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REVIEW

Toward optimal prosthetic strategies: the biomechanical impact of design and material in posterior implant-supported fixed partial denture

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Keywords: Finite element analysis, High-performance polymers, Implant-supported fixed partial denture, Stress distribution, Zirconia

ABSTRACT

Implant-supported fixed partial dentures (iFPDs) are used for posterior rehabilitation. Biomechanical problems arise in the posterior due to complicated occlusal stresses and insufficient bone support. Prosthetic design and material stiffness affect stress distribution on peri-implant bone and components, affecting iFPD success. This systematic review examined the biomechanical performance of zirconia, PEKK, and PEEK two- and three-unit iFPDs with fixed-fixed and cantilever designs. FEA was used to evaluate stress distribution and clinical implications. PICO criteria and Boolean operators were used to search PubMed, Scopus, ScienceDirect, and MyEBSCO for 2020–2025 studies. Five of 158.353 documents met PRISMA 2020 criteria. Von Mises stress, prosthesis configurations, material stiffness, and stress concentration zones were extracted. Cantilever designs had the highest stress values, especially at the connector and prosthesis-abutment interface. Due to its stiffness, zirconia shielded the periimplant bone, while PEKK and PEEK reduced prosthesis stress but transferred more stress to the bone. Connectors were the most biomechanically susceptible in all designs and materials. The synergistic interplay between prosthetic design, material mechanical properties, and loading direction determines the stress distribution pattern and long-term stability of implant-supported prosthetic structures. (IJP 2025;7(1):1-7)

Introduction

Implant-supported Fixed Partial Dentures (iFPDs) have become a common rehabilitative option for patients with posterior tooth loss. Rehabilitation in the posterior region presents complex biomechanical challenges due to high occlusal loads and uneven masticatory force distribution compared to the anterior region.[1-3] Two principal designs are typically employed in iFPDs: the fixed-fixed and cantilever configurations. Although the cantilever design is often selected for economic reasons or limited prosthetic space, it carries a higher biomechanical risk, as it can induce excessive stress concentration on peri-implant bone and prosthetic components—particularly when applied in the posterior area.[4-7] In contrast, the fixed-fixed design provides greater stability by allowing a more uniform load distribution between two or more supporting implants.[8]

With the advancement of prosthetic materials, zirconia has gained wide application due to its superior strength and esthetic properties. However, its high rigidity may increase stress at the implant–bone interface.[9,10] Conversely, high-performance polymers such as polyetheretherketone (PEEK) and polyetherketoneketone (PEKK) have been introduced as alternatives, offering a lower elastic modulus that enables better masticatory force absorption and reduces stress transmission to the bone.[11-14]. Therefore, both material selection and prosthetic design must be carefully determined with respect to the biological and biomechanical conditions of patients.

According to Callister (2010), conventional testing methods for allceramic fixed partial dentures have been extensively used in in vitro studies to evaluate fracture resistance. Although considered a standard approach, these methods possess inherent limitations, including time-consuming procedures, high costs, operator-dependent variability, and limited ability to reveal detailed internal stress distributions. Moreover, physical test outcomes are often influenced by microscopic flaws within the specimens, which are difficult to control and may lead to data inconsistencies.[15]

To overcome these limitations, Finite Element Analysis (FEA) has emerged as a preferred approach for biomechanical simulation in prosthodontics. By enabling numerical interpretation of complex structures, FEA provides a comprehensive visualization of stress distribution that cannot be achieved through conventional experimental methods. It allows for predicting of stress patterns in peri-implant bone, abutments, and prosthetic components under various loading and geometrical conditions.[16-19] Despite the extensive clinical application of implant-supported Fixed Partial Dentures (iFPDs), there remains a significant gap in understanding how the interplay between prosthetic design and material properties affects biomechanical stress distribution. Hence, a systematic review of contemporary evidence is essential to clarify the influence of design and material on biomechanical stress distribution. This review represents the first attempt to integrate design parameters, material

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characteristics, and stress locations within a unified biomechanical framework for posterior implant-supported Fixed Partial Dentures (iFPDs) using finite element analysis.

