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Review Article

Precision Prosthodontics: Integrating Patient-Specific Risk Assessment, Digital Technologies, Biomaterials, and Clinical Decision-Making for Personalized Oral Rehabilitation

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Abstract

Precision medicine has encouraged a shift from standardized treatment strategies toward decision-making based on individual patient characteristics. This concept is increasingly relevant to prosthodontics, where treatment outcomes are influenced by biological, anatomical, functional, behavioral, esthetic, and psychosocial factors. Contemporary digital technologies and biomaterials provide new opportunities to incorporate these variables into prosthodontic treatment planning, but their clinical value varies according to indication and level of evidence.

This narrative review examines the emerging concept of precision prosthodontics with emphasis on patient-specific risk assessment, digital diagnostics, biomaterial selection, implant rehabilitation, functional and occlusal assessment, patient-reported outcomes, and individualized maintenance. Particular attention is given to the distinction between established clinical applications and emerging technologies that remain insufficiently validated for routine use. The review also proposes a Precision Functional Assessment Pyramid comprising biological assessment, functional evaluation, digital assessment, personalized prosthetic design, and patient-centered outcomes.

Current evidence supports the selective use of digital workflows, prosthetically driven implant planning, contemporary biomaterials, functional assessment, and patient-reported outcome measures in appropriately selected clinical situations. However, evidence remains heterogeneous for several emerging technologies, particularly artificial intelligence, predictive analytics, digital twins, and biomarker-based approaches. High technical accuracy does not necessarily translate into improved patient outcomes, and long-term prospective evidence remains limited.

Precision prosthodontics should therefore be regarded as an evolving decision-making framework rather than a technology-driven replacement for conventional prosthodontic principles. Future research should establish which components provide measurable clinical benefit, identify appropriate patient populations, and evaluate long-term clinical, patient-reported, and economic outcomes.

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Keywords

Biomaterials; Digital dentistry; Implant dentistry; Oral rehabilitation; Personalized dentistry; Precision medicine; Precision prosthodontics; Prosthodontics.

Introduction

Prosthodontic rehabilitation has traditionally been guided by established clinical principles, diagnostic examination, clinician experience, and standardized treatment protocols. These approaches remain fundamental to contemporary care; however, patients receiving apparently similar prosthodontic interventions may demonstrate substantial differences in biological response, functional adaptation, prosthesis longevity, and satisfaction. Such variability has increased interest in individualized treatment strategies that account for patient-specific anatomical, biological, functional, behavioral, and psychosocial characteristics.[1]

The concept of precision medicine provides a broader framework for such individualized care. In dentistry, this concept has evolved into precision dentistry, in which patient-specific information is integrated with diagnostic technologies and clinical evidence to support individualized prevention and treatment.[2] Prosthodontics is particularly suited to this approach because treatment outcomes depend on the interaction between the supporting tissues, residual dentition, occlusal function, systemic health, material properties, prosthetic design, patient expectations, and maintenance behavior.[3]

Digital technologies have substantially expanded the ability to characterize these variables. Cone-beam computed tomography (CBCT), intraoral and facial scanning, digital smile design, virtual articulators, jaw-tracking, photogrammetry, computer-aided design/computer-aided manufacturing (CAD/CAM), and artificial intelligence (AI) can provide complementary anatomical, functional, and esthetic information.[4] However, the availability of these technologies should not be equated with improved clinical outcomes. Their value depends on diagnostic indication, data quality, clinician expertise, interoperability, cost, and the strength of evidence supporting their clinical use.[5]

A similar principle applies to biomaterials. Contemporary ceramics, high-performance polymers, CAD/CAM polymers, and additively manufactured materials provide a broader range of restorative options than was previously available. Nevertheless, no material is universally optimal. Material selection must be interpreted in relation to mechanical loading, esthetic requirements, remaining tooth structure, biological conditions, restorative space, maintenance requirements, and patient priorities.[6-9]

Accordingly, precision prosthodontics should be understood not simply as the adoption of digital technologies or advanced materials, but as a decision-making framework in which patient-specific information is used to select, modify, and monitor prosthodontic treatment. The critical question is not whether a technology is more sophisticated than a conventional method, but whether its use improves diagnostic confidence, treatment planning, clinical outcomes, efficiency, patient experience, or long-term maintenance.

The literature addressing these components remains fragmented. Existing reviews commonly examine individual technologies, materials, implant workflows, or digital applications, whereas comparatively little attention has been directed toward integrating these domains into a clinically coherent framework.[7-9] Therefore, this narrative review synthesizes the contemporary evidence relevant to individualized prosthodontic care, with particular emphasis on patient-specific risk assessment, digital diagnostics, biomaterial selection, implant rehabilitation, functional and occlusal assessment, patient-reported outcomes, and risk-based maintenance. In addition, a conceptual Precision Functional Assessment Pyramid is proposed to illustrate how biological and functional assessment can precede digital planning and personalized prosthetic design.

The objective is not to suggest that individualized prosthodontics has replaced conventional principles, but to identify where patient-specific assessment can meaningfully refine established prosthodontic decision-making and where the current evidence remains insufficient for routine implementation.

