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REVIEW

Evaluating the Pros and Cons of Common Dental Polymers in Dentistry: Review

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ABSTRACT

Dental polymers play a central role in modern dentistry, offering versatility in applications ranging from removable dentures and prosthetic frameworks to implant abutments and bioactive scaffolds. Common materials like PMMA, PEEK, and nylon are valued for their formability, cost-effectiveness, and aesthetic properties, while emerging biopolymers including chitosan and alginate offer promising biocompatible alternatives. However, both conventional and bio-based polymers exhibit limitations in terms of chemical stability, mechanical wear, and microbial adhesion. Recent advancements in polymer science have expanded the material palette through innovative biopolymer formulations and advanced surface engineering techniques such as antimicrobial coatings and nanocomposites, introducing novel solutions for improving polymer performance across both synthetic and biological material categories. Clinical and preclinical findings suggest that incorporating drug delivery systems, modifying surface topography, and using biofunctional materials can reduce biofilm formation and enhance osseointegration. Still, persistent issues related to polymer degradation, cytotoxicity, and bonding challenges limit broader clinical adoption. This review explores the current understanding of polymer applications in dentistry, identifies critical limitations, and highlights innovative strategies aimed at improving safety, longevity, and biological functionality in polymer-based dental systems.

Keywords: Bacterial adhesion, Antimicrobial coatings, Prosthodontics, Biofilm, Surface modification

1. Introduction

Dental polymers are resins for dental fillings, braces, dentures, and other water-insoluble resins [1]. Usually, they're some type of plastic that's mixed with other materials to create a hard, tooth-like appearance that lasts a long time. Most dentists use some form of polymer in at least some of their cosmetic dental work. There are different types and brands of dental polymers, but it gets its name from mixing several different materials together to make a filling. The physical properties of polymers are affected by temperature and environmental changes as well as the composition, structure, and molecular weight of the polymer [2]. In general, the higher the

temperature, the softer and more brittle the polymer becomes [3].

Denture plastics can be divided into different groups according to the type of hardening. In general, there are thermoset materials, self-polymerizing materials, thermoplastic materials, light-activated materials, and microwave-curable materials [4]. Among them, polymethyl methacrylate (PMMA) is an important material in dental laboratories (for the manufacture of orthodontic retainers and dentures and for restorations) [5], dental offices (for relining of dentures and temporary crowns) and in industry [6]. The most used polymers in dental implants (such as the manufacture of artificial teeth), while regarding crowns and bridges, crowns made of metal veneers

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are the most popular type of tooth-colored crowns [7].

Despite extensive advancements in dental polymer research and development, significant gaps remain in achieving optimal long-term biocompatibility, antimicrobial efficacy, and mechanical performance under oral conditions. Although materials like PMMA, PEEK, and nylon are widely used in prosthodontics and implantology, their susceptibility to microbial adhesion, chemical degradation, and mechanical wear poses ongoing clinical challenges. Furthermore, while emerging strategies such as antimicrobial coatings and biopolymer-based scaffolds show promise, clinical data supporting their long-term safety and effectiveness remains limited. Thus, there is a pressing need for more translational research bridging material science innovations with real-world clinical outcomes in dentistry.

1.1. Non-biopolymers and their roles in dental fields

The foundation of modern dental practice relies heavily on non-biopolymer materials, which encompass a diverse range of synthetic and inorganic substances engineered for specific dental applications. These materials have been extensively developed and refined over decades to meet the demanding mechanical, chemical, and biological requirements of the oral environment [8]. Metallic materials represent one of the most established categories of non-biopolymer dental materials, valued for their exceptional mechanical properties and long-term clinical performance [9].

Cobalt-chromium alloys have emerged as preferred materials for removable partial denture frameworks and implant superstructures [10]. These alloys offer superior wear resistance compared to stainless steel and demonstrate excellent biocompatibility in the oral environment. The high elastic modulus of cobalt-chromium alloys makes them particularly suitable for applications requiring minimal deformation under occlusal loads, while their corrosion resistance ensures long-term stability in the presence of saliva and bacterial metabolites [11]. Titanium and its alloys have revolutionized implant dentistry through their unique combination of mechanical strength, corrosion resistance, and osseointegration properties [12]. Pure titanium (Grade 1-4) and titanium alloys, particularly Ti-6Al-4V, demonstrate exceptional biocompatibility due to the formation of a stable oxide layer that prevents metal ion release and promotes direct bone-to-implant contact [13]. Ceramic materials have gained prominence in restorative dentistry primarily due to their aesthetic properties and chemical stability [14]. Porcelain, composed primarily of

feldspar, quartz, and kaolin, has been the gold standard for dental ceramics due to its ability to mimic the optical properties of natural tooth enamel [15]. The material's high hardness and wear resistance make it suitable for crown and bridge applications, though its brittleness requires careful consideration in high-stress areas.