Table 1. **Compilation of keywords and corresponding related terms.**

Component	Keywords	Related Terms
P (Population)	Zirconia, PEEK, or PEKK Implantsupported Fixed Partial Dentures	"Implant-supported Bridge" "Implant-Borne Prosthesis" "Posterior Implant Prosthesis" "Posterior Implant Bridge" "Implant-supported 2-abutment FPD" "3-unit Posterior Implant Prosthesis"
I (Intervention)	Fixed-Fixed design	"Fixed-Fixed Prosthesis" "Rigid Connector Design" "Fixed-Fixed Bridge" "Fixed-Fixed Configurations"
C (Comparison)	Cantilever design	"Cantilever Bridge" "Cantilever Prosthesis" "Cantilever Extension" "Cantilever-type Prosthesis" "Cantilever Framework" "Cantilever Configurations"
O (Outcome)	Biomechanical	"Finite Element Analysis" "Stress Distribution" "Fracture Resistance" "Mechanical Behavior" "Mechanical Properties" "Load-bearing Performance"

Table 2. **Summary database.**

Data Base	First screening based on keywords	Custom Range (20202025)	Subject Area	Document type, Source type, Language, Open acces	Exclude screening	Title screening	Abstract screening	Fulltext screening
Scopus	53	25	14	12	11	9	4	1
Data Base	First screening based on keywords	Custom Range (2020-2025)	Subject Area	Document type, Source type, Language, Open access	Exclude screening	Title screening	Abstract screening	Fulltext screening
PubMed	1.164	300	291	87	85	64	6	1
MyEBSCO	1.240	635	323	31	30	18	5	1
Science Direct	155.896	61.641	2.652	552	551	26	4	2
TOTAL	158.353	62.601	3.280	682	677	117	19	5

Table 3. **Assessment of the risk of bias in the included studies.**

Author (Year)	GM	MQ	MP	ETS	BC	LC	CD	A	MV	SA	OV	CR	Total (Max 24)
Aboelfadl et al. (2023)	2	2	2	2	2	2	2	2	0	0	2	2	20
Sadek et al. (2025)	2	2	2	2	2	2	2	2	0	1	2	2	21
Ahmed et al. (2022)	2	2	2	2	2	2	2	2	0	1	2	2	21
Alberto et al. (2022)	2	2	2	2	2	2	2	2	1	2	2	2	23
Botsali et al. (2025)	2	2	2	2	2	2	2	2	1	1	2	2	22

Table 4. **Biomechanical characteristics of restorative materials based on elastic modulus and poisson's ratio.**

Structure	Modulus Elastisitas (GPa)	Poisson's Ratio
Cortical Bone(15,22–25)	13.70	0.30
Cancellous Bone(22,24)	1.37	0.30
Prosthesis Monolithic Zirconia(22,23,25)	200	0.26
Prosthesis Polyetherketoneketone	3.5(25) 5.10(22)	0.36(25) 0.36(22)
Titanium(24)	110	0.30
Implant Complex(22,23,25)	110	0.34
Implants Screws(15)	110	0.35
Framework Zirconia(15)	210	0.30
Framework PEEK(23)	3.5	0.36
Enamel(24)	84.1	0.33
Dentin(24)	18.6	0.32
Periodontal Ligament(24)	0.05	0.45
VITA Ambria(24)	100	0.20

Methods

Protocol Registration and Research Question

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) guidelines were followed in the preparation of this review, as shown in Figure 1. This review investigates the biomechanical performance of iFPDs with two distinct prosthetic designs, i.e, fixed-fixed and, cantilever fabricated from different prosthetic materials, including zirconia, PEEK, and PEKK was focused research question used in this study, using the PICO framework where (P) the population is iFPDs fabricated using zirconia, PEEK or PEKK materials, intervention (I) is fixed-fixed design, comparison (C) is cantilever design, and outcome (O) is biomechanical performance of stress distribution on peri-implant bone, implant components, and iFPDs materials.

Eligibility Criteria

Inclusion Criteria; Inclusion criteria for this systematic literature review involved the following: (a) articles published in English, (b) articles published in the last 5 years between May 2020 and May 2025 (searches completed on 30 May 2025, (c) full-text research articles published in academic journals, (d) studies related to finite element analysis measurement method, and (e) evaluating the biomechanics of 3-unit implant supported prosthetic material using zirconia, PEEK or PEKK with fixed-fixed bridge design or cantilever bridge design; Exclusion Criteria; Exclusion criteria for this systematic literature review involved the following: (a) articles published more than 5 years ago or before May 2020, (b) articles published were not written in English, (c) autobiography, bibliography, biography, books and documents, interview, lecture, legal case, legislation, letter, meta-analysis, news, newspaper, study design randomized control trial, in vitro studies, case report, preprint, review, scientific integrity review or systematic review, (d) studies that are multi-unit prostheses, overdenture, tooth-implant supported prostheses, (e) full text not available/accessible, and (f) articles not published in academic journals.

Data Sources and Search Strategy; During the period from May 2020 to May 2025, the initial searches for this study were systematically conducted using four electronic databases, which are PubMed, ScienceDirect, Scopus, and MyEBSCO. We used these databases as they are recognized for the high-quality, peer-reviewed literature related to medicine and dentistry. Only English publications published during this period were selected. The literature search was conducted using a combination of keywords aligned with the research question, applying Boolean operators (AND, OR, NOT), quotation marks ("…") as part of the search strategy in each database MeSH terms (if applicable in PubMed) and TITLE-ABS-KEY (if applicable in Scopus/ScienceDirect/MyEBSCO) were utilized to integrate the terminology from each component. The list of keywords and their potential related terms is presented in table 1.

