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Review article

Contemporary Restorative Approaches in Maxillofacial Prosthodontics: Materials, Retention Systems, and Digital Technologies

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Abstract:

Background: Particularly after head and neck cancers, maxillofacial prosthodontics is essential to the rehabilitation of patients with facial defects brought on by trauma, congenital abnormalities, or surgical resection. The functional and aesthetic results of facial prosthesis rehabilitation have been greatly enhanced by developments in biomaterials, retention systems, and digital technologies.

Objective: The goal of this review is to present a thorough analysis of restorative techniques in maxillofacial prosthodontics, encompassing digital technologies, implant-supported systems, innovative materials, and conventional treatments. **Methods:** With the use of electronic resources including PubMed, Scopus, and Google Scholar, a narrative literature review was carried out. Using predetermined keywords associated with maxillofacial prosthesis, face rehabilitation, prosthetic materials, retention systems, and digital fabrication technologies, peer-reviewed publications published between 2010 and 2024 were filtered. Included were pertinent papers on intraoral and extraoral prosthesis rehabilitation. **Results:** According to available data, acrylic resins are still used in some intraoral applications, but silicone elastomers continue to be the preferred material for extraoral prosthesis because of their better biomechanical and aesthetic qualities. When compared to adhesive-based methods, implant-retained prostheses exhibit better retention, stability, and patient satisfaction. Additionally, the combination of digital processes, three-dimensional printing, and CAD/CAM technology has improved customization, decreased manufacturing time, and increased prosthesis precision.

Conclusion: Digitally driven, patient-specific rehabilitation techniques that prioritize functional restoration, aesthetics, and quality of life have become the norm in modern maxillofacial prosthodontics. The current level of care is represented by the mix of digital technology, dependable retention methods, and improved materials. It is anticipated that future advancements combining tissue engineering and artificial intelligence would significantly alter clinical judgment and prosthetic results.

Keywords: Maxillofacial prosthesis; Facial rehabilitation; Prosthetic materials; Implant retention; CAD/CAM; Digital prosthodontics

Introduction

In maxillofacial rehabilitation, face impairments brought on by trauma, oncologic resections, congenital abnormalities, or infections provide a serious clinical challenge. (1,2) These abnormalities can affect extraoral (like the nose, ear, or orbit) or intraoral (like the palate, maxilla, or tongue) structures, resulting in noticeable facial deformity and functional impairment. (3,4) In addition to anatomical replacement, restoration of these

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complicated abnormalities necessitates functional and aesthetically pleasing reconstruction that is customized for each patient.

Mastication, swallowing, speech, and breathing are all significantly impacted by maxillofacial abnormalities (5,6). Facial disfigurement frequently results in psychological discomfort, social isolation, and a lower quality of life in addition to functional disability (7,8). Restoring both physical function and psychological well-being requires effective prosthesis rehabilitation (9,10).

From early materials to contemporary silicone elastomers and acrylic resins, the history of maxillofacial prosthetics has been chronicled (11,12). Because of their superior biocompatibility and aesthetic qualities, silicone polymers are currently the most commonly utilized (13, 14).

When compared to adhesive devices, implant-supported prostheses have shown better retention and patient satisfaction (15,16).

Recent studies have emphasized the significance of CAD/CAM technology and 3D printing technologies in improving accuracy, customization, and productivity (17). Furthermore, tissue technology and AI are emerging as promising avenues for the field's future (8).

There is little thorough integration of traditional and contemporary restorative approaches under a single organized framework, despite the fact that numerous research has examined materials, retention systems, and digital technologies independently (9,12).

Study Design

This study was designed as a narrative literature review aimed at evaluating contemporary restorative approaches in maxillofacial prosthodontics, with a specific focus on prosthetic materials, retention systems, and digital technologies used in facial rehabilitation.

Search Strategy

A comprehensive electronic literature search was conducted using the following databases: PubMed, Scopus, and Google Scholar. The search was performed to identify relevant peer-reviewed articles published between January 2010 and December 2024.