1.2. Biopolymers and their roles in dental fields

Recent investigations provide compelling clinical and preclinical evidence underscoring the efficacy of biopolymers; particularly chitosan and alginate; in dental regenerative applications as shown in Fig. 1. A 2021 randomized clinical trial demonstrated that incorporating chitosan nanohydrogel into bone grafts led to significantly greater improvement in clinical attachment levels for chronic periodontitis patients (a mean CAL reduction from 8.7mm to 1.6mm) compared to graft alone, indicating enhanced periodontal regeneration [16]. However, a separate 2021 study on chitosan particles in three-wall intrabony periodontal defects found no statistically significant advantage over conventional flap surgery after 12 months, highlighting the variability of outcomes depending on formulation and delivery method [17]. Meanwhile, a 2025 in vitro review on chitosan-based barrier membranes for guided tissue/bone regeneration confirmed favorable properties—biocompatibility, biodegradability, antimicrobial function—and highlighted ongoing advancements in composite and gradient membrane designs [18].

On the bioprinting front, a 2019 study demonstrated that 3D-printed alginate–gelatin scaffolds significantly enhanced adhesion, proliferation, and osteogenic differentiation of human dental pulp stem cells; marked by elevated alkaline phosphatase activity and mineralization gene expression; surpassing non-printed controls [19]. Additionally, a 2025 experiment using allograft–alginate–gelatin scaffolds coated with stromal vascular fraction and platelet-rich fibrin showed in vitro osteogenic potential, supporting the use of alginate-based hydrogels for bone tissue engineering [20]. These findings align with broader reviews reporting alginate's favorable printability, mechanical tunability, and controlled drug-release behavior; critical features for dental scaffold applications [21].

Acrylate polymers are a group of polymers made from acrylate monomers [22]. They are also commonly known as acrylics or polyacrylates [23]. These plastics are characterized by transparency, breaking strength, and elasticity [24]. It allows for repositioning of the base when the supporting tissue changes,

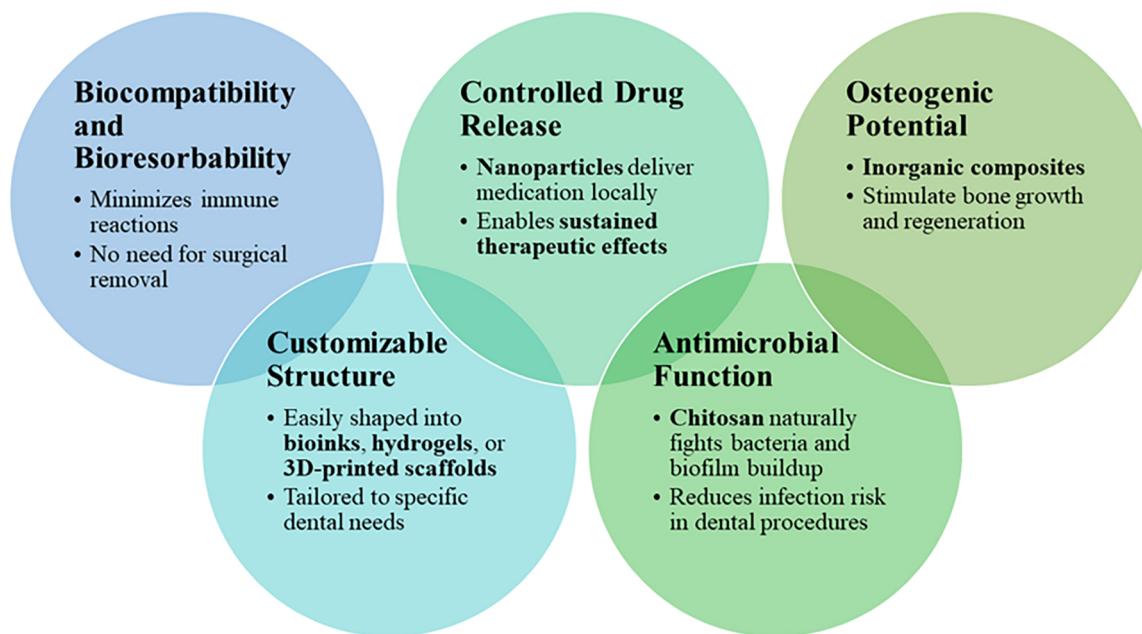


Fig. 1. Benefits of biopolymers in dentistry.

