*The journal of*
PROSTHETIC
AND IMPLANT
DENTISTRY
**Official Publication of Indian Prosthodontic Society
Kerala State Branch**

# FACIAL PROSTHETIC REHABILITATION OF CRANIOFACIAL DEFECTS: CURRENT CONCEPTS, MATERIALS, AND DIGITAL ADVANCES — A NARRATIVE REVIEW

*Karthik V. C., *Sonia Abraham, *Kirubakaran A., **Sooryanarayanan T., **Kalvi Karasi V.

*Associate Professor, **Asst. Professor, Department of Prosthodontics and Crown & Bridge, Adhiparasakthi Dental College & Hospital, Melmaruvathur, Tamil Nadu, India. Corresponding Author: Dr. Karthik V. C., Email: drkarthikvc@gmail.com

https://doi.org/10.55231/jpid.2026.v09.i03.07

## Abstract

*Craniofacial defects arising from congenital anomalies, trauma, or oncologic resection can profoundly affect facial aesthetics, functional ability, and psychological well-being. When surgical reconstruction is not feasible or is declined by the patient, facial prosthetic rehabilitation serves as a predictable and minimally invasive treatment alternative. This narrative review summarizes current concepts in facial prosthetics, including patient selection, implant placement planning, prosthesis design, biomaterials, psychological considerations, and recent digital advancements. Silicone elastomers continue to be the material of choice due to their favourable esthetic qualities, flexibility, and biocompatibility, while implant-supported prostheses provide superior retention, stability, and patient satisfaction compared with adhesive-retained options. The integration of computer-aided design, three-dimensional imaging, and additive manufacturing has significantly enhanced diagnostic accuracy, surgical precision, and prosthesis fabrication; however, challenges remain in achieving optimal durability and replicating dynamic facial expressions. Successful rehabilitation relies on a multidisciplinary approach, realistic patient expectations, and long-term maintenance protocols. Continued progress in biomaterials and digital technologies is expected to further improve functional and esthetic outcomes, ultimately enhancing the quality of life for individuals with craniofacial defects.*

***Keywords: facial prosthesis, maxillofacial prosthetics, craniofacial defects, prosthetic rehabilitation***

## Introduction

Craniofacial defects represent complex clinical challenges that compromise both function and social identity. Common etiologies include oncologic resection, traumatic injury, and congenital malformations, often resulting in impaired speech, mastication, and facial expression[1-3]. Although reconstructive surgery is frequently considered the definitive treatment, its success may be limited by systemic conditions, previous radiation therapy, defect size, or patient

The journal of
PROSTHETIC AND IMPLANT DENTISTRY
Official Publication of Indian Prosthodontic Society Kerala State Branch

preference[3,4]. Facial prostheses therefore, remain an indispensable component of maxillofacial rehabilitation, offering predictable esthetic restoration with relatively low morbidity[5]. Early prostheses relied primarily on adhesives or mechanical retention; however, the introduction of osseointegrated implants revolutionized retention by improving stability, comfort, and long-term clinical outcomes[6,7]. Survival rates exceeding 90% have been reported for craniofacial implants, supporting their reliability[5,11]. Recent decades have witnessed a paradigm shift toward digital prosthodontics. CAD-CAM technology allows precise transfer of anatomical data into virtual designs, improving reproducibility while reducing fabrication time[28]. Simultaneously, additive manufacturing has enabled patient-specific prostheses with enhanced accuracy and customization[33,34].

## Extraoral Facial Prosthetics

Facial prosthetics is a specialized discipline focused on restoring structures such as the auricle, orbit, and nose1. Successful rehabilitation requires multidisciplinary collaboration among prosthodontists, surgeons, radiologists, and psychologists to address both functional and emotional consequences of facial disfigurement[27]. Implant-retained prostheses are widely considered the standard of care due to superior retention and reduced soft-tissue irritation compared with adhesive-retained prostheses[6,22]. Studies evaluating patient satisfaction consistently report improved comfort, confidence, and prosthesis wear time following implant therapy[24,25]. Computer-assisted surgical planning further enhances treatment predictability by enabling prosthetically driven implant positioning and fabrication of surgical guides[28].