Evolution of Precision Medicine into Precision Prosthodontics

Precision medicine introduced a shift from population-based treatment strategies toward decision-making informed by individual biological and clinical characteristics. In dentistry, this concept has evolved into precision dentistry, where clinical examination, imaging, digital records, biological information, and patient preferences may be integrated to support individualized care.[10]

Prosthodontics provides a particularly relevant clinical setting because treatment success is determined by multiple interacting variables rather than by the prosthesis alone. Residual ridge anatomy, periodontal and peri-implant health, bone quality, occlusal function, salivary status, parafunctional activity, esthetic requirements, systemic health, treatment expectations, and maintenance behavior can all modify clinical outcomes.[11]

The development of implant therapy further demonstrated the limitations of purely site-based treatment planning. Although osseointegration provided predictable support for fixed and removable implant prostheses, clinical outcomes remained dependent on

patient-related, biological, mechanical, and maintenance factors.[12] This encouraged a transition from bone-driven toward prosthetically driven planning and, subsequently, toward more comprehensive patient-specific assessment.

Digital dentistry has accelerated this transition by enabling multiple sources of information to be combined within a single workflow. CBCT can characterize three-dimensional anatomy, intraoral scanning can record dental morphology, facial scanning can contribute esthetic information, and digital articulation and jaw-tracking can provide additional functional data.[13] However, these technologies should be regarded as complementary diagnostic tools rather than replacements for clinical examination.

The contemporary concept of precision prosthodontics therefore represents an integration of established prosthodontic principles with patient-specific data and selected technological advances. Its defining characteristic is not the number of digital devices used, but the extent to which information is translated into clinically justified decisions. A technologically sophisticated workflow that does not alter diagnosis, treatment selection, risk management, or patient outcomes should not automatically be considered more precise.

This distinction is particularly important when interpreting emerging technologies. Digital workflows, advanced biomaterials, AI, and predictive analytics may expand the range of available treatment options, but their clinical value remains dependent on evidence quality, appropriate indication, cost-effectiveness, accessibility, and clinician expertise. Precision prosthodontics should therefore be viewed as an evolving framework whose individual components have different levels of clinical maturity rather than as a fully validated replacement for conventional prosthodontic care.

Table 1 summarizes the conceptual transition from conventional prosthodontic treatment toward precision prosthodontics. Conventional approaches generally rely on standardized diagnostic and treatment protocols, whereas precision prosthodontics integrates patient-specific biological, anatomical, functional, behavioral, esthetic, digital, and patient-reported information into clinical decision-making. The comparison emphasizes that precision prosthodontics is not intended to replace established prosthodontic principles but to refine them through individualized risk assessment, selective use of digital technologies, personalized biomaterial selection, individualized occlusal management, and patient-centered outcome assessment. This framework places the individual patient's characteristics and treatment objectives at the center of prosthodontic planning.

Table 1. Comparison between Conventional Prosthodontics and Precision Prosthodontics

Parameter	Conventional Prosthodontics	Precision Prosthodontics
Treatment philosophy	Standardized treatment protocols	Individualized patient-centered rehabilitation
Diagnostic approach	Clinical examination and conventional radiographs	Comprehensive digital and biological assessment
Treatment planning	Prosthesis-oriented	Patient-oriented
Data utilization	Limited clinical parameters	Integration of anatomical, biological, functional, behavioral, and digital data
Biomaterial selection	Material availability and clinician preference	Customized according to patient-specific functional and esthetic requirements
Occlusal evaluation	Conventional articulators and clinical assessment	Digital occlusal analysis, virtual articulators, jaw-tracking
Implant planning	Conventional radiography	CBCT-guided and digitally planned implant placement
Outcome assessment	Prosthesis survival and clinician evaluation	Clinical outcomes combined with patient-reported outcome measures (PROMs)
Recall protocol	Uniform maintenance schedule	Personalized maintenance based on individual risk profile
Future integration	Limited predictive capability	Artificial intelligence, predictive analytics, digital twins, and precision medicine

Patient-Specific Risk Assessment: The Foundation of Precision Prosthodontics

Patient-specific risk assessment should precede definitive prosthodontic treatment and integrate systemic, oral, functional, behavioral, psychological, and socioeconomic factors. Conditions such as diabetes, osteoporosis, cardiovascular disease, autoimmune disorders, radiotherapy, and medication use should be evaluated according to disease control and individual risk rather than considered absolute contraindications.[14]

Oral and Biological Risk Assessment: Assessment should include residual ridge morphology, periodontal and peri-implant status, mucosal and salivary health, and bone quantity and quality, as these directly influence support, retention, tissue stability, implant prognosis, and prosthesis tolerance. Digital scanning, CBCT, and implant-planning software facilitate individualized evaluation.[15]

Functional Risk Assessment: Occlusion, mandibular movements, parafunction, temporomandibular disorders, and masticatory demands should be assessed. Digital occlusal analysis, jaw tracking, and virtual articulators can improve objective evaluation and individualized treatment planning.[16]

Behavioral and Lifestyle Risk Assessment: Smoking, oral hygiene, nutritional status, and maintenance compliance substantially affect treatment outcomes. Risk modification should include smoking cessation, individualized hygiene instruction, nutritional assessment, and tailored maintenance protocols.[17]

Psychological and Socioeconomic Assessment: Expectations, anxiety, esthetic preferences, previous dental experiences, affordability, and access to maintenance influence treatment acceptance and satisfaction. Shared decision-making, realistic counseling, informed consent, and digital visualization can help align treatment with patient-defined goals.[18]

Overall, precision prosthodontics emphasizes risk stratification rather than risk labeling. Patients with the same diagnosis may require different treatment strategies according to their biological reserve, functional demands, expectations, and ability to maintain the prosthesis.