is aesthetically superior to metal bases, and is easier to repair. But it has less detrimental effect on dimensional stability than metal-based warping and less strength than metal - large spans, porous hygiene, and low thermal conductivity [25]. PMMA is the scientific name for a synthetic polymer commonly known as acrylic, acrylic glass, and plexiglass [26]. If not modified, it is brittle, transparent, and light. It is translucent and can be modified to provide a variety of cast color options, textures, and shapes.

Polyetheretherketone (PEEK) is a colorless organic thermoplastic polymer belonging to the polyaryletherketone (PAEK) family used in engineering and medicine [27]. Due to its aesthetic properties [28], it is considered an alternative to traditional dental materials and is a scientifically recognized material [29]. Restoratively, it can be used for removable partial dentures, fixed partial dentures, implants, abutments, implant crowns, and restoration of maxillofacial defects [30].

PEEK and its composites are emerging as promising alternatives to traditional implant materials in dentistry due to their bone-like elasticity, radiolucency, and biocompatibility [31]. Finite element analyses demonstrate that carbon fiber-reinforced PEEK (CFR-PEEK) implants generate equivalent stress on supporting bone under vertical loads and significantly lower lateral stress under oblique loads compared to titanium, suggesting reduced crestal bone loss [32]. Among CFR-PEEK formulations, those with ~60% carbon fiber show more uniform stress distribution in peri-implant bone than both titanium

and lower fiber-content variants [33]. However, pure PEEK abutments exhibit higher fixture stresses and lower biomechanical performance than titanium, underscoring the need for reinforcement or surface engineering [34]. While the overall literature reflects PEEK's favorable mechanical compatibility, a recent scoping review found limited clinical evidence and uncertain long-term outcomes, especially in implant prosthodontics [35].

1.3. Bacterial adhesion on dental polymers

Although reinforcing PEEK with ceramics (BioHPP) does not significantly reduce biofilm formation according to Lee et al., 2018 [36], chemical grafting of PMMA with pHEMA or PEGMA improves resistance to *E. coli* and *S. mutans*, with pHEMA showing slightly better performance due to higher hydrophilicity and negative surface charge. However, these benefits are not statistically significant under salivary pellicle conditions. Also, beyond the work of Bächle et al. in 2023 on manufacturing impacts, several other studies highlight nuanced strategies to reduce bacterial adhesion on dental polymers [37]. In another notable case, Ishihama et al. in 2021 applied ionic silver nanoparticle coatings to PEEK implants and demonstrated dramatic bactericidal activity in vitro, with near-complete prevention of biofilm formation and absence of infection in vivo in a murine soft-tissue model [38]. In terms of polymer modification beyond coatings, Acet et al. in 2023 attached

