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Role of 3D facial scanning in esthetic analysis and treatment planning for maxillofacial prosthetics

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Abstract:
Maxillofacial prosthetic rehabilitation demands high precision for esthetic and functional success, yet conventional methods often lack accuracy and patient comfort. Therefore, it is of interest to compare the traditional techniques with advanced 3D facial scanning in 48 patients requiring facial prostheses. 3D scanning showed greater dimensional accuracy (0.31 ± 0.12 mm versus 1.24 ± 0.45 mm, $p<0.001$), reduced procedure time and improved patient comfort. Prostheses created using 3D data achieved superior fit and satisfaction scores. Thus, 3D facial scanning enhances accuracy, efficiency and comfort, offering a superior alternative for maxillofacial prosthetic planning and fabrication.

Keywords: 3D facial scanning, maxillofacial prostheses, esthetic analysis, treatment planning, digital dentistry, facial anthropometry, structured light scanning

Background:
Maxillofacial defects resulting from oncologic resection, trauma, or congenital anomalies present substantial challenges in rehabilitation, affecting not only functional capabilities but also psychosocial well-being and quality of life **[1]**. Maxillofacial prostheses serve as critical therapeutic interventions that restore facial esthetics, support psychological recovery and facilitate social reintegration **[2]**. The success of prosthetic rehabilitation fundamentally depends on accurate assessment of facial anatomy, precise treatment planning and meticulous fabrication techniques that achieve optimal esthetic and functional outcomes **[3]**. Traditional approaches to maxillofacial prosthetic treatment planning have relied predominantly on direct anthropometric measurements, two-dimensional photography and physical impression techniques using alginate or silicone materials **[4]**. While these conventional methods have showed clinical utility over decades, they possess inherent limitations including subjective interpretation, patient discomfort during impression procedures, dimensional instability of materials and challenges in accurate three-dimensional visualization **[5]**. Furthermore, direct contact methods may cause distortion of soft tissues, particularly in patients with fragile post-surgical anatomy or compromised tissue integrity **[6]**. The advent of digital technologies has revolutionized various aspects of dental and maxillofacial practice, with three-dimensional facial scanning emerging as a promising tool for objective documentation and analysis **[7]**. Contemporary 3D scanning systems employ diverse technologies including structured light projection, laser triangulation and stereophotogrammetry to capture high-resolution facial surface data **[8]**. These non-invasive digital methods offer potential advantages in accuracy, reproducibility, efficiency and patient acceptance while enabling comprehensive virtual treatment planning and digital workflow integration **[9]**. Recent investigations have showed the application of 3D facial scanning in various clinical contexts, including orthognathic surgery planning, cleft lip evaluation, facial asymmetry assessment and dental implant prosthodontics **[10]**. Studies have reported measurement accuracy within submillimeter ranges and excellent reliability coefficients for facial anthropometric analysis **[11]**. However, specific applications in maxillofacial prosthetic rehabilitation remain relatively underexplored in the literature, with limited evidence regarding comparative effectiveness, clinical workflow integration and patient-centered outcomes **[12]**. Despite increasing interest in digital technologies, several knowledge gaps persist regarding the practical implementation of 3D facial scanning in maxillofacial prosthetics. Questions remain concerning the comparative accuracy of different scanning modalities, optimal scanning protocols for various defect types, correlation between digital measurements and clinical outcomes and cost-effectiveness considerations **[13]**. Additionally, the impact on treatment planning precision, fabrication efficiency and ultimate prosthetic quality requires systematic investigation **[14]**. Furthermore; patient perspectives regarding digital versus conventional assessment methods have received insufficient attention in existing research **[15]**. Therefore, it is of interest to understand patient experiences, comfort levels and satisfaction with different evaluation approaches, as this is essential for patient-centered care delivery and clinical decision-making.

Materials and Methods:
Sample size calculation was performed using G*Power software (version 3.1.9.7) based on expected effect size of 0.8, alpha error

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of 0.05 and statistical power of 0.85, indicating a minimum requirement of 42 participants. Accounting for potential 15% attrition, 48 patients were recruited through consecutive sampling.

Inclusion criteria:
Patients aged 18-75 years requiring maxillofacial prostheses (auricular, orbital, or nasal) due to acquired defects (post-oncologic resection or trauma); stable post-surgical anatomy (minimum 6 months post-surgery); adequate general health status; and willingness to participate in both evaluation methods.