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Table 5. Data extraction results.

TITLE, AUTHOR, YEAR & PUBLISHER	METHOD, MAGNITUDE AND DIRECTION OF LOADING	DESIGN AND MATERIAL FIXED PARTIAL DENTURE	VALUE OF VON MISES STRESS	MAIN CONCLUSION
Biomechanical behavior of implant retained prostheses in the posterior maxilla using different materials: a finite element study. Aboelfadl, et al. 2024 BMC Oral Health	In silico by using Finite Element Analysis with a total axial load of 300 N was statically applied in the axial direction on each experimental model, where each central fossa was subjected to a 100 N load.	DESIGN 3-unit implant-supported prostheses a. Fixed-fixed (MF-ZR, MF-PEKK) b. Mesial cantilever (MM-ZR, MM-PEKK) c. Distal cantilever (MD-ZR, MDPEKK) MATERIAL a. Monolithic zirconia b. Polyetherketone ketone (PEKK)	MAXIMUM FPD MD-Zr 105 MPa IMPLANT MD-PEKK 111,6 MPa PERI-IMPLANT BONE MD-PEKK 100,0 MPa MINIMUM FPD MF-PEKK 35,4 MPa IMPLANT MF-ZR 48,9 MPa PERI-IMPLANT BONE MF-ZR 19,6 MPa	Stress Distribution: -Monolithic zirconia as a rigid prosthetic material transmits less stress than PEKK to the implant and bone interfaces in implant-supported fixed prostheses. -Mesial cantilever design together with zirconia as a rigid prosthetic material is suggested as a second alternative with acceptable biomechanical behavior in clinically demanding conditions.
Biomechanical Evaluation of Cantilevered 2-Unit Implant Supported Prostheses: A 3D Finite Element Study Sadek, et al. 2025 International Dental Journal 75	In silico by using Finite Element Analysis: The first scenario involved applying a 100 N vertical load, the second used a 50 N oblique load at a 30° angle, and the third involved a 50 N oblique load at a 45° angle.	DESIGN 2-unit implantsupported prostheses: a. First premolar implant supporting a second premolar (M1) b. Second premolar implant supporting a first premolar (M2) c. Second premolar implant supporting a first molar (M3) d. First molar implant supporting a second premolar (M4) MATERIAL a. Monolithic Zirconia b. Polyetherketone ketone (PEKK)	MAXIMUM 100 N VERTICAL LOAD MODEL M3 PEKK 117 MPa CORTICAL BONE) 50 N OBLIQUE LOADING 30° MODEL M3 PEKK 95 MPa & Zr 90 MPa (IMPLANT) 50 N OBLIQUE LOADING 45° ▪MODEL M4 Zr 95 MPa (IMPLANT) ▪MODEL M1 Zr 82 MPa (PROSTHESIS) MINIMUM 100 N VERTICAL LOAD MODEL M2 Zr 37 MPa and PEKK 35 MPa (IMPLANT) 50 N OBLIQUE LOADING 30° MODEL M2 Zr and PEKK 35 MPa (PROSTHESIS) 50 N OBLIQUE LOADING 45° MODEL M2 Zr and PEKK 45 MPa (CORTICAL BONE)	Stress Distribution: -In the vertical loading scenario, the highest von Mises stress values were concentrated at the connectors of the cantilevered crowns. -The monolithic zirconia models showed slightly higher stress values in the prosthetic body. -Zirconia better resists bending forces and reduces implant stress compared to PEKK. PEKK models exhibited greater implant and cortical bone stress. -Oblique loading caused higher stress in implants and prostheses.
Effect of prosthetic design and restorative material on the stress distribution of implant-supported 3-unit fixed partial dentures: 3D-FEA Ahmed, et al. 2022 Brazilian Dental Science	In silico by using Finite Element Analysis. 6 different screwretained implant restorations were designed and fabricated using a CAD/CAM system. Each subgroup was subjected to a vertical load of 100 N, and their biomechanical behaviour was evaluated using a strain gauge (Kyowa, Japan)	DESIGN These implants were divided into three main groups according to each design: a. Group FB (fixed bridge) b. Group CB (cantilever bridge) c. Group SC (separate crowns) MATERIAL a. Ultratranslucent multi-layered zirconia b. Combination of PEEK framework and zirconia crowns.	MAXIMUM CANTILEVER ZIRCONIA 1098 MPa (RESTORATIONS) CANTILEVER ZIRCONIA 2720.53 MPa (IMPLANTS) MINIMUM FIXED-FIXED PEEK & ZIRCONIA 182.97 MPa (RESTORATIONS) FIXED-FIXED PEEK & ZIRCONIA 250.34 MPa (IMPLANTS)	Stress Distribution: -Among all prosthetic designs, the cantilever configuration consistently exhibited the highest von Mises stress values, irrespective of the type of restorative material applied -The fixed bridge showed the lowest von Mises stress values. -The lowest von Mises stress value was recorded in the fixed bridge with combined PEEK and zirconia. -The highest von Mises stress value was recorded in the cantilever bridge with the zirconia.
Three-Dimensional Finite Element Analysis of Different Connector Designs for All-Ceramic ImplantSupported Fixed Dental Prostheses. LHJ Alberto, et al. 2022 Multidisciplinary Digital Publishing Institute (MDPI)	In silico by by using Finite Element Analysis. Evaluate the influence of the different radii of curvature of the gingival embrasure on the stress distribution of a three-unit allceramic implant-supported under a 100 N applied load at the central fossa of the pontic.	DESIGN The gingival embrasure radius of the distal 3-unit fixed-fixed implantsupported prostheses connector was adjusted: a. 0.25 mm b. 0.50 mm c. 0.75 mm MATERIAL Zirconia	MAXIMUM 0.25 mm 194 MPa MINIMUM 0.50 mm 56 MPa	Stress Distribution: ▪The radius of curvature of gingival embrasure had a significant influence on the stress distribution at the assessed components. ▪The tensile peak stresses at all structures were highest in the 0.25 mm model, while the 0.50 mm and 0.75 mm models presented similar values and more uniform stress distribution.
Mechanical Evaluation of Two Different ZirconiaReinforced Lithium Silicate Ceramics: a Finite Element Analysis Merve Botsali,et al. 2025 Ataturk University Publications	In Silico by using Finite Element Analysis. 500 N under vertical and oblique 45° loading to evaluate the von Mises and minimum principal stresses.	DESIGN Six different models were analyzed. -Tooth-supported anterior crown (TA) -Tooth-supported posterior crown (TP) -Tooth-supported 3-unit bridge (TB) -Implant-supported anterior crown (IA) -Implant-supported posterior crown (IP) - Implant-supported 3-unit bridge (IB) MATERIAL Zirconia-reinforced lithium silicate	MAXIMUM OBLIQUE 45° LOADING: ▪IMPLANTSUPPORTED BRIDGE (IBS) 179.95 MPa ▪IMPLANTSUPPORTED CROWN (IBA) 176.17 MPa MINIMUM TOOTHSUPPORTED POSTERIOR CROWN (TP)	Stress Distribution: -Connector regions exhibited increased stress levels irrespective of the type of support, whether in tooth-supported or implant-supported bridge configurations -Tooth-supported restorations showed lower stress values than implantsupported forms of the same restoration. -Stresses were higher and distributed over a larger surface under oblique loading compared to vertical loading. Implant-supported bridge model under oblique loading -shows the highest stress. However, both milling and pressable forms of zirconiareinforced lithium silicate didn't make a difference on the stress concentration and distribution areas.