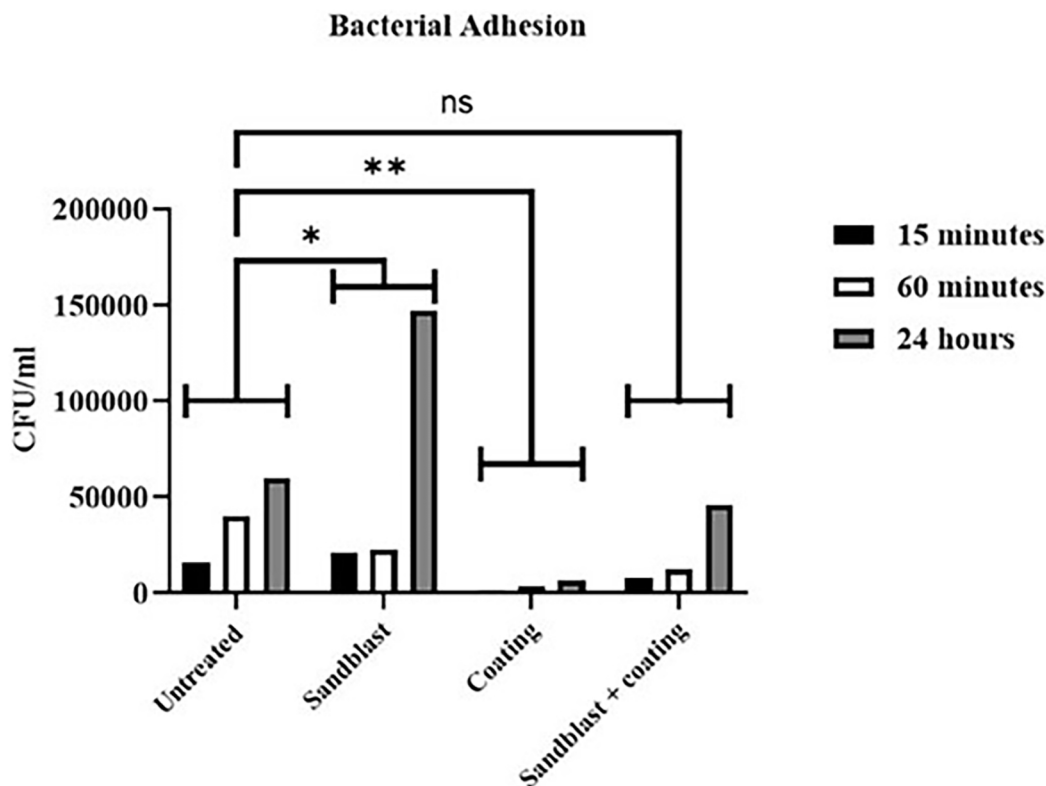


Fig. 2. Pt coating reduces bacterial adhesion on sandblasted PEEK, enhancing antimicrobial performance significantly.

epigallocatechin gallate (EGCG) to p(HEMA-co-GMA) membranes, achieving a dose-dependent inhibition of *S. aureus* adhesion—up to 71% at 1,000 $\mu\text{g}/\text{mL}$ after 4h exposure [39]. Lastly, Singh et al. in 2024 conducted a clinical split-mouth trial comparing milled versus self-cure acrylic crown materials, showing significantly lower *Streptococcus mutans* counts on milled PMMA at both 1 and 3 weeks ($p < 0.005$) [40]. Faadhila et al. in 2024 investigated the effects of surface modifications on bacterial adhesion and stability of PEEK implants [41]. Their study showed that sandblasting increased surface roughness ($R_a \approx 1.2\mu\text{m}$), enhancing mechanical stability but significantly increasing bacterial adhesion after 24 hours as shown in Fig. 2. However, when a platinum (Pt) sputter coating was applied after sandblasting, bacterial adhesion was reduced by approximately 67%, without compromising cell viability. The combined sandblast + Pt coating treatment achieved bacterial adhesion levels statistically similar to untreated PEEK, demonstrating an effective balance between improved implant stability and reduced microbial colonization.

Collectively, these studies underscore that microbial adhesion is not only governed by base material and roughness but also by surface treatments; including ion coatings, bioactive molecule attachment, and advanced manufacturing; offering critical path-

ways to enhance hygiene and longevity of dental polymers.

1.4. Antibiofilm and antimicrobial polymer coatings in dentistry

Antibiofilm and antimicrobial polymer coatings have emerged as a critical frontier in dental implantology, addressing the persistent challenge of biofilm-associated infections that often lead to implant failure [42]. According to Heydariyan et al. (2023), bacterial colonization and biofilm formation on dental implants not only compromise osseointegration but also hinder systemic antibiotic efficacy due to poor local bioavailability [43]. Their comprehensive review highlights several strategies to counteract these issues, including polymer-based local drug delivery, metal/metal oxide nanoparticle coatings, and antimicrobial peptides [44]. In a related study, Shakerinasab et al. (2025) developed a SiO_2/ZnO nanocomposite coating on yttria-stabilized tetragonal zirconia [45], demonstrating a 70% reduction in biofilm formation by *Enterococcus faecalis* and improved hardness, without compromising cytocompatibility—marking a major advancement in dual-function implant coatings. Similarly, Xing et al. in 2024 introduced a renewable N-halamine

