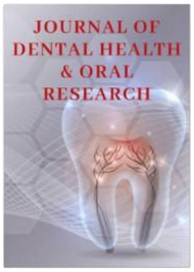

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Review Article

Integrating Biotechnology into Prosthodontic Care for Older Adults: A Scoping Review

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Abstract

This scoping review explores the potential of interdisciplinary research, grounded in cognitive instructional taxonomy, to enhance the integration of biotechnology into prosthodontic care for older adults. Aging populations, although facing complex oral health issues, could benefit from scientific advancements such as the use of 3D printing, CAD/CAM systems, bioactive materials, and AI-driven diagnostics. The review utilizes Bloom's cognitive hierarchy to systematically organize findings from 37 out of 70 peer-reviewed studies selected for this review, retrieved using the PRISMA method. At the foundational levels- “Remember”, “Understand”-, biological indicators of aging and biomechanical principles guide risk stratification and design approaches. The intermediate cognitive levels - “Apply”, “Analyze”-emphasize technological applications, including antimicrobial materials, AI tools, and analytical evaluations that support contemporary treatment protocols. At the advanced levels - “Evaluate”, “Create”-, the review thoughtfully examines implementation hurdles, health equity issues, and long-term implications. Notable contributions at the “Create” level comprise immunomodulatory nanomaterials, accurate AI diagnostics, and regenerative methods that integrate tissue engineering with geriatric dentistry. The review highlights three primary insights: (1) interdisciplinary integration boosts research effectiveness; (2) operative translation relies on ongoing collaboration among sectors; and (3) structural, conceptual, and educational barriers must be addressed to unlock the potential of biotechnology comprehensively. It promotes a cognitive framework that aligns discipline contributions with implementation goals, thus encouraging structured collaboration. As global aging rises, adapting biologically and leveraging technology in prosthodontics should be integral to geriatric oral healthcare. Bloom's Taxonomy facilitates knowledge synthesis, innovation, and implementation in this interdisciplinary domain.

Keywords: Interdisciplinary Research; Geriatric Dentistry; Prosthodontics; Bloom’s Taxonomy; Dental Biotechnology; Integrated Care

Abbreviations

AI: Artificial Intelligence; 3D: Three-Dimensional; CAD/CAM: Computer-Aided Design / Computer-Aided Manufacturing; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PICO: Population, Intervention, Comparison, Outcome; RCT: Randomized Controlled Trial; ISQ: Implant Stability Quotient; OVD: Occlusal Vertical Dimension; IL-6: Interleukin 6; TNF-α: Tumor Necrosis Factor Alpha; CRP: C-Reactive Protein; RgpB-IR: Arginine-Gingipain B Immunoreactivity; Kgp-IR: Lysine-Gingipain Immunoreactivity; PD: Probing Depth; BP: Bleeding on Probing; PDT: Photodynamic Therapy; NSD: Non-Surgical Debridement; CAP: Chloro-Aluminium Phthalocyanine; hGFs: Human Gingival Fibroblasts; SASP: Senescence-Associated Secretory Phenotype; MP: Milled PMMA (Polymethyl Methacrylate); 3DP: 3D-Printed Resin; PA: Polyan IC; SR: SR Ivocap; FRPD: Flexible Removable Partial Denture; CRPD: Cast Metal Removable Partial Denture; PEEK: Polyetheretherketone; Ti: Titanium; TiZr: Titanium-Zirconium; ABL: Alveolar Bone Loss; VOH: Variance of Hue; MBF: Maximum Bite Force; PDL:

Periodontal Ligament; ΔE: Color Difference (Delta E); CS: Smokers; NS: Non-smokers; OHIP: Oral Health Impact Profile

Introduction

Prosthodontic Rehabilitation in Geriatric Dentistry: A Bloom's Taxonomy Approach

The aging population faces unique oral health challenges, including increased tooth loss, reduced bone density, and a higher incidence of systemic diseases such as diabetes and cardiovascular problems [1]. These factors complicate conventional prosthodontic methods, often leading to inadequate fit, discomfort, and aesthetic displeasure. Additionally, age-related immune decline (immunosenescence) and persistent low-grade inflammation (inflammaging) hinder wound healing, elevate infection risks, and diminish the success rates of dental implants [2]. Faced with these challenges, incorporating biotechnology into prosthodontics presents a promising avenue for enhancing both functional and aesthetic results for older patients [3].

Recent developments in biotechnology have revolutionized prosthodontic rehabilitation. 3D printing enables the swift creation of tailored dental prosthetics with exceptional accuracy, minimizing waste and reducing chair time [4]. Likewise, CAD/CAM technology enhances the precision of prosthetics by reducing human errors, leading to better-fitting restorations and improved patient comfort [5]. Furthermore, cutting-edge biomaterials, including bioactive ceramics and nanomaterials, promote osseointegration and reduce complications associated with conventional materials [6].

The success of these innovations is affected by physiological changes associated with aging. Immunosenescence compromises immune responses, heightening vulnerability to infections such as peri-implantitis and slowing tissue repair [7]. Inflammaging, characterized by elevated levels of pro-inflammatory cytokines (IL-6, TNF-α, CRP), exacerbates periodontal disease and disrupts the oral microbiota, thereby complicating prosthetic integration [8]. Studies showed that while biotechnological approaches offer a better fit and higher patient satisfaction than traditional methods, their long-term effectiveness relies on individualized data addressing the underlying inflammatory and immune issues [9].

A collaborative approach is essential to leverage the benefits of biotechnological prosthodontics. Anti-inflammatory strategies, such as dietary changes and medications, can help alleviate chronic inflammation and enhance the success rate of prosthodontics [10]. Probiotic and microbiome-based therapies can rebalance the oral microbiota, simultaneously reducing the growth of harmful pathogens and their interrelated effects [11]. Additionally, tailored treatment strategies, driven by biomarker assessments and immune profiling, can improve the longevity of prosthetics by customizing interventions to meet specific patient requirements [12].