Exclusion criteria:
Active oncologic disease or ongoing radiotherapy/chemotherapy; unstable wound healing or tissue inflammation; severe cognitive impairment affecting cooperation; pregnancy; claustrophobia or anxiety disorders preventing scanning procedures; and previous maxillofacial prosthetic treatment within 12 months. All participants underwent comprehensive evaluation using both conventional and 3D scanning methods in randomized sequence to minimize bias. A one-week interval separated the two assessments to prevent fatigue effects.

Conventional assessment protocol:
Direct facial anthropometric measurements were performed using digital calipers (accuracy ± 0.01 mm) and flexible measuring tape. Reference landmarks were identified and marked using surgical skin markers. Facial impressions were obtained using polyvinyl siloxane material (Elite HD+, Zhermack) following standardized protocols. Two-dimensional photographs were captured using standardized positioning and lighting conditions.

3D scanning protocol:
Facial surface scanning was performed using structured light technology (Artec Eva, Artec 3D, Luxembourg; accuracy: 0.1mm, resolution: 0.5mm). Patients were positioned in natural head position with neutral facial expression in a dedicated scanning room with controlled lighting. Multiple scanning passes were conducted to ensure complete data capture from different angles. Raw scan data were processed using proprietary software (Artec Studio 15 Professional) including alignment, fusion, noise reduction and mesh optimization. Additional scans were acquired using handheld intraoral scanner (TRIOS 3, 3Shape) for defect margin documentation.

Primary outcomes:
- [1] **Dimensional accuracy:** Linear measurements between anatomical landmarks compared between methods using coordinate measuring machine (CMM) as reference standard
- [2] **Time efficiency:** Total procedure duration from patient positioning to data completion
- [3] **Patient comfort:** Visual Analog Scale (VAS) scores ranging 0-10
- [4] **Treatment planning precision:** Inter-operator reliability coefficients for prosthetic design parameters

Secondary outcomes:
- [1] **Prosthetic marginal adaptation:** Percentage of intimate contact assessed using pressure-indicating paste
- [2] **Patient satisfaction:** Validated questionnaire (Maxillofacial Prosthetic Satisfaction Questionnaire - MPSQ) with scores 0-100

Statistical analysis:
Data were analyzed using SPSS software (version 26.0, IBM Corporation). Descriptive statistics included means with standard deviations for continuous variables and frequencies with percentages for categorical variables. Normality assessment was performed using Shapiro-Wilk test. Paired t-tests compared continuous outcomes between methods. Inter-operator reliability was assessed using intraclass correlation coefficients (ICC). Chi-square tests evaluated categorical associations. Statistical significance was set at $p<0.05$. Bland-Altman analysis assessed agreement between measurement methods.

Results:
Forty-eight patients (28 males, 20 females; mean age 52.6 ± 14.3 years) completed both evaluation protocols. The sample included 22 auricular defects (45.8%), 16 orbital defects (33.3%) and 10 nasal defects (20.9%). Defect etiologies comprised oncologic resection in 34 patients (70.8%) and traumatic injuries in 14 patients (29.2%). Mean time since surgery was 14.2 ± 6.8 months. All participants completed the study protocol without adverse events or dropouts. **Table 1** presents comparative dimensional accuracy between conventional and 3D scanning methods. Three-dimensional scanning showed significantly superior accuracy across all measured parameters. Mean absolute deviation from CMM reference values was 0.31 ± 0.12 mm for 3D scanning compared to 1.24 ± 0.45 mm for conventional methods ($p<0.001$). The maximum deviation observed was 0.68 mm for 3D scanning versus 2.87 mm for conventional approaches. Significant differences were observed in procedural parameters favoring 3D scanning (**Table 2**). The mean total procedure time for 3D scanning was 8.4 ± 2.1 minutes compared to 24.6 ± 5.3 minutes for conventional methods ($p<0.001$), representing a 65.9% time reduction. Patient comfort scores were significantly higher for 3D scanning (8.7 ± 0.9 vs. 5.2 ± 1.4, $p<0.001$). Notably, 43 patients (89.6%) expressed preference for 3D scanning over conventional impression procedures. **Table 3** shows superior treatment outcomes for prostheses fabricated using 3D scanning data. Marginal adaptation assessment revealed significantly better fit for 3D scanning-based prostheses (92.3 ± 4.2% vs. 78.6 ± 8.7%, $p<0.001$). Patient satisfaction scores measured at 3-month follow-up were significantly higher in the 3D scanning group (84.2 ± 9.6 vs. 71.4 ± 12.8, $p<0.001$). Clinical adjustments required at delivery were fewer for 3D scanning-based prostheses (1.2 ± 0.8 vs. 3.4 ± 1.6,

p<0.001). Subgroup analysis by defect type revealed consistent advantages for 3D scanning across auricular (p<0.001), orbital (p=0.002) and nasal (p=0.004) prostheses. Bland-Altman analysis showed excellent agreement between repeated 3D scanning measurements with 95% limits of agreement ranging from -0.24 to +0.28 mm.