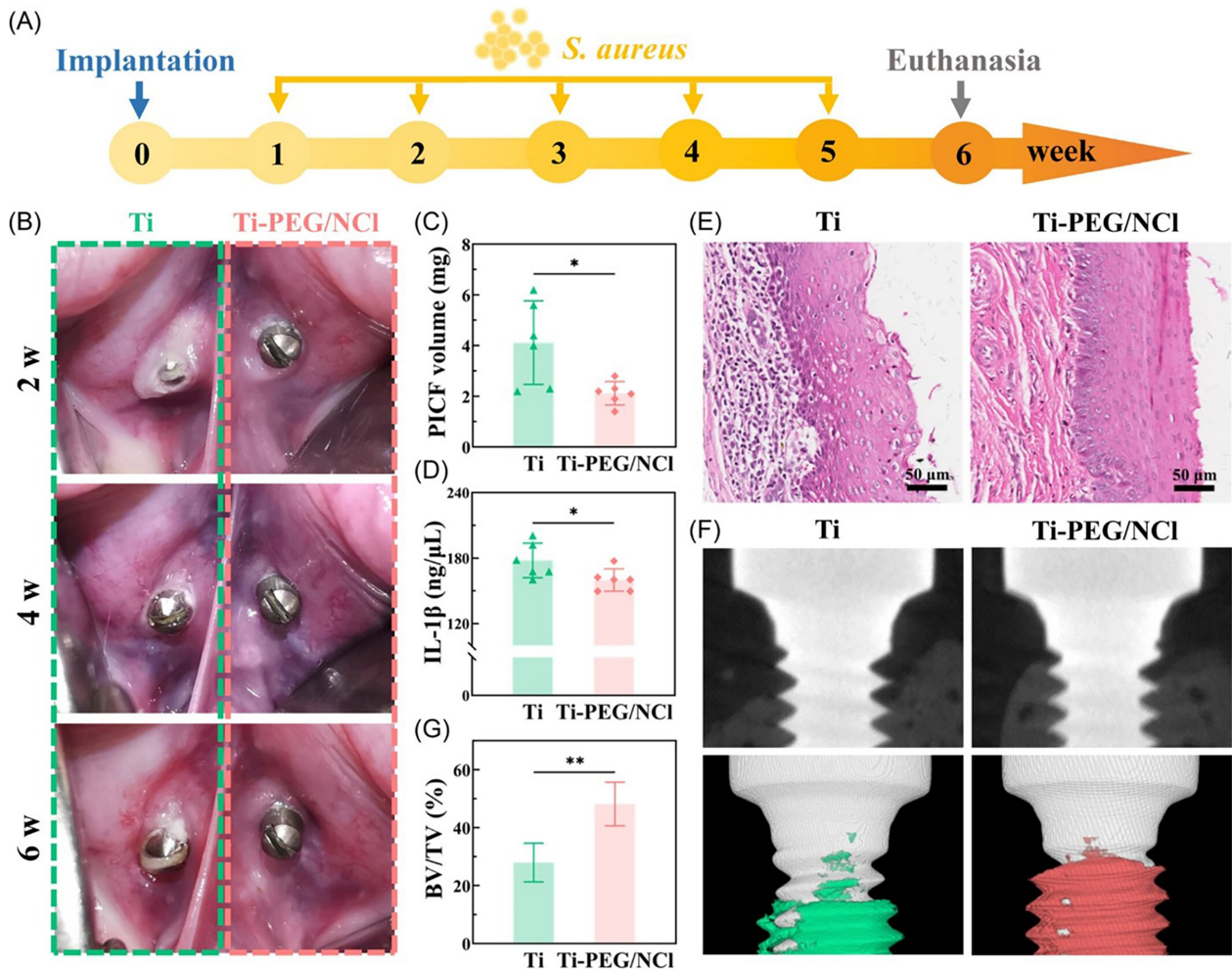


Fig. 3. (A) outlines a 6-week study timeline. Clinical images (B) show reduced inflammation around Ti-PEG/NCl implants compared to uncoated titanium. Quantitative analysis revealed significantly lower peri-implant crevicular fluid (PICF) volume (C) and IL-1 β levels (D) in the coated group ($p < 0.05$), indicating reduced inflammation. Histological staining (E) confirmed milder tissue response in the Ti-PEG/NCl group. Micro-CT scans and 3D reconstructions (F) demonstrated improved bone preservation around coated implants, supported by a significantly higher bone volume-to-total volume ratio (BV/TV) (G) ($p < 0.01$).