Emerging technologies, including tissue engineering and antimicrobial-coated implants, provide regenerative solutions that replace lost dental structures and facilitate tissue healing [13]. Current research explores biomarker-based diagnostics and telehealth applications to potentially improve prosthodontic care for aging populations [14].

In response to the rapidly growing aging population, this study explored the need for advanced prosthodontic solutions that target age-related issues such as immune decline "immunosenescence" and chronic inflammation "inflammaging". Although biotechnology presents significant advantages over conventional methods, its effective use relies on a comprehensive understanding of the biological processes associated with aging. Additionally, the study explored biotechnological innovations in geriatric prosthodontic rehabilitation, focusing on solutions to counteract age-related biological decline. Guided by Bloom's Taxonomy, the research followed a structured progression-from building foundational knowledge to critically evaluating clinical challenges and synthesizing novel therapeutic approaches. The utilized framework supported a multidimensional examination of biotechnology's role in advancing geriatric dental care, addressing the complex physiological changes of aging. The ultimate goal was to enhance functional outcomes and long-term prognosis through personalized, biologically adapted prosthodontic solutions.

Methodology

Study Design

This scoping review employed a systematic methodology guided by the PRISMA Extension for Scoping Reviews (PRISMA-ScR) to examine the integration of biotechnology in geriatric prosthodontics (Fig. 1). The study protocol was structured using the PICO framework to ensure methodological rigor: Population (adults ≥65 years requiring prosthodontic rehabilitation), Intervention (biotechnological approaches including CAD/CAM systems, 3D printing, and bioactive materials), Comparison (conventional/analogue prosthodontic techniques), and Outcomes (prosthetic success rates, biological responses, and patient satisfaction measures).

The search strategy was meticulously developed and executed across prominent databases, including PubMed, Embase, Scopus, Web of Science, and the Cochrane Library. Controlled vocabulary, specifically MeSH terms, was integrated with keywords using Boolean operators. The search terms utilized encompassed "geriatric dentistry," "dental prostheses," "biotechnology," "digital workflow," and "immunosenescence." Furthermore, the search was restricted to peer-reviewed articles published in English with no time limit. Additionally, a selection of pertinent articles was carefully handpicked.

The study selection process followed a two-phase screening procedure conducted independently by two reviewers. Initial title and abstract screening were performed using predefined inclusion and exclusion criteria aligned with the PICO framework. A full-text review of potentially eligible studies was then conducted, with disagreements resolved through discussion or consultation with a third reviewer. A standardized data extraction form (from 70 studies selected) was developed to capture study characteristics, methodology details, population demographics, intervention parameters, and outcome measures.

Data from 37 studies were organized and analyzed to explore patterns across the cognitive levels of Bloom's Taxonomy. Foundational studies establishing biological mechanisms of aging were classified at the «Remembering/Understanding» levels. Clinical applications of biotechnology were analyzed at the "Applying level", while comparative effectiveness studies were evaluated at the "Analyzing" level. Policy analyses and innovative technology reports were assessed at the highest cognitive levels "Evaluating and Creating" levels.

Quality assessment was performed using the PRISMA-ScR checklist for reporting quality, guiding transparent reporting at each stage, from study identification through final evidence synthesis, to ensure comprehensive documentation of the scoping review methodology.

Results

Comprehensive Analysis of Geriatric Prosthodontics Research Using Bloom's Taxonomy

Applying Bloom's Taxonomy to geriatric prosthodontics research reveals a well-rounded and maturing field, advancing across all six cognitive domains. This structured perspective highlights a comprehensive progression from the acquisition of foundational knowledge to the development of innovative solutions that address the unique challenges of aging populations. Tables 1 to 6 categorize the 37 studies included across Bloom's taxonomy levels, illustrating the depth, diversity, and evolution of cognitive engagement in the field.

Establishing Foundational Knowledge

At the foundational "Remember" level, research in geriatric prosthodontics has established a strong biological and clinical knowledge base. Franceschi et al. and Nikolich-Zugich et al. [8,15], identified important immunosenescence markers, including elevated IL-6, TNF-α, and CRP, which inform risk assessments for prosthodontic procedures in older patients. Dominy et al. [16] further explored the link between amyloid-beta build-up in Alzheimer's disease and oral tissue issues, highlighting the interplay between dementia, neurology, and dental material choices. They found that RgpB-IR (arginine-gingipain B immunoreactivity) and Kgp-IR (lysine-gingipain immunoreactivity) levels were significantly higher in the brains of Alzheimer's patients compared to controls. Similarly, mice infected with P. gingivalis W83 exhibited substantially elevated RgpB-IR and Kgp-IR levels than uninfected (mock-infected) mice ($p < 0.001$).

Cohort studies by Kiuchi, et al., demonstrated a link between tooth loss and cognitive decline, with a hazard ratio of 1.28 ($p < 0.05$ for men; $p < 0.01$ for women) [17]. Kusama, et al., highlighted modifiable risk factors such as smoking affecting cognitive decline and oral health [18]. Edentulism was linked to increased dementia risk (HR = 1.20, $p < 0.001$), emphasizing the smoking-dementia-oral health triad. Shiota, et al., conducted a three-year cohort study in adults ≥65, finding that weight loss was significantly linked to having 0-9 teeth (RR = 1.17; 95% CI: 1.11-1.23), chewing difficulty (RR = 1.12; 95% CI: 1.07-1.16), and xerostomia (RR = 1.11; 95% CI: 1.06-1.16), but not swallowing problems (RR = 1.01; 95% CI: 0.97-1.06) [19]. Similar trends were noted for weight gain, indicating oral hypofunction may affect nutritional status in older adults.