Table 2 presents a multidimensional framework for patient-specific risk assessment before prosthodontic treatment. It demonstrates that treatment planning should extend beyond the local dental condition and incorporate systemic, biological, functional, behavioral, psychological, and socioeconomic determinants. These factors may influence healing, prosthesis support and stability, implant prognosis, material selection, treatment acceptance, maintenance requirements, and long-term outcomes. Accordingly, precision prosthodontics emphasizes risk stratification rather than assigning patients to uniform treatment pathways, allowing the treatment strategy and maintenance protocol to be adapted to the individual's biological reserve, functional demands, expectations, and ability to maintain the prosthesis.

Table 2. Comprehensive Patient-Specific Risk Assessment Framework in Precision Prosthodontics

Risk Domain	Assessment Parameters	Clinical Implications
Systemic	Diabetes, osteoporosis, cardiovascular disease, autoimmune disorders, head and neck radiation, medication	Healing capacity, implant prognosis, infection risk, prosthesis selection
Biological	Ridge morphology, periodontal status, bone quality, salivary function, mucosal health	Prosthesis support, retention, stability, osseointegration
Functional	Occlusion, bruxism, temporomandibular disorders, masticatory efficiency	Material selection, occlusal design, prosthesis longevity
Behavioral	Smoking, oral hygiene, compliance, dietary habits	Maintenance planning, biological complications
Psychological	Expectations, motivation, anxiety, esthetic demands, quality-of-life concerns	Shared decision-making, treatment acceptance, satisfaction
Socioeconomic	Financial capacity, accessibility, treatment preferences	Feasibility of treatment options and long-term maintenance

This multidimensional framework distinguishes precision prosthodontics from conventional prosthodontic planning by recognizing that treatment success depends on the integration of systemic, biological, functional, behavioral, psychological, and socioeconomic determinants, rather than prosthesis design alone. Individualized risk profiling enables clinicians to select the most appropriate restorative strategy, anticipate complications, personalize maintenance protocols, and ultimately improve long-term clinical outcomes and patient-centered care.

Precision Diagnostics: Digital Technologies Enabling Personalized Prosthodontic Care

Digital diagnostics have expanded the amount and type of information available for prosthodontic treatment planning. Their principal contribution is not simply increased measurement accuracy but the ability to combine anatomical, functional, and esthetic information before definitive treatment. Nevertheless, the clinical usefulness of each technology depends on indication, data quality, operator competence, cost, and whether the additional information changes treatment decisions.

CBCT is particularly valuable when three-dimensional assessment of bone, anatomical structures, implant sites, or complex pathology is required. Its routine use in patients for whom such information is unlikely to influence management is difficult to justify because radiation exposure, cost, and interpretation requirements remain relevant considerations.[19]

Intraoral scanning provides efficient digital records and facilitates CAD/CAM integration, laboratory communication, and longitudinal data storage. Its performance is well established for many tooth-supported applications, but accuracy may decrease with extensive edentulous surfaces and challenging scanning conditions.[20] Thus, digital scanning should be selected

according to clinical indication rather than assumed to be universally superior to conventional impression procedures.

Facial scanning and digital smile design can improve visualization of facial relationships and facilitate communication of esthetic objectives. Their greatest value may occur in complex esthetic rehabilitation, where tooth position must be considered in relation to facial form and lip dynamics. However, the accuracy of the final clinical result remains dependent on the quality of the records, software workflow, clinician interpretation, and transfer of the virtual plan to the definitive restoration.[21]

Virtual articulators and jaw-tracking systems provide additional information regarding mandibular movement and dynamic occlusion. These technologies may be useful in complex full-mouth rehabilitation, significant occlusal discrepancies, and selected temporomandibular disorders. However, their increased measurement capability does not necessarily demonstrate superior patient outcomes, and their routine use requires accurate digital records and appropriate interpretation.[22]

Photogrammetry is particularly promising for full-arch implant rehabilitation because accurate recording of multiple implant positions may reduce cumulative impression-related errors. Its clinical relevance is greatest when passive fit and implant positional accuracy are critical. Nevertheless, equipment cost and workflow requirements may limit widespread adoption.[23]

Artificial intelligence represents the most rapidly evolving component of digital prosthodontics. Current applications include image analysis, anatomical segmentation, treatment planning, and prosthesis design. Although high diagnostic performance has been reported in selected datasets, external validation, dataset diversity, interpretability, regulatory oversight, and integration into real-world clinical workflows remain important limitations.[24] AI should consequently be considered an adjunct to, rather than a replacement for, clinician-led diagnosis and treatment planning.

Overall, the evidence supports a selective rather than technology-maximalist approach. The most appropriate digital workflow is the one that provides clinically relevant information with acceptable accuracy, cost, complexity, and patient burden.

Table 3 outlines the principal digital diagnostic technologies currently relevant to precision prosthodontic care, together with their major clinical applications, advantages, and limitations. Cone-beam computed tomography, intraoral and facial scanning, digital smile design, virtual articulators, jaw-tracking systems, photogrammetry, and artificial intelligence provide complementary anatomical, esthetic, functional, and predictive information. Their clinical value, however, depends on the indication, accuracy of the acquired data, operator expertise, interoperability, cost, and ability to influence treatment decisions. Therefore, the table supports a selective, clinically justified approach to digital technology rather than indiscriminate adoption of increasingly sophisticated digital systems.

