a)]FaceReader (Noldus Information Technology BV).

the same AI software (Noldus) in analyzing postoperative outcomes across various procedures, including facial reanimation surgery, cosmetic procedures, and facial transplantations [10-17]. These studies support the accuracy and utility of AI software in evaluating postoperative results.

Patients with dentofacial deformities often present with functional and dynamic impairments, including altered smile aesthetics, orofacial myofunctional changes, and modifications of the smile arc [1,2,18]. Ekman and Friesen [19] pioneered the facial action coding system for categorizing human facial expressions into discrete AUs. The smile—typically associated with happiness—is initiated by the cheek raiser (AU6) and the lip corner puller (AU12), which are controlled by the orbicularis oculi and the zygomaticus major/minor muscles, respectively.

Although the impact of dentofacial deformities on these muscles remains unclear, it is well established that these conditions can affect the smile arc [20]. Orthognathic surgery, particularly in class III patients, can significantly improve smile asymmetry [21], as evidenced by an increase in the relevant AUs postoperatively. Additionally, there was a notable decrease in expressions of anger and disgust after surgery in both repose and smiling photographs, indicating an overall improvement in the resting state following correction of dentofacial deformities.

Historically, objective evaluation of aesthetic surgery outcomes has been time-consuming and has required cumbersome tools such as Facial Assessment and Cosmetic Enhancement Quality of Life Questionnaire and additional questionnaires like FAST and DS5921 [22,23]. The advent of AI provides a more efficient and objective alternative. Patcas et al. [6] used AI to evaluate facial attractiveness after orthognathic surgery, reporting significant improvements and a reduction in apparent age. Similarly, Lo et al. [24] assessed facial attractiveness using AI-based 3D imaging, and Zhang et al. [25] employed AI to predict facial age in Chinese cosmetic surgery patients. Our study uniquely contributes by objectively evaluating emotional expression after orthognathic surgery, demonstrating significant improvements in this parameter.

Further sub-analysis revealed consistent improvements in emotional expression among both class II and III patients, despite their characteristic differences [26,27]. Notably, patients with insufficient incisor show exhibited the lowest baseline "happiness" and the most substantial improvement postoperatively, consistent with previous investigations [28,29].

Our study examining the impact of surgery on perceived age found a significant postoperative decrease in estimated age compared to the actual age in repose. Preoperatively, there was no significant difference between actual and estimated age in repose. These results align with prior research using both AI and human observers [6,30].

Limitations

Our study has limitations, including incomplete data regarding the specifics of orthognathic surgical movements and their potential correlation with emotion analysis. Future investigations should address these research gaps. Additionally, our predominantly younger, female, and Chinese cohort may limit the generalizability of our findings to broader populations, although it also lends strength to our results.

Conclusion

This study investigated the use of AI to assess emotional expression in a sizable cohort of patients who underwent orthognathic surgery for dentofacial deformities. Our findings, consistent with conventional evaluation approaches, reveal an increase in the expression of happiness, a reduction in expressions of anger and disgust, and a decrease in estimated age following surgery. Both class II and III patients exhibited substantial improvements across all measured parameters postoperatively.

NOTES

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

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Ethical approval

The study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (IRB No. 17-009087) and performed in accordance with the principles of the Declaration of Helsinki. The informed consent was waived because this study design is a retrospective chart review.

Patient consent

The patient depicted in Fig. 2 provided written informed consent for the publication and use of his images.

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Jen Chen, Chuan-Fong Yao. Visualization: Thanapoom Boonipat. Writing - original draft: Thanapoom Boonipat, Jason Lin, Sai Cherukuri. Writing - review & editing: Thanapoom Boonipat, Jason Lin, Zhi Yang Ng, Eugene Yu-Jen Chen, Chuan-Fong Yao. Investigation; Resources; Software: Thanapoom Boonipat, Eugene Yu-Jen Chen, Chuan-Fong Yao. Supervision; Validation: Chuan-Fong Yao. All authors read and approved the final manuscript.

Supplementary materals

Supplemental data can be found at: https://doi.org/10.7181/acfs.2025.0007.

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