Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol.14 , Issue 13s (2025)
https://www.jneonatalsurg.com

Advances in Dental Materials and Their Impact on Prosthetic Outcomes

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Cite this paper as: Mane Hashan Mohammed Almunajjim (2025) Advances in Dental Materials and Their Impact on Prosthetic Outcomes. Journal of Neonatal Surgery, 14, (13s) 1434-1438

Received -5-04-2025 , Revised - 10-04-2025 , Accepted - 15-04-2025 , Available Online-24-04-2025

ABSTRACT

Dental prosthetics have undergone remarkable advancements over the past two decades due to innovations in biomaterials, digital dentistry, and manufacturing technologies. Modern dental materials not only restore aesthetics but also improve mechanical performance, biocompatibility, longevity, and patient satisfaction. The introduction of high-strength ceramics, advanced resin composites, bioactive materials, and computer-aided design/computer-aided manufacturing (CAD/CAM) technologies has transformed prosthodontic treatment outcomes. This review discusses the evolution of contemporary dental materials, evaluates their mechanical and biological properties, and examines their influence on prosthetic success. Additionally, recent developments such as nanotechnology, bioactive ceramics, and additive manufacturing are explored, highlighting their future potential in personalized prosthodontics..

Keywords: Dental materials, Prosthodontics, CAD/CAM, Zirconia, Lithium disilicate, Biomaterials, Digital dentistry, Bioactive materials..

INTRODUCTION

Prosthodontics aims to restore oral function, aesthetics, and patient quality of life through the replacement of missing or damaged teeth. The success of prosthetic rehabilitation largely depends on the physical, chemical, and biological characteristics of the restorative materials employed.

Historically, dental prostheses relied on metal alloys and feldspathic porcelain, which often required compromises between aesthetics and mechanical strength. The emergence of advanced ceramic systems, reinforced polymers, nanocomposites, and digital manufacturing techniques has dramatically improved prosthetic performance.

Recent developments have enabled clinicians to select materials tailored to individual clinical conditions, thereby improving long-term clinical outcomes while reducing complications such as chipping, fracture, wear, and biological incompatibility.

2. EVOLUTION OF DENTAL PROSTHETIC MATERIALS

The development of dental materials has progressed through several stages:

Gold alloys

Base metal alloys

Porcelain-fused-to-metal (PFM)

Glass ceramics

Lithium disilicate ceramics

Zirconia ceramics

High-performance polymers (PEEK)

Bioactive restorative materials

Nanotechnology-enhanced composites

Each generation has attempted to overcome the limitations of previous materials regarding strength, esthetics, and biological integration..:

3. CONTEMPORARY DENTAL MATERIALS

3.1 Zirconia

Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) has become the material of choice for posterior crowns, implant-supported restorations, and long-span fixed prostheses.

Advantages include:

High fracture toughness

Excellent flexural strength (>1000 MPa)

Low wear

High biocompatibility

CAD/CAM compatibility

Limitations include:

Limited translucency in early generations

Veneering porcelain chipping

New translucent zirconia generations have significantly improved aesthetics while maintaining adequate strength.

3.2 Lithium Disilicate Ceramics

Lithium disilicate combines superior aesthetics with moderate mechanical strength.

Characteristics:

Flexural strength: approximately 360–500 MPa

Excellent translucency

Strong adhesive bonding

Ideal for anterior crowns and veneers

Clinical studies demonstrate survival rates exceeding 95% after ten years.

3.3 Resin-Based CAD/CAM Blocks

Hybrid ceramics and resin nanoceramics provide:

Elastic modulus similar to dentin

Reduced brittleness

Easier repair

Shock absorption

These materials are increasingly used for minimally invasive restorations.

3.4 Polyetheretherketone (PEEK)

PEEK has gained attention because of:

Lightweight structure

Low plaque accumulation

High fatigue resistance

Excellent biocompatibility

Applications include:

Implant abutments

Removable partial denture frameworks

Maxillofacial prostheses

4. BIOACTIVE DENTAL MATERIALS

Bioactive restorative materials interact positively with surrounding tissues.