## Patient Selection and Indications

Appropriate patient selection is fundamental for successful outcomes. Typical candidates include patients with defects secondary to malignancy, trauma, or congenital anomalies[2,3]. Prosthetic rehabilitation is particularly beneficial when surgical reconstruction is impractical or declined.[4] Beyond restoring physical appearance, facial prostheses contribute significantly to psychosocial well-being. Improvements in self-esteem, social interaction, and overall quality of life have been widely documented [24,25]. Conversely, contraindications include inadequate bone volume, uncontrolled systemic disease, poor hygiene, and unrealistic expectations[15].

## Implant Placement Planning

Advances in three-dimensional imaging have revolutionized craniofacial implant planning. Computed tomography enables detailed visualization of bone anatomy, allowing clinicians to select optimal implant positions while avoiding critical structures[8]. Virtual planning combined with surgical guides improves placement accuracy and reduces intraoperative complications[12]. Long-term follow-up studies confirm favourable survival rates for extraoral implants when proper planning protocols are followed[26]. Zygomatic implants may serve as alternative anchorage in patients with severe midfacial defects where conventional implant sites are unavailable[9].

## Prosthesis Design and Digital Workflow

### 3-Dimensional Facial Scanning

Three-dimensional scanning technologies have largely replaced conventional impression techniques by improving patient comfort and minimizing distortion[31]. These systems allow rapid acquisition of facial morphology and facilitate digital prosthesis design.

### Computer-Aided Design

Digital sculpting software enables mirrored reconstruction using contralateral anatomy or pre-defect records, enhancing symmetry and esthetic outcomes[28]. Hybrid workflows integrating digital design with conventional silicone processing remain the most predictable clinical approach[32].

## Biomaterials in Facial Prosthetics

Silicone elastomers remain the gold standard for facial prostheses because of their flexibility, durability, and lifelike appearance[16,18]. Nevertheless, environmental exposure, ultraviolet radiation, and daily handling contribute to progressive discolouration and mechanical degradation[17,19].

Pigments and opacifiers have been shown to influence colour stability, while ongoing material modifications aim to improve tear strength and longevity[15,20]. Despite these advancements, most silicone prostheses require replacement every 1.5–2 years[5].

## Polyetheretherketone (PEEK) and Advanced Polymers

PEEK has emerged as a promising biomaterial for craniofacial reconstruction due to its high strength-to-weight ratio, radiolucency, and chemical resistance[37]. Mechanical studies demonstrate that manufacturing parameters such as build orientation can significantly affect material performance[36]. Clinical investigations report favourableesthetic and functional outcomes with patient-specific PEEK implants, particularly in complex craniofacial defects[21]. However, the bioinert nature of PEEK may limit osseointegration, prompting research into surface modifications to enhance bone interaction[37].

## Psychological Considerations

Facial disfigurement is strongly associated with depression, anxiety, and social withdrawal. Prosthetic rehabilitation has been shown to substantially improve psychological health and interpersonal relationships[24]. However, clinicians must emphasize that most facial prostheses are static devices incapable of replicating natural movement, making expectation management essential for long-term satisfaction[15].

## Multidisciplinary Care and Clinical Outcomes

Patients requiring facial prostheses often undergo ablative surgery for head and neck malignancies, making coordinated multidisciplinary care essential[3]. Preservation of anatomical landmarks during surgery can significantly enhance prosthetic retention and esthetics[27].

Additionally, removable prostheses permit visualization of surgical sites, facilitating early detection of disease recurrence[1]. Although prostheses cannot perfectly replicate native tissues, they enable patients to function confidently in social environments[5].

## Recent Advances in Facial Prosthetics

### Artificial Intelligence

Artificial intelligence is increasingly being explored for automated prosthesis design, diagnostic support, and predictive treatment planning, potentially improving efficiency and personalization[35].

### Additive Manufacturing

Rapid prototyping technologies have transformed fabrication workflows by enabling precise, patient-specific prostheses[29]. Systematic reviews confirm the growing clinical efficacy of 3D printing in maxillofacial prosthodontics[32].