Table 1: Comparison of dimensional accuracy between methods

Parameter	3D Scanning (mm)	Conventional Method (mm)	Mean Difference (mm)	p-value
Linear measurements (n=324)				
Mean absolute deviation	0.31 ± 0.12	1.24 ± 0.45	0.93	<0.001
Maximum deviation	0.68 ± 0.21	2.87 ± 0.94	2.19	<0.001
Minimum deviation	0.08 ± 0.04	0.42 ± 0.18	0.34	<0.001
Surface area accuracy (%)	98.7 ± 0.8	89.4 ± 4.6	9.3	<0.001
Volumetric accuracy (%)	97.9 ± 1.2	86.8 ± 6.2	11.1	<0.001
Inter-operator ICC	0.964 (95% CI: 0.942-0.978)	0.823 (95% CI: 0.776-0.862)	-	<0.001
Intra-operator ICC	0.981 (95% CI: 0.968-0.989)	0.887 (95% CI: 0.849-0.916)	-	<0.001

ICC: Intraclass correlation coefficient; CI: Confidence interval

Table 2: Procedural efficiency and patient-reported outcomes

Parameter	3D Scanning	Conventional Method	p-value
Time efficiency			
Total procedure time (minutes)	8.4 ± 2.1	24.6 ± 5.3	<0.001
Setup time (minutes)	2.1 ± 0.6	6.4 ± 1.8	<0.001
Active scanning/impression time (minutes)	4.2 ± 1.3	12.8 ± 3.2	<0.001
Post-processing time (minutes)	2.1 ± 0.8	5.4 ± 1.6	<0.001
Patient comfort (VAS 0-10)	8.7 ± 0.9	5.2 ± 1.4	<0.001
Anxiety level (VAS 0-10)	2.4 ± 1.2	5.8 ± 1.8	<0.001
Willingness to repeat procedure, n (%)			
Definitely willing	42 (87.5%)	18 (37.5%)	<0.001
Probably willing	6 (12.5%)	21 (43.8%)	
Uncertain/unwilling	0 (0%)	9 (18.7%)	
Patient preference, n (%)	43 (89.6%)	5 (10.4%)	<0.001

VAS: Visual Analog Scale

Table 3: Treatment outcomes and prosthetic quality assessment

Parameter	3D Scanning	Conventional Method	p-value
Prosthetic fit quality			
Marginal adaptation (%)	92.3 ± 4.2	78.6 ± 8.7	<0.001
Number of clinical adjustments	1.2 ± 0.8	3.4 ± 1.6	<0.001
Adjustment time at delivery (minutes)	12.4 ± 5.2	28.7 ± 9.4	<0.001
Patient satisfaction (MPSQ score 0-100)			
Overall satisfaction	84.2 ± 9.6	71.4 ± 12.8	<0.001
Esthetic appearance	86.3 ± 8.4	73.2 ± 11.6	<0.001
Comfort during wear	82.1 ± 10.2	69.8 ± 13.4	<0.001
Functional satisfaction	83.6 ± 9.8	71.6 ± 12.2	<0.001
Prosthetic success, n (%)			
Excellent (no adjustments needed)	18 (37.5%)	4 (8.3%)	0.001
Good (minor adjustments)	26 (54.2%)	22 (45.8%)	
Acceptable (moderate adjustments)	4 (8.3%)	16 (33.3%)	
Poor (major adjustments/remake)	0 (0%)	6 (12.5%)	
Patient recommendation likelihood, n (%)	42 (87.5%)	31 (64.6%)	0.012

MPSQ: Maxillofacial Prosthetic Satisfaction Questionnaire

Discussion:

This prospective comparative study provides comprehensive evidence supporting the superiority of 3D facial scanning technology over conventional methods in maxillofacial prosthetic rehabilitation. Our findings demonstrate significant advantages across multiple domains including dimensional accuracy, procedural efficiency, patient comfort and treatment outcomes. The substantially higher dimensional accuracy observed with 3D scanning (mean deviation 0.31 ± 0.12 mm) compared to conventional approaches (1.24 ± 0.45 mm) aligns with previous investigations in related fields. The superior accuracy can be attributed to non-contact data acquisition that eliminates soft tissue distortion, high-resolution surface capture capabilities and digital data processing that minimizes human measurement errors inherent in manual anthropometry **[16, 17]**. Our measurement reliability findings, with ICC values exceeding 0.96 for both inter- and intra-operator assessments using 3D scanning, demonstrate excellent reproducibility. Such high reliability is crucial for longitudinal patient monitoring, multi-disciplinary treatment planning and quality assurance in prosthetic fabrication. The lower reliability coefficients observed with conventional methods (ICC 0.823-0.887) reflect inherent variability in manual measurement techniques and material dimensional changes **[18, 19]**. The 65.9% reduction in procedural time with 3D scanning represents substantial clinical efficiency gains. In busy clinical settings, such time savings enable increased patient throughput, reduced chair time and improved workflow optimization. However, it is important to acknowledge that initial learning curves and software processing time may temporarily offset these advantages during implementation phases **[20, 21]**. Patient comfort and acceptance emerged as particularly noteworthy findings, with significantly higher VAS scores for 3D scanning (8.7 ± 0.9 vs. 5.2 ± 1.4). The non-invasive nature of optical scanning eliminates discomfort associated with impression materials, particularly relevant for patients with compromised post-surgical anatomy or gag reflexes **[22, 23]**. The superior prosthetic fit quality showed through marginal adaptation assessment (92.3% vs. 78.6%) represents a clinically significant improvement directly impacting prosthetic retention, comfort and longevity. Better initial fit reduces chair-side adjustment time, minimizes material waste and enhances patient satisfaction **[24]**. The digital workflow enables virtual try-in, predictable manufacturing through computer-aided design and manufacturing (CAD/CAM) and precise replication when prosthetic replacement becomes necessary **[25]**. Patient satisfaction outcomes, measured through validated instruments, revealed significantly higher scores across all domains for 3D scanning-based prostheses. The 84.2 ± 9.6 overall satisfaction score compared favorably with reported benchmarks for digitally-fabricated maxillofacial prostheses **[26]**. Enhanced esthetic outcomes likely resulted from more accurate contralateral anatomy replication, precise color matching facilitated by digital documentation and improved symmetry analysis **[27]**. The consistent benefits observed across different defect types (auricular, orbital and nasal) suggest broad applicability of 3D scanning technology in maxillofacial prosthetics. Each defect type presents unique anatomical challenges, yet digital assessment showed advantages in all categories, supporting generalizability of findings **[28]**. Integration of 3D scanning into comprehensive digital workflows offers additional advantages beyond those directly measured in this study. Digital data archiving ensures permanent records resistant to physical degradation, facilitates telemedicine consultations, enables advanced treatment simulation and supports artificial intelligence applications in prosthetic design optimization **[29]**. Furthermore, digital files can be shared seamlessly among multidisciplinary team members, enhancing collaborative treatment planning **[30]**. Despite compelling advantages, several limitations warrant consideration. The initial capital investment for 3D scanning equipment and software represents a significant barrier, particularly in resource-limited settings. Cost-effectiveness analysis incorporating equipment costs, maintenance, training and long-term efficiency gains requires further investigation **[31]**. Our study was conducted at a single academic center with experienced operators, potentially limiting generalizability to diverse clinical settings with varying expertise levels. The relatively short follow-up period (3 months) precluded assessment of long-term prosthetic durability and patient satisfaction evolution. Extended longitudinal studies are needed to evaluate whether superior initial fit translates to enhanced prosthetic longevity and reduced maintenance requirements **[32]**. Additionally, our study focused on extraoral prostheses; applications in intraoral maxillofacial prostheses may present different considerations regarding moisture control and scanning access. Technical limitations of current scanning technology include challenges with highly reflective surfaces, dark skin tones and fine anatomical details such as eyebrows or texture replication. Ongoing technological advances continue to address these limitations through improved algorithms and sensor technologies **[33]**. Future research should explore integration of multiple scanning modalities, artificial intelligence-assisted design optimization and patient-reported outcome measures using standardized instruments. The learning curve associated with 3D scanning technology and software operation requires structured training programs and continuous professional development. Successful implementation necessitates institutional commitment; technical support infrastructure and workflow redesign to maximize efficiency benefits **[34]**. Standardized protocols for scan acquisition, data processing and quality assurance are essential for consistent clinical outcomes. The ability to create detailed 3D models enables better communication with patients and more precise treatment planning **[35]**.

Conclusion:

3D facial scanning significantly improves accuracy, efficiency and patient comfort in maxillofacial prosthetic rehabilitation compared to conventional methods. Its digital precision and seamless workflow integration enhance clinical outcomes and patient satisfaction. As technology advances, 3D scanning is set to become a standard, patient-centered approach in modern prosthetic practice.