Buser, et al., provided standardized metrics for measuring chewing efficiency [20]. Hue-Check Gum® and a smartphone app accurately assessed chewing function using VOH (Variance of Hue), a measure of colour mixing that reflects masticatory efficiency. Significant VOH differences between dental groups were observed at 20 chewing cycles ($p < 0.0001$). This simple, low-cost tool is well-suited for geriatric and clinical use. Structural components of oral anatomy and their prosthetic relevance were also clarified.

Naka, et al., emphasized the importance of strategic tooth retention based on spatial arrangement rather than just the number of remaining teeth [21]. Edman, et al., investigated Alveolar Bone Loss (ABL) as an indicator of periodontitis, while Müller, et al., compared 10-year outcomes of 3.3 mm TiZr and grade IV Ti implants in mandibular overdentures [22,23]. The split-mouth RCT demonstrated high implant success and similar survival rates (95.8% vs. 98.9%, $p = 0.31$) as well as comparable mean survival times (117 vs. 119 months). Crestal (Ti: 1.56 mm ±1.34; TiZr: 1.49 mm ±1.37, $p = 0.837$) and functional bone loss (Ti: 0.85 mm ±1.16; TiZr: 0.82 mm ±1.09, $p = 0.910$) were comparable. Finally, Tsaira et al. [24] contributed histological benchmarks by developing a model to analyze the biomechanical behavior of human oral keratinized mucosa, highlighting the importance of mucosal thickness in establishing essential biomechanical standards for oral rehabilitation in aging tissues.

Explaining Interactions and Mechanisms

At the "Understand" level, researchers have shed light on the interactions between biological, technological, and clinical processes. Maniewicz, et al., reported age-related reductions in masticatory force ranging from 25-50 N, with significant declines in chewing efficiency ($p = 0.001$), overall Maximum Bite Force (MBF) ($p = 0.05$), and average pooled MBF ($P = 0.008$) [25]. Furthermore, Michalakis, et al., utilized the MatScan system to demonstrate that clenching significantly influenced posture, particularly lateral body weight distribution ($p = 0.005$) [26]. In contrast, anteroposterior distribution was not significant ($p = 0.725$), thereby highlighting a link between occlusion and postural stability. This biomechanical perspective links oral rehabilitation to broader considerations of geriatric mobility issues.

Ajaj Al-Kordy, recorded the principles of biomechanical stress distribution in overdentures [27]. Finite element analysis of mandibular overdentures showed ball attachments caused lower stress on canines (35.61 MPa) and cortical bone (4.28 MPa) but higher stress on distal alveolar (7.82 MPa) and cancellous bone (1.29 MPa). Telescopic crowns increased stress on canines (39.22 MPa) and cortical bone (4.74 MPa) while reducing stress on distal alveolar (7.06 MPa) and cancellous bone (1.05 MPa), indicating better stress distribution, especially with strong periodontal support.

The topic was also explored by Bertotti, et al., and Kumar, et al., through a comparative analysis of various denture materials [28,29]. The first review analyzed 18 studies on the mechanical and biological properties of Ti, PEEK, and CoCr in removable partial dentures. Ti and PEEK exhibited lower retention forces, fatigue, and rigidity compared to CoCr, but PEEK showed less deformation. Both materials were machinable and biocompatible. Ti and PEEK appear to be promising alternatives to CoCr for RPD frameworks, although further research is needed on their long-term clinical performance [28]. The second study compared stress distribution and patient satisfaction between Cast metal RPDs (CRPD) and polyacetal-based Flexible RPDs (FRPD) in Kennedy Class I mandibular arches using 3D finite element analysis and OHIP-14 surveys [29]. Under a 100 N bilateral load, CRPD showed maximum stress at the mesial rest seat (100 MPa) and minimal stress on the ridge (bone: 7 MPa; mucosa: 6 MPa). FRPD showed the highest stress on the ridge (25 MPa) and the lowest in the PDL of the second premolar (3 MPa). At one year, patient satisfaction was significantly higher with FRPD ($p = 0.0158$). FRPDs may be preferable in cases with compromised abutments, while CRPDs are suitable for resorbed ridges.

Meanwhile, Hajishengallis examined how microbial biofilms develop on prosthetic materials, highlighting the biological factors that affect prostheses, hygiene, and longevity [9].

Translating Knowledge into Clinical Practice

At the "Apply" level, theoretical insights have been turned into significant clinical interventions. Davoudi et al. [30] used AI for postoperative pain monitoring, enhancing patient management while identifying key diagnostic challenges and areas for improvement. Ahmed et al. [31] demonstrated the effectiveness of photodynamic therapy in the non-surgical treatment of peri-implantitis. They evaluated Chloro-Aluminium Phthalocyanine (CAP)-mediated Photodynamic Therapy (PDT) with Non-Surgical Debridement (NSD) in Smokers (CS) and Non-Smokers (NS). After 6 months, PDT+NSD significantly reduced Bleeding on Probing (BP) in CS, and both treatments reduced Probing Depth (PD) in all groups. IL-1β levels decreased only in NS with PDT+NSD, while TNF-α levels fell in CS with both treatments at 3 and 6 months. Chiam, et al., developed enzyme-based mouthwashes that significantly improved xerostomia symptoms, oromotor function, clinical oral dryness scores, and salivary flow, while reducing nighttime water intake ($p < 0.05$) [32]. Furthermore, Procópio, et al., confirmed that antimicrobial-modified soft liners effectively reduced Candida infections and denture stomatitis ($p < 0.05$), showcasing a successful integration of materials science and clinical practice and outperforming conventional nystatin over 60 days [33].