Table 3. Digital Diagnostic Technologies in Precision Prosthodontics

Technology	Primary Clinical Applications	Advantages	Limitations
Cone-Beam Computed Tomography (CBCT)	Bone assessment, implant planning, TMJ evaluation, pathology	Three-dimensional imaging, high anatomical accuracy	Radiation exposure, higher cost
Intraoral Scanner	Digital impressions, CAD/CAM workflows, implant impressions	High accuracy, patient comfort, digital records	Accuracy decreases in extensive edentulous arches
Facial Scanner	Facial analysis, smile design, maxillofacial rehabilitation	Comprehensive esthetic assessment	Equipment cost and learning curve
Digital Smile Design	Esthetic planning, patient communication	Improved visualization and interdisciplinary planning	Dependent on image quality and software expertise
Virtual Articulator	Occlusal analysis, full-mouth rehabilitation	Dynamic simulation of mandibular movements	Requires accurate digital records
Jaw-Tracking System	Functional analysis, TMD evaluation	Objective mandibular movement assessment	Limited availability
Photogrammetry	Implant position recording	Exceptional accuracy for full-arch implant prostheses	High equipment cost
Artificial Intelligence	Image analysis, treatment planning, predictive diagnostics	Improved efficiency, consistency, and data integration	Requires large datasets, ethical and regulatory considerations

Digital diagnostic technologies have transformed prosthodontics from a discipline dependent on static clinical observations into one capable of comprehensive patient-specific analysis. Within the philosophy of precision prosthodontics, these technologies function

synergistically to improve diagnostic accuracy, personalize treatment planning, enhance interdisciplinary communication, and optimize long-term clinical outcomes. Their integration forms the technological foundation upon which individualized oral rehabilitation is built.

Precision Biomaterial Selection: Individualizing Restorative Materials for Personalized Oral Rehabilitation

Material selection in precision prosthodontics should be individualized according to mechanical, biological, functional, esthetic, and patient-specific factors rather than laboratory strength alone. Zirconia is advantageous for high-load, posterior, implant-supported, and bruxism cases, whereas lithium disilicate is preferred for highly esthetic, adhesive, and moderately loaded restorations.[25] PEEK and PEKK offer lightweight, resilient, biocompatible alternatives for selected removable, implant-supported, and maxillofacial applications, although esthetic limitations and limited long-term evidence require careful case selection.[26] CAD/CAM PMMA remains valuable because of its affordability, repairability, and predictable clinical performance, while additive manufacturing enables efficient fabrication of individualized prostheses and requires consideration of material durability, aging, polymerization, surface characteristics, and regulatory status.[27]

Material selection should consider **age, systemic health, remaining tooth structure, occlusal load, bruxism, periodontal and implant support, esthetic expectations, restorative space, oral hygiene, maintenance capacity, financial factors, material sensitivities, and patient preference**. The appropriate material is therefore not necessarily the strongest or newest, but the one providing the most favorable **biological, functional, esthetic, and long-term outcome for the individual patient**.

Table 4 provides a patient-centered framework for selecting contemporary prosthodontic biomaterials according to their advantages, limitations, and clinical indications. Rather than considering one material universally superior, precision prosthodontics requires material selection to be based on the interaction between mechanical loading, remaining tooth structure, periodontal and implant support, esthetic requirements, restorative space, systemic and biological conditions, parafunctional activity, oral hygiene, maintenance capacity, and patient preferences. The matrix therefore emphasizes that the most appropriate material is the one that provides the most favorable overall biological, functional, esthetic, and long-term outcome for the individual patient rather than simply the material with the greatest mechanical strength or newest technological profile.

Table 4. Precision Biomaterial Selection Matrix

Material	Major Advantages	Limitations	Ideal Clinical Indications
Monolithic Zirconia	Excellent strength, low wear, high biocompatibility	Moderate translucency	Bruxism, posterior crowns, implant prostheses, full-mouth rehabilitation
Lithium Disilicate	Superior esthetics, adhesive bonding, translucency	Lower fracture resistance	Veneers, anterior crowns, partial coverage restorations
Hybrid Ceramic	Shock absorption, conservative preparations	Limited long-term evidence	Inlays, onlays, minimally invasive restorations
PEEK	Lightweight, metal-free, stress distribution	Limited esthetics	RPD frameworks, obturators, implant prostheses
PEKK	Higher strength than PEEK, excellent biomechanical behavior	Cost, limited availability	Implant-supported frameworks, extensive rehabilitations
CAD/CAM PMMA	Accurate fit, repairability, affordability	Lower long-term wear resistance	Complete dentures, provisional prostheses
3D-Printed Resins	Rapid fabrication, customization	Variable mechanical properties	Surgical guides, trial dentures, provisional restorations

Precision biomaterial selection extends beyond material science by integrating biological compatibility, biomechanics, esthetics, patient expectations, and maintenance considerations into restorative decision-making. As biomaterials continue to evolve alongside digital technologies and artificial intelligence, future prosthodontic rehabilitation will increasingly rely on predictive, patient-specific material selection algorithms that optimize both clinical outcomes and long-term quality of life.