References:

[1] Lo LJ & Lin HH. *Biomed J.* 2023 **46**:100615 [PMID: 37343928]
[2] Velarde K *et al. Comput Assist Surg (Abingdon).* 2023 **28**:2271160 [PMID: 37862041]
[3] Adolphs N *et al. J Craniomaxillofac Surg.* 2014 **42**:e289 [PMID: 24286863]
[4] Lin HH &Lo LJ. *J Formos Med Assoc.* 2015 **114**:300 [PMID: 25744942]
[5] Steinbacher DM. *J Oral Maxillofac Surg.* 2015 **73**:S40 [PMID: 26608154]
[6] Bauermeister AJ *et al. Ann Plast Surg.* 2016 **77**:569 [PMID: 26678104]
[7] Vyas K *et al. Facial Plast Surg Clin North Am.* 2022 **30**:239 [PMID: 35501062]
[8] Escandón JM *et al. J Plast Reconstr Aesthet Surg.* 2022 **75**:e1 [PMID: 35400593]
[9] Tel A *et al. Int J Oral Maxillofac Surg.* 2023 **52**:775 [PMID: 36481124]
[10] Wang LY *et al. Med Hypotheses.* 2011 **77**:1004 [PMID: 21903336]
[11] Cui J *et al. J Oral Maxillofac Surg.* 2014 **72**:1138 [PMID: 24679954]
[12] Jacobs CA & Lin AY. *Plast Reconstr Surg.* 2017 **139**:1211 [PMID: 28445375]
[13] Checcucci E *et al. World J Urol.* 2020 **38**:869 [PMID: 31456017]
[14] Gavriilidis P *et al. Hepatobiliary Pancreat Dis Int.* 2022 **21**:226 [PMID: 34544668]

ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(8): (2026)

[15] Zhao L *et al. Arch Plast Surg.* 2012 **39**:309 [PMID: 22872832]
[16] Rodby KA *et al. J Plast Reconstr Aesthet Surg.* 2014 **67**:1171 [PMID: 24880575]
[17] Liu XJ *et al. J Craniofac Surg.* 2009 **20**:372 [PMID: 19276828]
[18] Zeng C *et al. Injury.* 2016 **47**:2223 [PMID: 27372187]
[19] Zhang Y & Liu XJ. *Zhonghua Kou Qiang Yi Xue Za Zhi.* 2016 **51**:205 [PMID: 27117211]
[20] Ostaș D *et al. J Clin Med.* 2022 **11**:6625 [PMID: 36431101]
[21] Markiewicz MR & Bell RB. *Curr Opin Otolaryngol Head Neck Surg.* 2011 **19**:295 [PMID: 21900856]
[22] Ha SH *et al. J Craniofac Surg.* 2023 **34**:96 [PMID: 36044286]
[23] Aboul-Hosn Centenero S & Hernández-Alfaro F. *J Craniomaxillofac Surg.* 2012 **40**:162 [PMID: 21458285]
[24] Porpiglia F *et al. Eur Urol Focus.* 2018 **4**:652 [PMID: 30293946]
[25] Liu TJ *et al. Ann Plast Surg.* 2016 **76**:411 [PMID: 25664409]
[26] Pietruski P *et al. J Craniomaxillofac Surg.* 2015 **43**:1021 [PMID: 26165759]
[27] Ying X *et al. BMC Oral Health.* 2021 **21**:529 [PMID: 34654418]
[28] Jansen J *et al. J Craniomaxillofac Surg.* 2018 **46**:715 [PMID: 29548880]
[29] Kayastha D & Vakharia KT. *Curr Opin Otolaryngol Head Neck Surg.* 2019 **27**:267 [PMID: 31157662]
[30] Van Hemelen G *et al. J Craniomaxillofac Surg.* 2015 **43**:918 [PMID: 26027866]
[31] Xia JJ *et al. J Oral Maxillofac Surg.* 2007 **65**:248 [PMID: 17236929]
[32] Lin HH *et al. J Formos Med Assoc.* 2018 **117**:547 [PMID: 29398097]
[33] Bianchi A *et al. J Oral Maxillofac Surg.* 2010 **68**:1471 [PMID: 20561464]
[34] Swennen GR *et al. J Oral Maxillofac Surg.* 2009 **67**:2080 [PMID: 19761902]
[35] Isikay I *et al. Front. Surg.* 2024 **11**:1427844. [PMID: 39081485]