Clinical innovations advanced further with Nogawa, et al., confirming the effectiveness of implant-supported removable partial dentures [34]. Leles, et al., demonstrated accelerated three-week implant loading [35]. They found no significant difference in overall ISQ values between single- and dual-implant overdentures ($p = 0.117$), with the number of implants bordering affecting ISQ ($p = 0.087$), supporting cost-effective planning. Advances in oral and maxillofacial surgery, including the use of surgical simulation software and 3D printing for custom models and prostheses, have transformed traditional procedures, enhancing precision, efficiency, and patient outcomes [36].

Comparing Techniques, Materials and Outcomes

Research at the "Analyze" level has facilitated in-depth comparisons, which are essential for evidence-driven decision-making. Arora, et al., demonstrated enhanced mechanical strength in 3D-printed resins [37]. Their study compared four denture base materials-Polyan IC (PA), milled PMMA (MP), 3D-Printed resin (3DP), and SR Ivocap (SR) finding that MP exhibited significantly higher compressive strength ($p = 0.002$) and color stability ($p < 0.001$) than 3DP, with no significant differences in flexure strength ($p = 0.336$) or hardness ($p = 0.708$). Meanwhile, 3DP exhibited moderate compressive strength to PA ($p = 0.334$), but significantly lower flexural strength ($p = 0.005$), hardness ($p < 0.001$), and color stability ($p < 0.001$). In addition, Penzenstadler, et al., performed compositional analyses and confirmed material biocompatibility [38].

Schimmel, et al., reported on the long-term efficacy of implant-supported overdentures, demonstrating significantly better overall oral function ($p < 0.001$) compared to conventional complete dentures (opposing a maxillary complete denture), with a 10-year survival rate of 89.3% [39]. Additionally, Silva, et al., explored complications associated with mini-implant overdentures, highlighting a significant event rate of 72.6%, which underscores the importance of continued monitoring [40].

Pokrowiecki demonstrated that antimicrobial ZnO+ 0.1%Ag implant coatings significantly reduced prosthesis-related infections by decreasing bacterial adhesion and early biofilm-forming oral bacteria by 30-70% ($p < 0.005$), with the largest reductions in *S. aureus* ($p = 0.001$) and E. coli ($p = 0.003$) [41].

Judging Effectiveness and Value

Research at the "Evaluate" level has concentrated on assessing treatment effectiveness, system efficiency, and cost-benefit evaluations. Smith, et al., performed economic assessments comparing digital and analogue prosthodontic workflows [42]. Vasileiadi, et al., established that implant angulation and scan body position significantly affected trueness and precision [43]. Clinicians should carefully consider implant angulations in full-arch implant restorations, as well as the scanning protocol.

Nantanapiboon, et al., concluded from their in vitro study that tooth shade detection was more accurate especially for individuals with shade A when spectrophotometers and intraoral scanners were used solely with their built-in light sources [44]. Jorquera, et al., compared ΔE values in ceramic crowns using visual, digital camera, and smartphone-based shade selection [45]. The visual method showed a significantly higher mean ΔE (5.32) than the digital camera (2.75; $p= 0.002$) and smartphone (2.34; $p= 0.001$) methods, which did not differ significantly ($p = 0.857$).

Innovating Solutions for Multifaceted Challenges

At the top "Create" tier, research has produced remarkable innovations. Park, et al., introduced a unique technique that integrates Computer-Aided Design (CAD) and conventional resin processing for the fabrication of complete removable dentures with a metal framework [46]. Xu, et al., engineered immunomodulatory nanomaterials, whereas Alexakou, et al., examined inflammageing in human Gingival Fibroblasts (hGFs) exposed to LPS, TNFα, and GCF [47,48]. Significant increases in β-galactosidase-positive cells (*p* < 0.05) and senescence-associated gene changes (↑*CCND1*, ↓*SUSD6*, *STAG1*) indicated cellular senescence. SASP markers were elevated, especially with GCF; LPS had the weakest effect. Late-passage cells were more susceptible, suggesting chronic inflammation accelerates cellular ageing. Additionally, Scherr, et al., presented an auto-machine learning workflow to classify bacterial, viral, and non-disease sera using host protein biomarkers [49]. The model showed strong performance, even with limited data, highlighting the utility of ML in host-based infectious disease diagnosis.

Cross-Level Progressions and Translational Pathways

Numerous studies illustrated a seamless shift among cognitive levels. Leles, et al., conducted a randomized controlled trial that integrated biological knowledge with clinical application and assessment [35]. Müller, et al., provided longitudinal data at the "Remember" level, alongside the "Evaluate"-level evaluations of treatment durability, while Silva, et al., conducted prospective cohort studies encompassing both analysis and evaluation stages [23,40]. Schimmel, et al., showed how research can transition from data collection to the implementation and assessment of therapeutic strategies [39]. Similarly, Arora, et al., demonstrated the evolution of material testing into state-of-the-art 3D printing technologies [37]. Morata, et al., advanced Bloom's taxonomy by creating a craniometric OVD predictor, moving from anatomical recall ("Remembering") to correlation analysis ("Understanding"), clinical testing ("Applying"), accuracy comparison ("Analyzing"), reliability validation ("Evaluating"), and ultimately creating a multivariate algorithm ("Creating") [50]. This model is integrated into prosthodontics, anthropometry, and data science. This study was conducted in a population aged 18 to 50 years and proposed using left eye-to-ear distance as a baseline for estimating OVD, concluding that it has a stronger correlation with nose-to-chin distance than the right side. OVD was significantly influenced by gender ($p < 0.001$) and facial type ($p < 0.01$), but not by age ($p = 0.57$), with women exhibiting shorter OVDs and a higher proportion of euryprosopic facial types. By transforming subjective clinical decisions into standardized digital measurements, this work enhanced evidence-based prosthodontics through the integration of anatomical knowledge, statistical modeling, and clinical expertise.