Precision Implant Prosthodontics: Individualized Planning for Predictable Oral Rehabilitation

Implant-supported prosthodontics has evolved from standardized implant placement toward a **patient-centered, prosthetically driven approach** integrating biological, mechanical, esthetic, functional, digital, and patient-related factors. Successful rehabilitation therefore depends on more than implant survival and requires individualized planning from diagnosis through maintenance.[28]

Comprehensive Patient Assessment

Assessment should include systemic health, oral and peri-implant conditions, facial esthetics, function, psychological expectations, socioeconomic factors, and maintenance requirements. Diabetes, osteoporosis, cardiovascular and autoimmune diseases, bisphosphonate therapy, smoking, and previous head and neck radiotherapy should be considered through **individualized risk stratification** rather than as automatic contraindications. Surgical protocols, loading, and recall intervals should reflect patient-specific biological risk.[29] Shared decision-making should incorporate esthetic expectations, affordability, treatment duration, maintenance, and functional priorities.

Prosthetically Driven Digital Planning

CBCT, intraoral and facial scanning, digital smile analysis, and implant-planning software enable integrated visualization of bone, soft tissues, occlusion, facial structures, and the proposed restoration. This facilitates prosthetically guided implant positioning, anatomical assessment, restorative-space and emergence-profile planning, improved interdisciplinary communication, and more accurate guided surgery.[30]

Bone Quality and Surgical Planning

Implant planning should consider bone quantity and quality, cortical thickness, trabecular architecture, vascularity, and remodeling potential. Implant dimensions, osteotomy preparation, drilling protocols, insertion torque, and healing duration should therefore be individualized. Dense bone may require modified osteotomy preparation, whereas low-density bone may benefit from undersized osteotomies or osseodensification to improve primary stability.[31]

Soft Tissue and Esthetic Risk

Peri-implant soft-tissue phenotype is critical to long-term esthetic stability. Thin phenotypes carry greater risks of recession, discoloration, and marginal bone remodeling and may require modification of implant position, emergence profile, abutment design, or soft-tissue augmentation. Digital facial and smile analysis further supports individualized assessment of smile line, gingival display, lip dynamics, and facial symmetry.[32]

Personalized Loading

Immediate, early, or conventional loading should be selected according to **primary stability, bone density, implant design, occlusal loading, implant number, prosthesis design, systemic health, smoking, and compliance**. Favorable stability, bone quality, controlled loading, and good systemic health may support immediate loading, whereas higher-risk patients may require prolonged healing.[33]

Emergence Profile and Prosthetic Design

Implant restorations should be individualized according to soft-tissue morphology, occlusion, hygiene accessibility, esthetic demands, and maintenance capacity. Customized CAD/CAM abutments and restorations can optimize emergence profiles, facilitate hygiene, and support peri-implant tissue health. Occlusal schemes should account for loading patterns, opposing dentition, parafunction, and prosthesis type because implants lack the shock-absorbing periodontal ligament.[34]

Risk-Based Maintenance

Long-term implant success requires individualized maintenance and monitoring for peri-implant mucositis and peri-implantitis. Recall frequency should reflect **periodontitis history, smoking, diabetes control, oral hygiene, prosthesis complexity, implant location, occlusal loading, salivary function, and previous biological complications**.[35] Low-risk patients may require annual maintenance, whereas high-risk patients may benefit from three- to four-monthly reviews. Digital monitoring and standardized peri-implant assessment can further support long-term care.

Future Directions

Emerging technologies—including **AI-assisted implant planning, predictive risk models, digital twins, dynamic navigation, robotic placement, smart implant surfaces, bioactive coatings, personalized regenerative therapies, salivary biomarkers, and genomic risk prediction**—may enable prediction of implant outcomes and complications and increasingly individualized treatment protocols.[36]

Overall, precision implant prosthodontics represents a shift from **standardized implant treatment to biologically informed, prosthetically driven, digitally integrated, and risk-adapted rehabilitation**.

Table 5 summarizes the major patient-specific factors that should influence decision-making in precision implant prosthodontics. Implant rehabilitation is

presented as a multidisciplinary and risk-adapted process in which systemic health, biological conditions, anatomical characteristics, functional demands, behavioral factors, esthetic expectations, and maintenance capacity interact to determine the most appropriate implant and prosthetic strategy. This approach moves beyond site-specific or bone-driven implant planning toward prosthetically driven and biologically informed rehabilitation, in which surgical planning, implant position, prosthetic design, material selection, occlusal management, and maintenance are tailored to the individual patient's risk profile.

Table 5. Patient-Specific Factors Influencing Precision Implant Prosthodontic Decision-Making

Clinical Domain	Patient-Specific Variables	Clinical Impact	Precision Prosthodontic Strategy
Systemic Health	Diabetes, osteoporosis, smoking, cardiovascular disease	Healing, osseointegration, infection risk	Medical optimization, individualized loading, risk-based maintenance
Bone Characteristics	Bone density, ridge morphology,cortical thickness	Primary stability, implant selection	CBCT-guided planning, modified osteotomy, implant design customization
Soft Tissue Profile	Gingival phenotype, keratinized tissue, smile line	Esthetics, recession risk	Customized emergence profile, soft tissue augmentation when indicated
Functional Factors	Bruxism, occlusal force, opposing dentition	Mechanical complications	Occlusal modification, high-strength materials, protective occlusal splints
Digital Assessment	CBCT, intraoral scans, facial scans, virtual planning	Diagnostic accuracy	Prosthetically driven digital workflow
Behavioral Factors	Oral hygiene, compliance, maintenance attendance	Long-term implant survival	Individualized recall schedule and patient education
Patient Preferences	Esthetics, treatment duration, affordability	Treatment acceptance	Shared decision-making and personalized treatment selection