polymer coating for dental unit waterlines [46], which maintained antimicrobial activity via active chlorine release and electrostatic repulsion, significantly preventing biofouling over time. Building on this innovation, Li et al. in 2024 engineered a coral-inspired therapeutic abutment integrating polyethylene glycol and N-halamine for sustained anti-biofilm performance [47]. These abutments not only prevented peri-implant infection but also allowed for localized re-treatment and reuse, offering a sustainable and clinically adaptable solution. Their in vivo evaluation in a rabbit model demonstrated clear benefits: the experimental timeline Fig. 3 included bacterial inoculation and observation over six weeks; clinical images (B) showed visibly reduced inflammation around Ti-PEG/NCl abutments compared to uncoated titanium; quantification of peri-implant crevicular fluid (PICF) volume (C) and IL-1 β levels

(D) confirmed significantly lower inflammation in the coated group ($p < 0.05$); histological staining (E) revealed less inflammatory cell infiltration; micro-CT imaging and 3D reconstruction (F) showed more preserved bone surrounding the coated implants; and bone volume fraction (BV/TV) analysis (G) confirmed significantly enhanced bone regeneration ($p < 0.01$). These results collectively validate the dual function of the Ti-PEG/NCl coating in both antibacterial defense and peri-implant tissue preservation.

Furthermore, Sahoo et al. in 2023 emphasized the broader potential of nanomaterial-based coatings—including metal, metal oxide [48], and 2D nanomaterials—on dental and biomedical implants, as these materials exhibit powerful antimicrobial activity through oxidative stress induction, membrane disruption, and metal ion release. Collectively, these studies underscore the shift

Table 1. Summary of recent antimicrobial polymer coatings and their efficacy against dental pathogens.

Coating Type	Effective Against	Characteristics & Findings
Ti + Ag/Cu/Zn coatings	Peri-implant pathogens	In vivo studies show Ti implants with Ag, Zn, Cu significantly reduce bacterial colonization and peri-implant inflammation while preserving tissue response.
ZnO–Ag nanocomposite	<i>P. aeruginosa</i> biofilms	ZnO–Ag on Ti6Al4V inhibited biofilm formation by >60% in vitro; synergizes both prevention and disruption.
SiO ₂ /ZnO layer	Mixed oral microbiota	Anti-fouling co-sputtered SiO ₂ /ZnO on zirconia significantly decreased multispecies biofilm adhesion in vitro.
N-halamine polymer	<i>S. aureus</i> , <i>P. gingivalis</i>	Coating on Ti implants achieved 96% bactericidal effect sustained 12–16 weeks and could be recharge-activated, demonstrating long-term antimicrobial capacity.
PMMA/ZnO–Ag composite	Broad oral pathogens (<i>C. albicans</i> , <i>S. mutans</i>)	PMMA with ZnO/GO increased mechanical strength (+23–31%) and reduced microbial colonies by up to 60%; retained effect after aging.
ZnO–GO nanocomposite in PMMA	<i>C. albicans</i> & bacteria	Study shows 0.2wt% ZnO/GO decreased bacterial colonies by ~60%, improved hydrophilicity, and maintained cytocompatibility.

toward smart, multifunctional, and bioresponsive coatings that can sustainably prevent infection, enhance osseointegration, and align with modern trends in minimally invasive, regenerative dental therapies. Table 1 compiles key in vitro and in vivo findings on antimicrobial polymer-based coatings, including metal and metal oxide nanoparticles (Ag, Cu, Zn) [49], nanocomposites (ZnO–Ag, ZnO–GO) [50], and polymeric systems (N-halamine). Coatings were effective against a range of oral pathogens *S. mutans*, *C. albicans*, *P. gingivalis*, and *P. aeruginosa* demonstrating significant biofilm reduction (up to 96%), mechanical property enhancements, and sustained antimicrobial activity over time.

1.5. Challenges and limitations of dental polymers

Despite significant advancements in polymer-based dental materials, several biological, mechanical, and chemical challenges continue to inhibit their broader clinical adoption [51]. These issues range from material degradation and toxicity to poor bioactivity and suboptimal mechanical performance.