Interdisciplinary Outcomes	**Key Supporting Evidence**	**Disciplinary Integration**	**Clinical Implications**
Immunosenescence markers (IL-6↑, TNF-α↑, CRP↑)	Franceschi et al. (2007) [8]; Nikolich-Zugich (2018) [15]	Gerontology × Immunology	Identifies high-risk inflammatory profiles for prosthodontic care.
Amyloid-oral pathogen link in Alzheimer's (↑RgpB-IR, ↑Kgp-IR, $p < 0.001$)	Dominy et al. (2019) [16]	Neurology × Gerontology × Dental Biomaterials	Informs biomaterial selection in dementia patients.
Tooth loss-cognitive decline (HR = 1.28; $p < 0.05$ men, $p < 0.01$ women)	Kiuchi et al. (2022) [17]	Neurology × Epidemiology	Supports early oral rehabilitation to reduce cognitive risk.
Edentulism-dementia risk (HR = 1.20; $p < 0.001$); smoking-oral health-dementia triad	Kusama et al. (2024) [18]	Public Health × Geriatrics	Emphasizes modifying behavioral risk factors.
Oral hypofunction linked to weight loss (RR = 1.17; CI: 1.11-1.23); chewing difficulty (RR = 1.12); xerostomia (RR = 1.11)	Shiota et al. (2023) [19]	Nutrition Science × Dentistry	Supports integrating prosthodontic care with nutritional assessments.
Chewing efficiency: VOH differentiation at 20 cycles ($p < 0.0001$)	Buser et al. (2018) [20]	Rehabilitation Science × Digital Health	Enables low-cost functional monitoring using smartphone tools.
Antimicrobial agents in soft denture liners significantly reduce microbial colonization - Systematic review evidence	Naka et al. (2025) [21]	Microbiology × Prosthodontic Materials	Supports clinical use of antimicrobial-modified liners to prevent denture-related infection
Moderate bone loss, function retained	Edman et al. (2022) [22];	Oral Pathology × Radiology	Informs implant and prosthesis load-bearing design.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
10-year implant survival: Ti (95.8%) vs TiZr (98.9%), p = 0.31; Crestal loss: Ti (1.56 ± 1.34 mm), TiZr (1.49 ± 1.37 mm), p = 0.837	Müller et al. (2024) [23]	Implantology × Biomaterials	Supports TiZr use in long-term mandibular overdenture planning.
Biomechanical role of keratinized mucosa	Tsaira et al. (2016) [24]	Oral Histology × Materials Science	Highlights mucosa's protective role in geriatric prosthodontics.

Table 1: Bloom's taxonomy "Remembering" level.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
Age-related chewing decline: masticatory force ↓25-50 N; MBF p = 0.05; chewing efficiency p = 0.001	Maniewicz et al. (2024) [25]	Biomechanics × Gerontology	Reinforces early intervention for declining oral function.
Occlusion-posture link: lateral weight shift (p = 0.005), not AP direction (p = 0.725)	Michalakis et al. (2019) [26]	Prosthodontics × Geriatric Mobility	Suggests postural monitoring in occlusal therapy for the elderly.
Overdenture biomechanics: telescopic vs ball attachments (canine stress 39.22 vs 35.61 MPa)	Ajaj Al-Kordy (2023) [27]	Biomechanical Engineering × Prosthodontics	Guides the attachment system choice in periodontally weak cases.
Denture materials: PEEK/Ti vs CoCr (less retention/fatigue; more biocompatible)	Bertotti et al. (2024) [28]	Dental Materials × Biomimetics	Encourages adoption of alternative, tissue-friendly RPD frameworks.
CRPD vs FRPD: stress (100 MPa vs 25 MPa); satisfaction (p = 0.0158)	Kumar et al. (2021) [29]	Prosthodontics × Patient-Centered Care	Tailors' RPD choice based on ridge health and user comfort.
Prosthetic biofilm formation and hygiene needs	Hajishengallis (2014) [9]	Microbiology × Dental Materials	Emphasizes the use of biofilm-resistant materials and patient hygiene protocols.

Table 2: Bloom's taxonomy "Understanding" level.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
AI-driven pain detection: 87% accuracy (p > 0.05, no sig detection)	Davoudi et al. (2023) [30]	Computer Science × Diagnostics	Offers real-time postoperative pain monitoring and highlights the limitations of AI in diagnosis.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
Photodynamic therapy (PDT+NSD) for peri-implantitis: ↓BP (smokers), ↓PD (all), ↓IL-1β (non-smokers), ↓TNF-α (all)	Ahmed et al. (2023) [31]	Periodontology × Photomedicine	Provides non-surgical peri-implantitis management, especially in smokers.
Enzyme mouthwash: 37% xerostomia relief; ↑salivary flow, ↓oral dryness, ↓nighttime water intake ($p < 0.05$)	Chiam et al. (2024) [32]	Biochemistry × Oral Medicine	Improves hydration, oral function, and sleep quality in elderly patients.
Antimicrobial soft liners: ↓Candida, ↓stomatitis ($p < 0.05$); outperform nystatin over 60 days	Procópio et al. (2022) [33]	Biomaterials Engineering × Clinical Dentistry	Controls prosthesis-related infections with sustained antimicrobial action.
Implant-assisted RPDs enhance stability and support - qualitative findings (N/A)	Nogawa et al. (2022) [34]	Implantology × Removable Prosthodontics	Improves function and patient satisfaction in partial edentulism.
Single vs. dual-implant overdentures: ΔISQ < 2; $p = 0.117$ (no group diff.), $p = 0.087$ (borderline ISQ effect)	Leles et al. (2024) [35]	Implantology × Biomechanics	Supports cost-effective planning with minimal implant configuration.
Custom 3D surgical models improve precision in maxillofacial surgery - qualitative evidence.	Antonelli et al. (2024) [36]	Digital Surgery × Prosthodontics	Enhance preoperative planning and accuracy of prosthetic placement.