The search terms were used individually and in various combinations and included: “maxillofacial prosthesis,” “facial prosthetic rehabilitation,” “extraoral prosthesis,” “intraoral prosthesis,” “prosthetic materials,” “implant-retained facial prostheses,” “retention systems,” “CAD/CAM,” “3D printing,” and “digital maxillofacial prosthodontics.”

Inclusion Criteria

Studies were included in the review if they met the following criteria:

- Peer-reviewed articles published in English.
- Studies addressing **intraoral and/or extraoral maxillofacial prostheses.**
- Articles focusing on **prosthetic materials**, **retention mechanisms**, or **digital fabrication technologies.**
- Clinical studies, systematic reviews, narrative reviews, and relevant case series.
- Articles providing clinical, material-based, or technological insights relevant to maxillofacial rehabilitation.

Exclusion Criteria

The following publications were excluded:

- Non-English articles.
- Conference abstracts, letters to editors, and unpublished manuscripts.
- Studies unrelated to prosthetic rehabilitation of maxillofacial defects.
- Articles focusing exclusively on surgical reconstruction without prosthetic involvement.
- Duplicated studies across databases.

Study Selection and Data Extraction

Titles and abstracts of the retrieved articles were initially screened for relevance. Full-text articles were then reviewed to confirm eligibility based on the inclusion and exclusion criteria. Data were extracted regarding prosthetic type, materials used, retention methods, fabrication techniques, and reported clinical outcomes.

Results

Through database searching, 44 articles in all were found. 32 full-text papers were evaluated for eligibility following the elimination of duplicates and the screening of titles and abstracts. Ultimately, 28 studies were included in the qualitative synthesis after meeting the inclusion criteria. Before screening, duplicates were eliminated. The most frequent justifications for full-text exclusion were insufficient information about materials, retention, or digital fabrication, as well as entirely surgical reconstruction without prosthetic results.

Clinical research, systematic reviews, narrative reviews, and case series concentrating on digital fabrication technologies, retention systems, and prosthetic materials made up the chosen studies.

Prosthetic Materials in Maxillofacial Rehabilitation

Silicone Elastomers (RTV vs HTV)

Because of its flexibility, good biocompatibility, and capacity to replicate the texture and contour of skin, silicone elastomers are generally considered the preferred material for the majority of extraoral maxillofacial prostheses. (12-14) Clinically, silicone prosthesis can offer good aesthetics for orbital, nasal, and auricular deformities; however, color stability and marginal integrity continue to have an impact on their long-term performance, especially when exposed to UV light and handled often. (13) In maxillofacial laboratories, room-temperature vulcanizing (RTV) silicones provide useful benefits such as simplicity of handling, quick processing, and compatibility with traditional dental laboratory environments. (12) However, in addition to issues with wettability and surface contamination, RTV materials may exhibit drawbacks such as increased weight, stiffness, and reliance on adhesive systems in certain clinical contexts. (12, 13)

When compared to certain RTV systems, heat-temperature vulcanizing (HTV) silicones are frequently said to have higher color stability and mechanical strength, which could contribute to longer-lasting facial prosthesis. (12) HTV silicone processing, on the other hand, may be more technique-sensitive and necessitate extra reinforcing at thin margins where tearing is a common clinical problem. (12, 13) Generally speaking, while selecting among RTV and HTV silicones, factors including defect location, required edge thickness, expected facial movements, environmental exposure, and available laboratory assets should all be taken into account. (13)

Acrylic Resins

In maxillofacial prosthodontics, acrylic resins (PMMA) are still crucial, especially for intraoral applications like obturators and prosthetic parts that need stiffness and structural support. (5,12) Because acrylic materials are readily available, affordable, and enable both intrinsic and extrinsic coloring, clinicians are accustomed to using them. Additionally, they are rather simple to reline and fix. (12)

However, their rigidity limits their use in highly dynamic extraoral regions where flexibility is required to accommodate functional motions and facial expressions. (12, 13) Clinically speaking, acrylic extraoral prostheses may be less aesthetically pleasing and realistic than silicone alternatives, which may affect patient acceptance in situations involving facial deformities that call for aesthetics. (3,13)