### Bioprinting

Bioprinting represents a future direction in which tissue-engineered constructs may integrate biologically with host tissues, offering the possibility of functional restoration rather than purely cosmetic replacement[38].

The journal of
PROSTHETIC
AND IMPLANT
DENTISTRY
Official Publication of Indian Prosthodontic Society
Kerala State Branch

### Implant Survival Evidence

Recent meta-analyses continue to support high survival rates for craniofacial implants, reinforcing their role in modern rehabilitation[39,40].

### Future Directions

The future of facial prosthetics is expected to be shaped by fully digital workflows, AI-assisted prosthesis design, smart biomaterials, and tissue-engineered scaffolds. Continued interdisciplinary research will be critical to translate these innovations into routine clinical practice.

## Conclusion

Facial prosthetic rehabilitation remains a cornerstone of contemporary maxillofacial care. Advances in implantology, biomaterials, and digital technologies have significantly improved treatment predictability and patient satisfaction. Nevertheless, challenges related to material durability, cost, and technical complexity persist. Future progress will depend on integrating emerging technologies with patient-centred treatment strategies to achieve optimal functional and psychosocial outcomes.

## References:

1. Beumer J III, Curtis TA, Marunick MT. Maxillofacial rehabilitation: prosthodontic and surgical considerations. St Louis: IshiyakuEuroAmerica; 1996.
2. Beumer J III, Curtis TA, Firtell DN. Maxillofacial rehabilitation: prosthodontic and surgical considerations. St Louis: CV Mosby; 1979.
3. Beumer J III, Marunick MT, Esposito SJ. Maxillofacial Rehabilitation: Surgical and Prosthodontic Management of Cancer-Related, Acquired, and Congenital Defects of the Head and Neck. 3rd ed. Chicago: Quintessence Publishing; 2011.
4. Nishimura RD, Roumanas E, Moy PK, Sugai T. Osseointegrated implants and orbital defects: UCLA experience. J Prosthet Dent. 1998;79(3):304-309.
5. Chrcanovic BR, Albrektsson T, Wennerberg A. Survival and complications of implants to support craniofacial prosthesis: a systematic review. J Craniomaxillofac Surg. 2016;44(10):1536-1552.
6. Karayazgan-Saracoglu B, Gunay Y, Atay A. Treatment outcome of extraoral implants in the craniofacial region. J Craniomaxillofac Surg. 2015;43(5):745-751.
7. Ridwan-Pramana A, Wolff J, Raziei A, Ashton-Milne J. Porous polyethylene implants in facial reconstruction: outcome and complications. J Craniomaxillofac Surg. 2015;43(8):1330-1334.
8. Parnia F, Hafezeqoran A, Mahboub F, Moslehifard E. Tomographic evaluation in patients requiring craniofacial implants. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2010;109(6):e32-e36.
9. Jung JH, Kim YK, Kim SG. Effects of dental implants exposed to the maxillary sinus cavity on sinus complications. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2006;102(5):602-605.
10. Choi JH, et al. Outcome of implants placed to retain craniofacial prostheses: a systematic review. Clin Implant Dent Relat Res. 2022;24(4):567-578.
11. Albrektsson T, Chrcanovic B, Wennerberg A. Long-term outcomes of craniofacial implants for restoration of facial defects. Int J Oral Maxillofac Surg. 2018;47(6):713-720.
12. Sharma S, et al. Treatment outcome and survival rate of bar-clip and magnet-retained auricular prostheses. J Oral Implantol. 2025;51(1):45-52.
13. Patel N, et al. Implant-supported auricular prostheses: current evidence and clinical outcomes. Appl Sci. 2026;16(3):1192.
14. Singh R, et al. Implants for auricular prosthesis – a systematic review. IOSR J Dent Med Sci. 2017;16(11):47-58.
15. Kiat-Amnuay S, Gettleman L, Mekayarajjananonth T, Khan Z. Effect of opacifiers on color stability of maxillofacial silicone elastomer. J Prosthet Dent. 2023;129(5):805-810.
16. Hatamleh MM, Watts DC. Mechanical properties and bonding of maxillofacial silicone elastomers. Dent Mater. 2010;26(2):185-191.
17. Goiato MC, Haddad MF, Pesqueira AA, Moreno A. Color stability of maxillofacial silicone after artificial aging. J Prosthodont. 2012;21(3):205-208.
18. Aziz T, Waters M, Jagger R. Analysis of the properties of silicone rubber maxillofacial prosthetic materials. J Dent. 2003;31(1):67-74.
19. Polyzois GL. Color stability of facial silicone prosthetic polymers after outdoor weathering. J Prosthet Dent. 1999;82(4):447-450.
20. Gary JJ, Smith CT. Pigments and their effect on color stability of silicone prostheses. J Prosthet Dent. 1998;80(3):320-326.
21. Lemon JC, Chambers MS, Wesley PJ, Martin JW. Technique for fabricating a mirror-image prosthetic ear. J Prosthet Dent. 1996;75(3):292-293.
22. Roumanas ED. Freestanding craniofacial implant-retained prostheses. J Prosthet Dent. 2002;88(1):55-62.
23. Toljanic JA, Eckert SE, Roumanas ED, Beumer J. Osseointegrated craniofacial implants in irradiated bone. J Prosthet Dent. 2005;93(6):545-551.
24. Goiato MC, Dos Santos DM, Haddad MF, Pesqueira AA. Patient satisfaction with maxillofacial prostheses. J PlastReconstrAesthet Surg. 2011;64(2):175-180.
25. Chang TL, Garrett N, Roumanas ED, Beumer J. Treatment satisfaction with facial prostheses. J Prosthet Dent. 2005;94(3):275-280.
26. Curi MM, Oliveira MF, Molina G, Cardoso CL. Extraoral implants in craniofacial rehabilitation: long-term follow-up. Int J Oral Maxillofac Surg. 2012;41(3):333-338.