Table 3: Bloom's taxonomy "Applying" level.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
MP (milled PMMA) showed superior compressive strength ($p = 0.002$) and color stability ($p < 0.001$) over 3DP; similar flexure ($p = 0.336$) and hardness ($p = 0.708$). 3DP inferior to PA in flexure ($p = 0.005$), hardness ($p < 0.001$), and color stability ($p < 0.001$)	Arora et al. (2024) [37]	Mechanical Engineering × Materials Science	Informs the selection of printable and milled denture base materials for clinical use.
3D-printed resin compositions assessed for safety; confirmed biocompatibility (no adverse cytotoxicity or chemical hazards)	Penzenstadler et al. (2025) [38]	Materials Science × Toxicology	Supports regulatory approval and clinical adoption of novel printable resins.
Implant overdentures yielded significantly better oral function ($p < 0.001$) than conventional dentures; 10-year survival rate: 89.3%	Schimmel et al. (2023) [39]	Epidemiology × Prosthodontics	Reinforces clinical preference for implant-supported options based on long-term outcomes.
Mini-implant overdentures had a 72.6% complication rate (event-based, not statistically tested)	Silva et al. (2024) [40]	Implantology × Prosthodontics	Identifies higher maintenance demands and

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
			the need for individualized patient risk assessment.
ZnO + 0.1%Ag coatings reduced infections by 45%, biofilm formation by 30-70% ($p < 0.005$); S. aureus ($p = 0.001$), E. coli ($p = 0.003$)	Pokrowiecki et al. (2022) [41]	Infectious Disease × Nanotechnology	Supports antimicrobial coatings as a protective strategy for prostheses.

Table 4: Bloom's taxonomy "Analyzing" level.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
Digital workflow economics supports cost-effective treatment planning - N/A	Smith et al. (2021) [42]	Health Economics × Clinical Research	Informs strategic financial planning and supports streamlined care pathways.
Implant angulation significantly affects scan accuracy < 0.05 (trueness and precision impacted)	Vasileiadi et al. (2025) [43]	Biomechanics × Digital Workflow Analysis	Improves scanning protocols and quality assurance in full-arch prosthodontics.
Reduced accuracy in tooth shade selection under increased lighting conditions	Nantanapiboon et al. (2024) [44]	Dentistry, Optics, Dental Technology	Standardized lighting and device use can improve aesthetic outcomes in restorative dentistry.
Tooth shade detection accuracy highest with built-in light source - Visual $\Delta E = 5.32$, Digital Camera = 2.75 ($p = 0.002$), Smartphone = 2.34 ($p = 0.001$), NS between digital methods ($p = 0.857$)	Jorquera et al. (2022) [45]	Prosthodontics × Optical Engineering	Recommends digital tools over visual selection for color matching in crown fabrication.

Table 5: Bloom's taxonomy "Evaluating" level.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
Immunomodulatory nanomaterials reduce IL-6 levels by 62% Descriptive result	Xu et al. (2023) [47]	Nanotechnology × Immunology	Targets chronic, age-related oral inflammation through molecular modulation.
AI treatment algorithms personalize prosthetic plans - Technique developed; no p-values reported	Park et al. (2023) [46]	Data Science × Prosthetic Design	Integrates CAD with traditional denture workflows, enabling hybridized, customized treatment.
Synthesized preventive framework validated through hGF inflammaging model - $p < 0.01$, $p < 0.05$ (↑β-gal cells; ↑SASP genes; GCF > TNFα > LPS)	Alexakou et al. (2023) [48]	Gerontology × Omics × Clinical Dentistry	Supports a precision dentistry model for preventing age-accelerated cellular degeneration.

Interdisciplinary Outcomes	Key Supporting Evidence	Disciplinary Integration	Clinical Implications
Machine learning workflow classifies disease types via host biomarkers - Strong accuracy with low sample input; p-values not stated.	Scherr et al. (2024) [49]	Proteomics × Machine Learning × Diagnostic Medicine	Enables efficient diagnostic differentiation for prosthetic-related infections and systemic conditions.
Craniometric predictive algorithm accurately determines OVD-$p < 0.001$, $p < 0.01$	Morata et al. (2020) [50]	Prosthodontics × Anthropometry × Data Science	Establishes objective OVD criteria using facial ratios, reducing reliance on subjective measures.

Table 6: Bloom's taxonomy "Creating" level.