Precision implant prosthodontics represents the convergence of digital technology, evidence-based medicine, biomaterial science, and patient-centered care. Rather than treating implants as isolated mechanical devices, this philosophy recognizes them as components of a complex biological and functional system unique to every individual. Successful rehabilitation therefore depends upon tailoring surgical protocols, prosthetic design, maintenance strategies, and long-term monitoring to each patient's specific biological and behavioral profile. By integrating comprehensive risk assessment with advanced digital planning and personalized maintenance, precision implant prosthodontics offers a pathway toward more predictable clinical outcomes, improved patient satisfaction, and enhanced longevity of implant-supported restorations.

Precision Occlusion and Functional Rehabilitation: Individualizing Functional Outcomes

Occlusal rehabilitation should restore harmonious mandibular function, mastication, phonetics, comfort, and biomechanical stability. Because no single occlusal scheme is universally superior, precision prosthodontics advocates individualized selection based on anatomical, functional, biological, and behavioral factors.[37]

The stomatognathic system functions as an integrated unit involving teeth, periodontium, TMJs, muscles, neuromuscular control, and craniofacial structures; therefore, occlusal planning should consider the patient's functional physiology and adaptive capacity.[38]

Functional Assessment

Assessment should include **maximum intercuspation, centric relation, VDO, mandibular movements, functional contacts, excursive guidance, force distribution, muscle and TMJ status, parafunction, and prosthetic wear patterns**. Conventional examination may be complemented by digital measurements and patient-reported symptoms.

Individualized Occlusal Schemes

Occlusal design should reflect remaining dentition, prosthesis type, periodontal and implant support, neuromuscular coordination, and functional demands.

Mutually protected, group-function, lingualized, and balanced occlusion remain appropriate in selected patients; precision prosthodontics emphasizes **individualized selection rather than adherence to a single philosophy**.[39]

Vertical Dimension

VDO should be determined using clinical, phonetic, esthetic, physiologic, and functional parameters rather than a fixed numerical value. Digital facial analysis, virtual articulators, facial scanning, provisional restorations, and functional recordings can support individualized assessment and adaptation.[40]

Digital Occlusal Analysis

Computerized occlusal analysis provides information on **contact location, timing, force distribution, balance, and functional interferences**, complementing articulating paper and enabling more objective occlusal adjustment and longitudinal monitoring.[41]

Bruxism

Bruxism increases the risk of ceramic fracture, implant overload, screw loosening, prosthetic fracture, tooth wear, and TMD symptoms. Management should be risk-based and may include **high-strength materials, adequate restorative thickness, optimized occlusion, occlusal splints, wear monitoring, and closer maintenance**.[42]

TMD and Neuromuscular Adaptation

TMD assessment should include joint sounds, pain, muscle tenderness, mandibular movements, functional limitations, psychosocial factors, and occlusal stability. Digital jaw tracking, virtual articulators, and MRI may assist selected cases. Prosthodontic rehabilitation should prioritize **comfortable function rather than theoretically ideal occlusion**. Individual variability in neuromuscular adaptation further supports avoiding unnecessary irreversible occlusal adjustment.[43]

Functional Outcomes

Treatment success should include both clinical and patient-reported outcomes, including **masticatory efficiency, chewing comfort, speech, muscle fatigue, TMJ comfort, dietary diversity, patient satisfaction, and oral health-related quality of life**.[44]
Overall, precision occlusion represents a shift from **standardized occlusal doctrines toward individualized, function-oriented, digitally informed, and patient-centered rehabilitation**.

Table 6 contrasts conventional occlusal approaches with an individualized precision-prosthodontic approach. Rather than advocating a single universally applicable occlusal philosophy, precision occlusion considers the patient's remaining dentition, prosthesis type, periodontal and implant support, neuromuscular coordination, parafunctional activity, temporomandibular status, functional requirements, and adaptive capacity. Vertical dimension, occlusal contacts, mandibular movements, occlusal adjustment, and functional assessment can be supplemented by digital occlusal analysis, virtual articulation, and jaw-tracking where clinically indicated. The emphasis is consequently shifted from adherence to a predetermined occlusal doctrine toward individualized functional rehabilitation and patient-centered outcomes.

Table 6. Individualized Occlusal Considerations in Precision Prosthodontics

Clinical Factor	Conventional Approach	Precision Prosthodontic Approach
Occlusal philosophy	Single preferred concept	Patient-specific occlusal scheme
Vertical dimension	Standardized clinical methods	Digital and functional individualized assessment
Occlusal adjustment	Subjective clinical interpretation	Objective digital occlusal analysis
Bruxism	General contraindication	Individualized risk management and material selection
TMD management	Occlusion-centered	Multidisciplinary functional assessment
Functional evaluation	Static occlusal contacts	Dynamic occlusal and neuromuscular analysis
Outcome assessment	Prosthesis survival	Function, comfort, adaptation, and quality of life

Precision occlusion represents a paradigm shift from rigid adherence to predetermined occlusal philosophies toward individualized functional rehabilitation based on each patient's biological characteristics, neuromuscular adaptability, digital functional analysis, and clinical requirements. Rather than seeking a universally ideal occlusion, precision prosthodontics strives to achieve a stable, comfortable, biologically compatible, and patient-specific functional relationship that supports long-term oral health and prosthesis longevity.