2. Chemical degradation & toxicity

Polymers used in dental applications are exposed to dynamic and often harsh oral conditions, including fluctuating pH, enzymatic activity, and thermal cycling, which can lead to chemical degradation over time [52]. Materials such as PMMA, PEEK, and nylon, though widely used in prosthodontics and removable dentures [53], are not entirely immune to these degradative processes [54]. As discussed by Tigmeanu et al. in 2022, additive manufacturing enables the rapid fabrication of personalized polymer-based restorations; however, the layer-by-layer approach can create internal stresses and microvoids that accelerate degradation in the moist oral environ-

ment [55]. Residual monomers released from PMMA during polymerization or degradation may lead to cytotoxicity, mucosal irritation, or hypersensitivity reactions, especially in patients with prolonged denture wear [56]. Likewise, although PEEK and nylon fiber are more chemically stable and exhibits improved mechanical durability [57]. They are still vulnerable to long-term hydrolytic aging and surface oxidation, which may compromise its inertness and lead to the release of trace degradation byproducts (Muhsin et al., 2019) [58]. The biocompatibility of these materials also varies based on surface treatments and manufacturing processes. According to Le Bars et al. (2023), microbial colonization can be exacerbated by surface roughness and chemical instability, further complicating the clinical performance of denture polymers [59]. Moreover, in restorative dentistry, PEEK's chemical resistance; though generally beneficial; presents challenges for bonding with conventional resin cements and composite veneering materials, often requiring aggressive surface conditioning or primers to ensure adhesive durability [60]. Therefore, while polymers like PEEK and PMMA remain promising due to their formability and esthetics, their long-term chemical stability, potential for monomer release [61], and surface reactivity demand careful selection, processing, and post-fabrication treatments to ensure safe and effective use in dental applications [62].

3. Mechanical weakness & wear

While polymers such as PMMA, PEEK, and nylon are extensively used in prosthodontics and removable dentures due to their processability and esthetics, they still exhibit inherent mechanical limitations [63]. PMMA, despite being cost-effective and easy to manipulate, has a relatively low impact and flexural strength [64], making it susceptible to cracking,

Table 2. Comparative overview of the physical, chemical, and biological properties of common dental polymers.

Property	PMMA	PEEK	Nylon
Physical Properties	Moderate strength, brittle under impact, good dimensional stability	High strength, excellent wear resistance, lightweight (radiolucent)	Flexible, low stiffness, good impact resistance
Thermal Stability	Low; may deform at high temperatures	High (up to 300°C); autoclavable	Moderate; softens at elevated temperatures
Surface Characteristics	Can be smooth, prone to microporosity if poorly processed	Smooth, hydrophobic; requires modification for bonding	Rougher, prone to water absorption
Chemical Resistance	Susceptible to solvents and hydrolytic degradation	Excellent chemical and hydrolytic stability	Moderate; absorbs water and degrades over time
Bonding Ability	Good with resins and adhesives	Poor without surface treatment	Limited; poor adhesion with standard resins
Biocompatibility	Biocompatible, but residual monomer may cause irritation	Excellent; bioinert and nonallergenic	Generally safe but may irritate soft tissues
Microbial Adhesion	Moderate; porous surfaces favor colonization	Low without modification, but may accumulate biofilm	Higher due to hydrophilicity and surface roughness
Common Applications	Denture bases, provisional crowns	Implant frameworks, removable partial dentures	Flexible dentures, liners

chipping, and fatigue failure, especially under cyclic masticatory loads [65]. Nylon, known for its flexibility and comfort in partial dentures, often shows reduced rigidity and poor fracture toughness, leading to deformation over time [66]. Even PEEK; although superior in tensile and flexural properties compared to PMMA; has demonstrated variation in strength and modulus based on processing conditions such as mold temperature [67], as highlighted by Muhsin et al. in 2019. Additive manufacturing (AM), including 3D-printing techniques [68], introduces additional concerns [69]; Tigmeanu et al. in 2022 noted that the layer-by-layer build-up creates internal interfaces, voids, and anisotropy that reduce mechanical uniformity and overall durability. These defects become critical in long-term applications like implant abutments or frameworks, where wear and fatigue resistance are paramount. As such, while polymers offer flexibility and customizability, their mechanical resilience under intraoral forces remains a pressing concern.