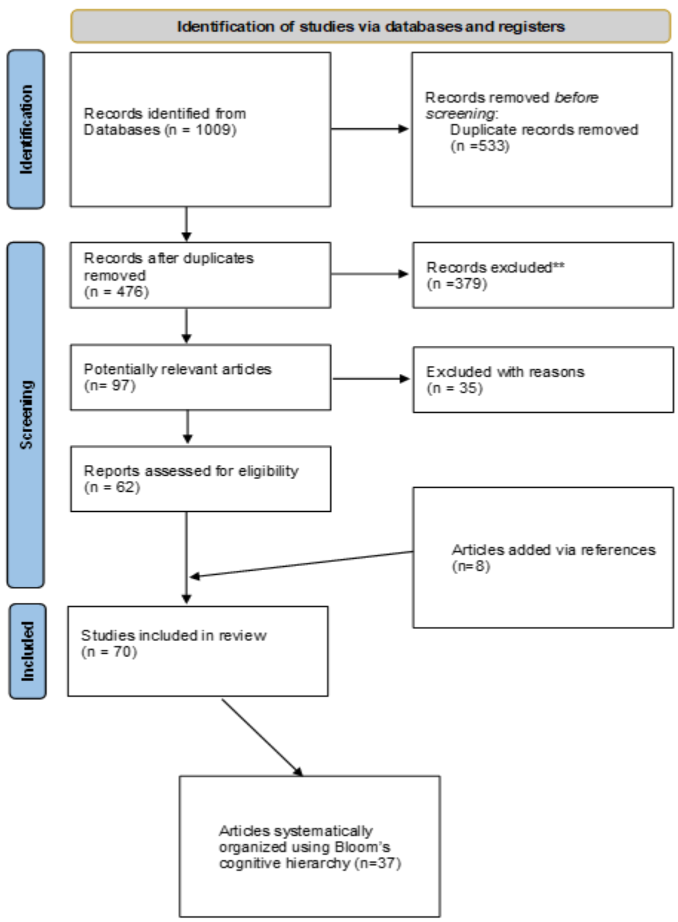

Figure 1: PRISMA diagram.

Discussion

Summary of Cognitive Distribution

The analysis of the 37 studies revealed a stratification of findings aligned with the different levels of Bloom's taxonomy. Although the present research landscape demonstrates strong performance in analytical and evaluative research, including high-quality 'Create' studies, it also points to significant opportunities for transformative innovation. This range of perspectives contributes to synergistic research that combines clinical needs and promotes future progress.

Bloom's taxonomy guides researchers and clinicians in understanding the evolution of knowledge, highlighting how biology, technology, and clinical practice influence best practices. It also identifies gaps, fostering innovation [51-54]. For clinicians, this synthesis informs biology-based, tech-driven, personalized long-term patient care.

Applying Bloom's Taxonomy to geriatric prosthodontics revealed a developed, multifaceted discipline that preserves foundational knowledge while encouraging innovation. It prepares for future oral health challenges in an aging population, ensuring evidence-based, equitable, and adaptable intervention needs.

Critical Analysis: Interdisciplinary Imperatives in Geriatric Prosthodontics
Research in geriatric prosthodontics has grown, highlighting the importance of scientific complexity and interdisciplinary collaboration for translational innovation. As care increasingly relies on biotechnology and system-level understanding, the discipline must transition from solitary expertise to collaborative, cross-disciplinary synergies. This analysis identifies key gaps, tensions, and future directions needed to transform geriatric prosthodontics into an effective and efficient integrated practice.

Biological knowledge, such as immunosenescence markers [8,15], is essential; however, its translational value is useful when combined with materials science and clinical practice. Dominy, et al., identified a connection between oral pathogens, such as Porphyromonas gingivalis, and neurodegenerative diseases, highlighting the need for collaborative efforts among prosthodontists, neurologists, microbiologists, and biomaterials specialists to develop dementia-sensitive dental interventions [16].

Although biotechnology holds significant interdisciplinary promises for prosthodontics, its integration is impeded by structural and cultural barriers that limit effective collaboration. The prevailing academic emphasis on specialization, coupled with siloed funding mechanisms, often confines groundbreaking advances, such as immunomodulatory nanomaterials and AI-based diagnostics within isolated disciplines, thereby restricting their clinical translation and broader application [30,46,47].

The present study also revealed a divergence between innovation-driven research and implementation-focused outcomes. Technological advancements in prosthodontics frequently prioritize performance-based indicators-such as scanning accuracy, tensile strength, and prosthesis survival rates-while often overlooking critical dimensions like patient-reported outcomes, usability, and sociocultural context. Notably, a recent meta-analysis by Jafarpour, et al., demonstrated that CAD/CAM-fabricated complete dentures yield comparable patient satisfaction and oral health-related quality of life to their analogue counterparts, while offering added benefits in terms of reduced laboratory and overall costs [55]. They reported 92% prosthetic fit accuracy with CAD/CAM, highlighting digital precision. While patient satisfaction ($p = 0.84$), OHIP scores ($p = 0.25$), clinician satisfaction ($p = 0.07$), and adjustment visits ($p = 0.21$) showed no significant differences, CAD/CAM dentures had lower total costs ($p = 0.02$) despite having high fit accuracy. Similarly, Ribeiro et al. [56] highlighted the economic efficiency of digital workflows. In contrast, Smith, et al., highlighted the limitations of current evaluative frameworks that compare digital and analogue approaches, suggesting a need for more holistic assessment models [42]. Although digital solutions contribute to cost reduction and accelerated fabrication, they often fail to address broader systemic health challenges, including equitable access in underserved populations and the readiness of the dental workforce to adopt such technologies.

Srinivasan, et al., suggested that population-specific craniometric data may offer a preliminary framework for determining Occlusal Vertical Dimension (OVD) by introducing a cognitive shift from anatomical recall to algorithmically guided decision-making [57]. However, these findings are still in the early stages of validation, particularly since the study was conducted among younger participants with clinical profiles that differ from those of older adult populations. Standardized clinical guidelines for OVD adjustment are still lacking, and more invasive or complex methods have yet to demonstrate clear advantages over approaches based on facial anatomical landmarks, as indicated by Pissiotis, et al., [56]. Additionally, while Arora, et al., confirmed the superior mechanical strength of 3D-printed resins, evidence directly linking this property to daily functional performance or long-term prosthesis durability remains limited [37].