DISCUSSION

The available evidence supports several components of individualized prosthodontic care, but it does not support the assumption that the complete concept of precision prosthodontics has already been clinically validated as a distinct treatment model. The current evidence is heterogeneous and varies substantially according to the technology, clinical indication, outcome assessed, and study design. Therefore, the concept should currently be regarded as a framework for clinical decision-making rather than as a validated therapeutic protocol.

Among digital technologies, intraoral scanning and CAD/CAM workflows have the most established clinical relevance in selected fixed prosthodontic applications.[45] Their principal advantages include digital data storage, rapid communication with the laboratory, improved workflow integration, and elimination of several steps associated with conventional impressions. However, accuracy is influenced by scanning strategy, arch length, edentulous anatomy, operator experience, and the specific clinical indication. Consequently, the evidence does not justify interpreting digital impressions as universally superior to conventional impressions in every prosthodontic situation.[46]

CBCT provides valuable three-dimensional information for implant planning and selected complex diagnostic situations. Nevertheless, its use must remain indication-based because radiation exposure, cost, image artifacts, and interpretation requirements limit its justification as a routine examination for all prosthodontic patients. The clinical benefit is therefore greatest when three-dimensional anatomical information is expected to alter diagnosis or treatment planning.[47]

The evidence for facial scanning, digital smile design, virtual articulators, jaw-tracking, and photogrammetry is promising but comparatively heterogeneous. These technologies can provide information that is difficult to obtain with conventional methods and may improve visualization, communication, and digital integration. However, improvements in measurement accuracy or workflow efficiency should not automatically be interpreted as improvements in patient-centered clinical outcomes. Long-term prospective evidence linking these technologies to prosthesis survival, biological complications, functional adaptation, or quality of life remains comparatively limited.[48]

Artificial intelligence represents an important emerging component of individualized prosthodontics. Current applications include image interpretation, anatomical segmentation, treatment planning, prosthetic design, and predictive modelling.[49] Nevertheless, algorithmic performance in controlled datasets does not necessarily translate into equivalent performance in routine clinical populations. Differences in imaging protocols, patient characteristics, training datasets, external validation, explainability, and regulatory requirements remain important barriers. AI should therefore function as decision support rather than as an autonomous substitute for clinical judgment.[50]

Evidence regarding contemporary biomaterials similarly supports a **case-dependent rather than material-superiority model**. Zirconia provides favorable mechanical performance in high-load situations, whereas lithium disilicate offers important optical and adhesive advantages in appropriately selected cases. High-performance polymers such as PEEK and PEKK may provide useful mechanical and weight-related advantages in selected applications, but their indications and long-term clinical evidence remain less established than those of conventional ceramics.[51] Additively manufactured materials provide substantial opportunities for customization and workflow efficiency, but their long-term dimensional stability, mechanical performance, surface characteristics, and clinical durability remain areas of active investigation.[52]

In implant prosthodontics, prosthetically driven digital planning represents a logical extension of established prosthodontic principles rather than an entirely new clinical philosophy. CBCT, intraoral scanning, virtual planning, and digital fabrication can improve coordination between the surgical and restorative components of treatment. However, digital planning cannot compensate for inadequate biological assessment, poor surgical execution, inappropriate prosthetic design, or inadequate maintenance. Implant outcomes remain dependent on the interaction of patient-related, biological, surgical, prosthetic, and behavioral factors.[53]

The evidence concerning individualized occlusal management also supports caution against universal treatment algorithms. Different occlusal concepts can be clinically successful when appropriately selected, and available evidence does not establish a single occlusal philosophy as optimal for every patient. Digital occlusal analysis and jaw-tracking may provide additional quantitative information, but their clinical value should be judged by whether that information changes treatment decisions or improves patient outcomes rather than by measurement capability alone.[54]

Patient-reported outcomes provide an essential complementary dimension of evaluation. Conventional measures such as prosthesis survival, marginal adaptation, radiographic findings, and mechanical complications remain important, but they do not fully capture comfort, function, esthetic satisfaction, speech, adaptation, or oral health-related quality of life. The integration of validated PROMs therefore represents one of the more clinically meaningful aspects of individualized rehabilitation.[55]

Taken together, the evidence suggests that precision prosthodontics is best understood as an **integrative decision-making model rather than a technology-driven treatment protocol**. Established components, such as comprehensive risk assessment, prosthetically driven planning, appropriate material selection, and structured maintenance, can be incorporated into routine practice. Other components—including AI-based prediction, digital twins, genomic profiling, wearable

monitoring, and biomarker-guided treatment—remain investigational or insufficiently validated for widespread clinical adoption. This distinction is essential to avoid overstating the current maturity of precision prosthodontics.

Original Concept: Precision Functional Assessment Pyramid

A central conceptual contribution of this review is the **Precision Functional Assessment Pyramid**, which organizes individualized prosthodontic decision-making into five sequential but interconnected levels: biological foundation, functional evaluation, digital assessment, personalized prosthetic design, and patient-centered outcomes.