4. Surface roughness & bacterial colonization

Surface texture plays a critical role in the microbial susceptibility of dental polymers [70]. Polished or smooth surfaces reduce plaque adhesion and facilitate hygiene maintenance, whereas rough or porous surfaces enhance bacterial retention, fostering biofilm formation [71]. Le Bars et al. in 2023 emphasized that surface roughness ($R_a > 0.2 \mu\text{m}$), particularly common in AM-fabricated or poorly polished prostheses, significantly increases the risk of colonization by oral pathogens such as *Streptococcus mutans*, *Candida albicans*, and *Porphyromonas gingivalis*. PMMA, if not

properly cured and finished, may have microporosities that trap food particles and bacteria. Similarly, PEEK’s bioinert surface, though less reactive, tends to be hydrophobic and lacks inherent antibacterial properties, requiring additional surface modification to reduce biofilm accumulation [72]. The problem is compounded when unmodified nylon bases are used, as they often exhibit high water absorption and surface porosity, leading to microbial embedding and staining [73]. Moreover, as noted by Alexakou et al. in 2019, PEEK’s resistance to chemical bonding complicates efforts to apply antimicrobial coatings or resins, limiting effective surface treatment [74]. Together, these factors demonstrate how both material composition and surface finish quality directly influence the biological behavior of polymers in the oral cavity.

As shown in Table 2, PMMA, PEEK, and nylon differ significantly in terms of mechanical strength, chemical stability, biocompatibility, and microbial adhesion. PEEK offers superior thermal and chemical resistance, while PMMA is more cost-effective but prone to degradation. Nylon is flexible but susceptible to moisture and biofilm accumulation.

4.1. Manufacturing techniques of removable dentures

The fabrication of removable dentures using polymer-based materials, particularly PMMA and PEEK, involves a series of meticulously planned steps to ensure both functional and aesthetic success [75]. For PMMA-based dentures, the process begins with an initial impression, followed by the creation of a custom tray and bite registration rim [76]. The framework is then fastened and bent, the model illustrated,



Fig. 4. Finishing manufacturing removable denture by using Acrylic polymers.

and inlay procedures completed [77]. This is followed by waxing, flasking, and mixing the acrylic components. Once the acrylic reaches the dough stage; suitable for molding; the mixture is packed into the flask and cured in a water bath under controlled thermal conditions. After gradual cooling, the denture is deflasked, finished, and polished for clinical use, as shown in Fig. 4 [78]. PMMA undergoes several physical transitions during mixing, from a fibrous to a doughy consistency, which impacts moldability and final properties. The dough development time is influenced by temperature, monomer-to-polymer ratio, and particle size. Dental flasks filled with PMMA are gradually heated in a water bath to ensure complete polymerization, followed by staged cooling to avoid internal stresses. The final PMMA restorations are finished and polished before intraoral use [79]. In contrast, PEEK-based removable dentures follow a CAD-CAM workflow that starts with taking an impression, scanning the model, and digitally designing the PEEK framework using software such as Exocad [80]. The design is then milled from a PEEK blank, followed by installation of teeth, waxing, flasking, acrylic mixing, pressing, and finally polishing. The prosthesis is smoothed with polishing paste and mop to create a natural luster [81].

5. Conclusion

Polymeric materials remain indispensable in modern dental practice due to their versatility, ease of processing, and adaptability to a wide range of restorative and prosthetic applications. However, inherent challenges such as microbial colonization, chemical degradation, and suboptimal mechanical properties continue to hinder their long-term clinical success. Recent innovations in surface modification, the integration of biopolymers, and the development of antimicrobial nanocoatings have shown significant

potential to overcome these limitations. Nonetheless, a lack of standardized protocols and long-term clinical data prevents the widespread adoption of these technologies. To bridge this gap, future research should focus on optimizing polymer formulations for intraoral stability, validating antimicrobial strategies through robust clinical trials, and integrating digital fabrication methods for patient-specific applications. A multidisciplinary approach combining material science, microbiology, and clinical dentistry will be essential to realize the full potential of dental polymers in achieving durable, biocompatible, and infection-resistant oral restorations. We recommend the use of the PEEK polymer, and studying it, we support work on it in dental clinics and the use of CAD-CAM technology.

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Conflict of interest

Declare conflicts of interest or state “The authors declare no conflict of interest.” Authors must identify and declare any personal circumstances or interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results.

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