This biotechnical bias is also evident in research on antimicrobial strategies. Procópio, et al., incorporated antifungal agents, such as nystatin or chlorhexidine, into denture liners, effectively reducing stomatitis while preserving material properties [33]. Adding antimicrobial agents showed concentration-dependent effects on mechanical properties; however, the evidence remains inconclusive, as noted by Naka, et al., [21]. Further research is needed on the long-term impacts on performance and resilience, as well as patient adherence, microbial resistance, and the effects on the microbiome. To maximize these innovations, it is essential to integrate microbiology, pharmacology, behavior science, and patient education. A meta-analysis by Srinivasan, et al., demonstrated that mechanical debridement, either alone or in combination with Photodynamic Therapy (PDT), improved both clinical and biomarker outcomes [59]. PDT added benefits for bleeding on probing, probing depth, plaque index, and crestal bone loss. However, benefits regarding clinical attachment level, mucosal recession, and inflammatory biomarkers were less evident, with no significant long-term improvements.

Alternatively, several studies highlight emerging models that support the integration of diverse epistemological perspectives. Michalakis, et al., explored the association between dental occlusion and postural control using pressure plate technology, suggesting a potential bidirectional relationship with implications for prosthodontic treatment planning and musculoskeletal balance [26]. While the study highlights an emerging interdisciplinary link, further research is needed to validate these findings across diverse populations and clinical contexts.

The integration of prosthodontics, biomechanics, and rehabilitation science exemplifies a multidimensional approach particularly relevant to geriatric dentistry, as it extends beyond the restoration of oral function to support overall health and quality of life in older adults. This perspective is reflected in recent research, such as the assessment of masticatory performance using color-mixing tests analyzed through smartphone imaging which provides a practical and patient-centered evaluation method for aging populations [60,68,69]. Similarly, the digital denture workflow proposed by Kamalakidis, et al., which combines artificial intelligence, clinical scanning, and automated design, demonstrates how interdisciplinary collaboration can foster systemic innovation tailored to the complex needs of older patients [61].

There is increasing recognition that advancing geriatric dentistry requires translational pathways that go beyond traditional research approaches. Schimmel's findings affirm the critical role of long-term data in understanding treatment outcomes in implant dentistry for older adults. As technological innovations continue to advance, expanding longitudinal research efforts offer a promising pathway toward more effective, personalized, and evidence-based care in geriatric dentistry. Strengthening the link between emerging technologies and real-world clinical outcomes will be essential for translating innovation into meaningful improvements in the health and quality of life of aging populations.

Bridging this gap requires coordinated efforts among researchers, clinicians, and policymakers to design studies that reflect the multifaceted nature of aging. Reforms should include interdisciplinary, problem-based education; institutional support for hybrid clinical-academic roles and cross-disciplinary centers; and funding priorities that emphasize methodological innovation, clinical relevance, and social impact.

Interdisciplinary teams that integrate ethicists, clinicians, and policymakers are uniquely positioned to navigate these complex challenges and foster innovation that is both ethically grounded and socially inclusive. [70].

Bloom's Taxonomy reflects the field's progress in generating increasingly sophisticated knowledge, while cautioning against stagnation in the absence of integrative frameworks [64]. Geriatric prosthodontics stands at a critical juncture: it may continue as a collection of isolated innovations or evolve into a coordinated, interdisciplinary model of care that is biologically informed, patient-centered, and responsive to systemic needs. The path chosen will significantly shape the future of oral health and improve the quality of life for older adults.

Limitations of the Scoping Review Process

Despite the rigorous methodology employed in this scoping review, certain limitations remain. Future research should aim to conduct systematic reviews or meta-analyses to critically evaluate the efficacy and clinical outcomes of specific biotechnologies in geriatric prosthodontics. However, the justification for a scoping review lies in the breadth, complexity, and evolving nature of the field. The biotechnology landscape in geriatric medicine is expansive and rapidly developing, making it difficult to formulate a singular, narrowly focused research question suitable for systematic synthesis. Additionally, the absence of a unified specialization within geriatric medicine/dentistry means that care delivery and research efforts remain distributed across various disciplines. These efforts, while collaborative, often lack full integration, resulting in fragmented approaches to complex patient needs. In this context, a scoping review serves as an appropriate and necessary method for mapping the existing evidence, identifying key themes, and highlighting gaps in knowledge across intersecting domains.

Conclusion

This review highlights the substantial progress in geriatric prosthodontics, encompassing foundational biological knowledge and advancements in materials science, digital technologies, and artificial intelligence. A key methodological contribution of this study is the novel integration of the PRISMA framework with Bloom's cognitive taxonomy, which enabled both transparent evidence selection and structured stratification of cognitive complexity within the literature. This combined approach offered a novel tool for assessing knowledge development in interdisciplinary research domains. While the convergence of fields such as bioengineering, gerodontology, and behavioral science presents significant potential, ongoing challenges, including fragmented research efforts, limited knowledge translation, and structural inequities, hinder comprehensive progress. Advancing geriatric prosthodontics requires enhanced interdisciplinary collaboration and a focus on ensuring that innovations align with the clinical and contextual needs of aging populations.

Recommendations for Future Research

Future research should prioritize interdisciplinary collaboration through integrated frameworks that align clinical outcomes with patient-centered data. Longitudinal studies are needed to investigate the interrelationships among aging, cognitive function, and oral health, while also addressing issues of digital equity, including access and usability. Evaluations of AI and CAD/CAM technologies must encompass diverse populations and care settings to ensure broad applicability. Adopting a biopsychosocial model is essential, particularly for individuals experiencing frailty, and should be supported by multidisciplinary teams and ethically grounded research that considers consent, privacy, and accessibility. Educational strategies must promote interprofessional learning and continuous professional development to prepare dental and healthcare professionals for emerging technologies. Collectively, these efforts will help establish geriatric prosthodontics as a leading model of patient-centered, translational care. Summarize the key findings and their significance. Provide a brief statement on the potential impact of the study and any recommendations for further research or practice.

Conflict of Interest

There are no conflicts of interest that may have influenced the research, authorship or publication of the article.

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Ethical Statement

This project was exempt from IRB review as it did not qualify as human subject research under federal regulations.

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