27. Wolfaardt JF, Gehl G, Farmand M, Wilkes GH. Indications and methods for extraoralosseointegrated implants. Int J Oral Maxillofac Implants. 2003;18(3):349-358.
28. Ciocca L, De Crescenzio F, Fantini M, Scotti R. CAD/CAM technologies in maxillofacial prosthodontics: a clinical report. J Prosthet Dent. 2009;102(5):319-322.
29. Bibb R, Eggbeer D, Evans P. Rapid prototyping technologies in soft tissue facial prosthetics. Rapid Prototyp J. 2010;16(2):130-137.
30. Ciocca L, Scotti R. Ocular prosthesis fabrication using rapid prototyping technology. J Prosthet Dent. 2004;92(6):576-579.
31. Eggbeer D, Bibb R, Evans P, Ji L. Evaluation of 3D scanning technologies in facial prosthetics. Proc Inst Mech Eng H. 2007;221(4):469-475.
32. Diment LE, Thompson MS, Bergmann JHM. Clinical efficacy of 3D printing in maxillofacial prosthodontics: a systematic review. Int J Prosthodont. 2017;30(2):182-190.
33. Javaid M, Haleem A. Current status and applications of additive manufacturing in dentistry. J Oral BiolCraniofac Res. 2019;9(3):179-185.
34. Revilla-León M, Özcan M. Additive manufacturing technologies for processing polymers in prosthodontics. J Prosthodont. 2019;28(2):146-158.
35. Javaid M, Haleem A, Singh RP, Suman R. Artificial intelligence applications in prosthodontics. J Oral BiolCraniofac Res. 2021;11(3):355-362.
36. Alharbi N, Osman RB, Wismeijer D. Effects of build direction on mechanical properties of 3D-printed PEEK. J Prosthet Dent. 2016;115(6):760-765.
37. Schwitalla AD, Müller WD. PEEK dental implants: a review of the literature. J Oral Implantol. 2013;39(6):743-749.
38. Mertens C, Hoffmann J. Bioprinting in craniofacial reconstruction: current concepts and future perspectives. J Craniomaxillofac Surg. 2019;47(5):703-710.
39. Chaturvedi S, et al. Implant failure of facial prostheses: systematic review and meta-analysis. J Craniomaxillofac Surg. 2025.
40. Albrektsson T, et al. Bone quality and implant failure: systematic review and meta-analysis. Int J Prosthodont. 2017;30(3):219-227.