Examples include:

Bioactive glass

Calcium silicate cement

Glass ionomer derivatives

Hydroxyapatite-containing composites

Benefits:

Remineralization

Antibacterial activity

Improved dentin sealing

Reduced secondary caries

5. NANOTECHNOLOGY IN DENTAL MATERIALS

Nanotechnology has significantly improved restorative materials by incorporating nanoparticles such as:

Nano-silica

Nano-zirconia

Nano-hydroxyapatite

Silver nanoparticles

These enhance:

Wear resistance

Surface polishability

Mechanical strength

Antibacterial properties

Color stability

6. DIGITAL DENTISTRY AND CAD/CAM TECHNOLOGY

Digital workflows have revolutionized prosthodontics through:

Intraoral scanning

Virtual design

CAD/CAM milling

3D printing

Advantages include:

Improved marginal accuracy

Reduced chairside time

Better patient comfort

Enhanced reproducibility

Clinical evidence indicates significantly lower remake rates compared with conventional workflows.

7. 3D PRINTING IN PROSTHODONTICS

Additive manufacturing has expanded rapidly.

Applications include:

Surgical guides

Temporary crowns

Denture bases

Custom trays

Implant models

Emerging printable ceramic materials may eventually replace conventional milling for definitive prostheses.

8. BIOLOGICAL PERFORMANCE

Ideal prosthetic materials should exhibit:

Biocompatibility

Low bacterial adhesion

Minimal inflammatory response

Color stability

Resistance to hydrolysis

Chemical stability

Surface modifications now enhance soft tissue integration around implant-supported restorations.

9. CLINICAL IMPACT ON PROSTHETIC OUTCOMES

Modern materials contribute to:

Increased restoration longevity

Lower fracture rates

Better esthetics

Improved patient satisfaction

Reduced maintenance

Higher implant success

Better periodontal response

Long-term studies consistently report survival rates exceeding 90–95% for contemporary ceramic restorations.

Table 1. Comparison of Contemporary Dental Prosthetic Materials

Material	Flexural Strength (MPa)	Esthetics	Biocompatibility	Common Applications	Major Advantages
Zirconia	900–1500	High	Excellent	Crowns, bridges, implant prostheses	High strength, fracture resistance
Lithium Disilicate	360–500	Excellent	Excellent	Veneers, anterior crowns	Superior translucency
PFM	90–120 (porcelain)	Moderate	Good	Long-span bridges	Proven long-term durability
Resin Nanoceramic	200–300	High	Good	Inlays, onlays, single crowns	Shock absorption, repairability
PEEK	170–250	Moderate	Excellent	Frameworks, implant abutments	Lightweight, low plaque accumulation

Material	Flexural Strength (MPa)	Esthe tics	Biocompa tibility	Common Applications	Major Advantages
Bioactive Glass Materials	Variable	Mode rate	Excellent	Liners, restorations	Remineralization and antibacterial activity

10. FUTURE PERSPECTIVES

Future prosthetic dentistry will likely incorporate:

Smart biomaterials

Self-healing restorative materials

Antibacterial nanocoatings

AI-assisted material selection

Personalized biomaterials

Stem cell-enhanced prosthetics

Fully printable ceramic restorations

The convergence of biomaterials science and digital technologies will continue to redefine prosthetic rehabilitation.

11. CONCLUSION

Advances in dental materials have substantially improved prosthetic outcomes by enhancing mechanical durability, aesthetics, and biological compatibility. High-performance ceramics such as zirconia and lithium disilicate remain the gold standard for many fixed prosthetic applications, while bioactive materials, nanotechnology, and digital manufacturing are shaping the future of restorative dentistry. Continued interdisciplinary research integrating materials science, biotechnology, and artificial intelligence is expected to further optimize personalized prosthodontic care and improve long-term clinical success.

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