Emerging and Modified Materials

Ongoing material research is addressing the main shortcomings of conventional maxillofacial elastomers, namely, tear strength, minimal durability, and long-term color stability. (13) Polyphosphazenes and silicone block copolymers are new tactics that have been proposed as practical ways to improve resistance to environmental deterioration and wear. Furthermore, reinforced polymers and inorganic fillers have been researched to enhance mechanical performance without compromising patient comfort or weight. (15) Many new materials still lack high-quality long-term clinical confirmation despite promising lab results, and routine clinical acceptability often depends on criteria such as cost, accessibility, technique sensitivity, and patient-specific demands. (12, 13)

Summary (Strengths, Weaknesses, and Clinical Evidence):

When rigidity and reparability are needed for intraoral rehabilitation, acrylic resins can still be helpful, but silicone elastomers provide superior flexibility and aesthetic integration for extraoral abnormalities. (5,12,13) Clinical data currently support silicone, especially in implant-retained or well-retained designs; however, problems including edge ripping, discoloration, and the need for ongoing maintenance persist. (9,13)

3. Retention Systems

Adhesive-Based Retention

For extraoral prostheses, adhesive retention is still a commonly utilized technique, especially in situations when implant insertion is not advised, is not practical, or is rejected by the patient. Sweat, skin oils, tissue movement, and gravity can all affect the clinical efficacy of adhesives, despite the fact that they provide an affordable and non-invasive alternative—particularly in big or heavy prostheses. In reality, skin tolerability, simplicity of application and removal, and consistency of retention during daily activities all have an impact on patient satisfaction. (18)

Mechanical Retention

Magnets, bars and clips, eyeglass frames, and extensions from intraoral prosthesis are examples of mechanical retention techniques. Magnets offer excellent cosmetic concealment, automatic reseating, and convenience of placement; nevertheless, if encapsulation integrity is compromised, corrosion-related degradation and decreased retentive effectiveness may result. (18) For orbital or nasal prosthesis, eyeglass-frame retention can be useful and cost-effective, but it may limit patient convenience and establish a functional dependency on wearing the frame. Although bar-and-clip systems can achieve high retention, they may eventually require maintenance and wear down the retentive components. (18)

Implant-Supported Retention

When compared to adhesives alone, implant-supported retention has grown in popularity because it offers better stability, predictable alignment, and increased patient satisfaction. (9, 16) By reducing daily reliance on adhesives and minimizing prosthesis movement during function, implant-retained prostheses can increase comfort and confidence. (16) However, consequences can include soft tissue problems around the implant, problems with hygiene, and the requirement for component replacement and long-term monitoring. (16, 18)

Comparative Overview (Stability, Longevity, Complications, Patient Satisfaction):

In general, well-designed mechanical retention systems and implant-supported prostheses exhibit the best levels of stability and patient satisfaction, whereas adhesives exhibit greater variability based on skin conditions and defect anatomy. (13, 16, 18) Longevity is typically increased because implant-based retention lessens marginal stress and displacement; nonetheless, biological issues and implant-associated care must be considered. (16, 18) Adhesive solutions have been associated with higher retention failure rates in humid or mobile environments and may irritate the skin of sensitive patients. (18)

4. Digital Technologies

CAD/CAM

By facilitating digital impression acquisition, virtual design, and controlled manufacture, CAD/CAM technologies have greatly improved the precision and personalization of maxillofacial prostheses. (17) The computerized method supports improved fit and symmetry in facial prosthetics by lowering manual variability and enabling iterative refining before production. (17)

3D Printing

Complex anatomical forms, substructures, and prototypes may now be produced more precisely and in less time thanks to three-dimensional printing. In the clinical setting, 3D printing facilitates quick prototyping, enhanced reproducibility, and patient-specific design—especially helpful for intricate orbital, nasal, or auricular deformities. (17)

Digital Workflow

Digital workflows that include scanning, virtual design, and additive or subtractive manufacturing can improve communication between the technical and clinical teams while cutting down on laboratory remakes and clinical chairside time. Additionally, digital storage and duplication are made easier by these workflows, which may be useful for prosthesis replacement or modification in the future. (17)

AI and Future Integration

It has been suggested that artificial intelligence can help with data-driven analysis to improve decision-making, automate design processes, and forecast the ideal prosthesis outlines. Even though they are still in their infancy, AI-assisted systems have the potential to increase personalization, decrease operator-dependent variability, and improve standardization—especially when combined with digital scanning and production systems.