The framework is intentionally hierarchical. **Biological assessment forms the foundation** because treatment cannot be considered predictable when systemic health, periodontal stability, supporting tissues, or bone conditions are inadequately controlled. **Functional evaluation follows**, incorporating occlusion, mandibular movement, temporomandibular status, muscular function, and parafunctional activity. These first two levels establish the clinical context in which digital information should be interpreted.

Digital assessment constitutes the third level, rather than the starting point of the process. CBCT, intraoral scanning, virtual articulation, digital occlusal analysis, jaw-tracking, and related technologies can increase the quantity and reproducibility of available information, but their clinical value depends on the biological and functional questions that they are intended to answer.

The fourth level is **personalized prosthetic design**, in which the accumulated information is translated into decisions concerning material selection, prosthesis design, occlusal scheme, implant strategy, and manufacturing workflow. The final level is **patient-centered outcome assessment**, encompassing function, esthetics, comfort, adaptation, quality of life, satisfaction, and long-term maintenance.

The conceptual advantage of this model is that it places technology within, rather than above, clinical reasoning. It therefore differs from technology-driven digital workflows in which data acquisition may precede clear definition of the clinical problem. The pyramid also emphasizes that personalization is an iterative process: patient-reported outcomes and maintenance findings may subsequently modify risk assessment and future treatment decisions.

The framework should presently be regarded as a **conceptual clinical model rather than a validated clinical prediction tool**. Its future value will depend on prospective studies determining whether implementation improves treatment selection, reduces complications, increases patient-reported benefit, or improves cost-effectiveness compared with conventional workflows.

Patient-Reported Outcome Measures (PROMs) and Long-Term Maintenance

Prosthodontic success should extend beyond technical outcomes to include **patient-reported comfort, function, esthetics, psychosocial well-being, and quality of life**. Validated PROMs such as **OHIP and GOHAI** provide objective assessment of patient experience and support shared decision-making.[56]

Patient expectations regarding esthetics, treatment duration, maintenance, and cost should be addressed through transparent communication, digital visualization, and continuous engagement. Long-term maintenance should be **risk-based rather than standardized**, considering systemic health, smoking, periodontal status, oral hygiene, prosthesis complexity, implant status, and parafunction. Follow-up should assess prosthesis integrity, occlusion, oral hygiene, peri-implant tissues, and patient-reported concerns, with digital photography, scanning, and quantitative occlusal analysis supporting longitudinal monitoring.[57]

Challenges and Future Perspectives

Precision prosthodontics remains limited by **heterogeneous evidence, variable patient populations, outcome measures, digital systems, operator expertise, and follow-up periods**. High costs, training requirements, limited interoperability, and restricted access to digital infrastructure may further hinder implementation.[58]

Emerging technologies—including **AI, predictive analytics, digital twins, dynamic navigation, robotics, biomarkers, and genomic approaches**—require robust clinical validation; high experimental accuracy alone does not establish improved patient outcomes.[59] Future research should prioritize **external validation, prospective multicenter studies, standardized outcomes, long-term follow-up, cost-effectiveness, treatment burden, prosthesis survival, complications, PROMs, and quality of life**.

Ethical priorities include **data privacy, cybersecurity, algorithmic bias, transparency, informed consent, and accountability for AI-assisted decisions**. Most importantly, research should determine **which patients benefit from which precision technologies**.[60] Precision prosthodontics should therefore remain **risk-adapted, evidence-based, clinically proportionate, and patient-centered rather than technology-driven**.

Conclusion

Precision prosthodontics is best understood as an evolving clinical framework for integrating patient-specific biological, functional, anatomical, digital, material, behavioral, and patient-reported information into prosthodontic decision-making. The principal value of the concept lies not in replacing conventional prosthodontic principles with technology, but in using additional

information to refine diagnosis, treatment selection, prosthetic design, and long-term maintenance.

Current evidence supports several components of this approach, particularly comprehensive risk assessment, prosthetically driven digital planning in appropriate indications, individualized biomaterial selection, structured functional assessment, patient-reported outcome evaluation, and risk-based maintenance. In contrast, technologies such as AI-based prediction, digital twins, genomic profiling, and biomarker-guided treatment remain promising but require stronger prospective clinical validation.

The proposed Precision Functional Assessment Pyramid provides a conceptual model in which biological and functional assessment precede digital data acquisition and personalized prosthetic design, with patient-centered outcomes serving as the final measure of clinical success. Its clinical utility remains to be validated prospectively.

Thus, the future of precision prosthodontics should not be defined by the maximum use of technology, but by the **appropriate use of validated information to improve patient-specific decisions and meaningful clinical outcomes**. Further prospective and multicenter research is required to establish which components provide measurable benefit, for which patients, and under which clinical circumstances.

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Ethical compliance

Not applicable. This study is a narrative review of published literature and did not involve human participants, animals, patient data, or biological specimens.

Conflict of interest

The authors declare that they have no competing interests. The authors have no financial or non-financial relationships that could have influenced the work reported in this manuscript.

Author contributions

Conceptualization: AS. Data curation: AS. Formal analysis: AS. Investigation: JS. Methodology: JS. Project administration: JS. Resources: JS. Software: VK. Supervision: VK. Validation: VK. Visualization: VK. Writing - original draft: AS. Writing - review and editing: RG.

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