Comparative Overview (Accuracy, Fabrication Time, Cost, Clinical Acceptance):

In comparison to traditional operations, digital technologies typically save manufacturing time while increasing accuracy and customization. (17) However, larger implementations may be hampered by the initial cost and the requirement for specialist equipment and training, especially in situations with limited resources. (17) As Table 1 shows, clinical acceptance is increasing as digital technologies offer consistent fit and aesthetic results, despite the need for more study on long-term comparative data and standardized methodologies.

Table 1. Comparative Overview of Contemporary Restorative Approaches in Maxillofacial Prosthodontics

Category	Type	Main Advantages	Main Limitations	Clinical Performance	Patient Satisfaction
Prosthetic Materials	RTV Silicone	Easy processing; good aesthetics; laboratory friendly	Edge tearing, weight, and color instability	Suitable for extraoral defects; moderate durability	Good when well-maintained
	HTV Silicone	Higher mechanical strength; better UV stability	Technique sensitive; reinforcement needed	Better long-term durability than RTV	High when retention is adequate

	Acrylic Resin	Rigid; cost-effective; easy repair	Poor flexibility; limited esthetics in extraoral use	Ideal for intraoral prostheses	Moderate to high (intraoral cases)
	Emerging Materials	Improved tear resistance; enhanced stability	Limited long-term clinical evidence	Promising but not widely standardized	Yet to be fully evaluated
Retention Systems	Adhesive-Based	Non-invasive; economical	Variable retention; skin irritation; sweat sensitivity	Lower stability in large defects	Variable; depends on patient compliance
	Mechanical (Magnets, Bars)	Improved positioning; no surgery required	Corrosion risk; wear of components	Moderate stability	Moderate to high
	Implant-Supported	Excellent stability; predictable positioning	Surgical intervention; maintenance needs	Highest long-term stability	Highest satisfaction rates
Digital Technologies	CAD/CAM	High accuracy; customization; reproducibility	Initial equipment cost	Improved marginal fit	Increasing acceptance
	3D Printing	Rapid prototyping; complex anatomy fabrication	Material limitations in some systems	Reduced fabrication time	High when esthetics achieved
	Digital Workflow	Better clinician–technician communication	Learning curve	Improved workflow efficiency	Positive acceptance
	AI Integration	Design automation; predictive modeling	Emerging technology; limited validation	Promising future application	Not yet widely implemented

When compared to adhesive and traditional mechanical techniques, implant-supported retention systems show better stability and long-term performance. While digital technologies continue to improve accuracy and productivity in fabrication processes, silicone elastomers continue to be the material of choice for extraoral rehabilitation.

Discussion

With a focus on prosthetic materials, retention techniques, and digital technology, the current narrative review offers an updated synthesis of modern restorative treatments in maxillofacial prosthodontics. The results show that in order to maximize function, appearance, and patient-centered outcomes, contemporary rehabilitation methods are depending more and more on a multidisciplinary, technologically advanced framework. (19)

Because of their flexibility, skin-like texture, and advantageous esthetic integration, silicone elastomers continue to rule the extraoral rehabilitation market for prosthetic materials. Despite variations in performance due to processing techniques and clinical specifications, both RTV and HTV silicones possess clinically acceptable properties. RTV systems provide more laboratory accessibility and simplicity of manufacturing, whereas HTV silicones typically show better mechanical strength and color stability. Even though silicone prostheses are used extensively, their lifetime may be jeopardized by marginal ripping, environmental deterioration, and long-term discoloration. On the other hand, acrylic resins continue to play a useful function in intraoral prosthesis, especially obturators, where cost-effectiveness, structural rigidity, and ease of repair are crucial. However, their rigidity restricts their use in dynamic extraoral areas. Emerging materials and reinforced polymer systems show promising laboratory performance; however, high-quality long-term clinical data remain insufficient to establish them as definitive alternatives. (20)

One important factor in determining the success of prosthetics is retention systems. According to the review's conclusions, implant-supported prostheses outperform adhesive-based or solely mechanical systems in terms of stability, predictable location, and patient satisfaction. Osseointegration improves functional dependability and patient confidence by increasing retention and decreasing prosthesis displacement during facial movement. However, implant therapy may not be appropriate for patients with limited resources or medical conditions because it necessitates surgical intervention, sufficient bone volume, and long-term maintenance. Although perspiration, gravity, skin diseases, and defect size may affect retention dependability, adhesive-based retention is still a feasible and non-invasive approach, especially when surgery is not recommended. When adequately designed, mechanical systems—such as magnets and bar-clip attachments—provide intermediate stability and can be effective; nonetheless, potential concerns include component degradation and corrosion. (20)

Digital technology has significantly transformed the procedures for maxillofacial prosthetics. CAD/CAM systems enhance accuracy in defect assessment and prosthesis design by reducing operator-dependent variability and boosting reproducibility. Three-dimensional printing enables the production of complex anatomical structures and rapid prototyping that would be difficult to achieve using conventional methods. Digital workflow integration speeds up fabrication, improves clinician-technician communication, and makes digital storage easier for future replication or modification. Despite these advantages, material limitations, software learning curves, and initial equipment costs remain barriers to broader usage, particularly in developing healthcare systems. Automation design optimization and prosthetic plan should benefit from artificial intelligence, but clinical validation is still in its infancy, and there are currently no widely used techniques. (21)

Clinical planning for maxillofacial prosthodontic treatment should remain individualized. Defect dimensions, tissue mobility, aesthetic desires, patient ability, systemic health, and socioeconomic challenges must all be taken into account while choosing and storing materials. Integration of digital technologies should complement clinical judgment and prosthodontic knowledge, not replace it. Ultimately, long-term follow-up care and psychological adjustment are just as crucial to the success of maxillofacial therapy as material quality and mechanical stability. (22)

This review is subject to some limitations. Being a narrative review, it is devoid of a quantitative meta-analysis and a comprehensive risk-of-bias evaluation. The design, outcome measurements, and follow-up time of the included trials vary, making direct comparisons between therapies difficult. Furthermore, some findings may become essential because technological advances are always evolving. (21)

Future research should focus on standardized digital fabrication procedures, retention system comparisons, and long-term clinical trials evaluating novel biomaterials. Additionally, further investigation into tissue engineering methods and AI applications may result in ground-breaking prospects for both practical and cosmetic rehabilitation.

Conclusion

The multidisciplinary, cutting-edge specialty of modern maxillofacial prosthodontics places a strong emphasis on functional rehabilitation, aesthetic integration, and patient-centered outcomes. While silicone elastomers remain the material of choice for most extraoral applications because of their superior flexibility and cosmetic features, acrylic resins continue to play important roles in intraoral prostheses that require structural strength. Among retention strategies, implant-supported systems offer the best stability and patient satisfaction; however, while making therapeutic decisions, one must take into account the unique characteristics of each patient, their maintenance requirements, and the viability of surgery.

The combination of digital processes, 3D printing, and CAD/CAM technologies has significantly increased the precision, repeatability, and efficiency of manufacturing. Despite these advancements, problems with long-term clinical validation, cost, and material durability persist. Future developments are expected to be driven by improved biomaterials, standardized digital protocols, and the application of artificial intelligence to enable prosthetic customization and planning.

Successful maxillofacial rehabilitation ultimately depends on individualized treatment planning that strikes a balance between material science, biomechanical stability, and digital innovation in order to restore function and quality of life.

Conflict of Interest: NIL

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