The search string used in Scopus/ScienceDirect/MyEBSCO: TITLE-ABSKEY ("Zirconia Implant-supported Fixed Partial Dentures" OR "Zirconia Implant-supported Bridge" OR "Zirconia Posterior Implant Prosthesis") AND TITLE-ABS-KEY ("Fixed-Fixed design" OR "Fixed-Fixed Prosthesis" OR "Rigid Connector Design") AND TITLE-ABS-KEY ("Biomechanical" OR "Finite Element Analysis" OR "Stress Distribution" OR "Fracture Resistance"). The search string used in PubMed: (("Zirconia Implant-supported

Fixed Partial Dentures"[All Fields] OR "Zirconia Implant-supported Bridge"[All Fields] OR "Zirconia Posterior Implant Prosthesis"[All Fields]) AND ("Fixed-Fixed design"[MeSH Terms] OR "Fixed-Fixed Prosthesis"[MeSH Terms] OR " Rigid Connector Design"[MeSH Terms])AND ("Biomechanical"[MeSH Terms] OR "Finite Element Analysis"[MeSH Terms] OR "Stress Distribution "[MeSH Terms])) OR " Fracture Resistance"[MeSH Terms])).

Choosing the Sources of Evidence; Following the comprehensive search across the designated databases, all identified records were subjected to a multistage screening process in accordance with the predefined eligibility criteria. The retrieved citations were initially exported to the Mendeley Reference Manager, where duplicate records were automatically identified and removed. Subsequently, the literature screening was performed using the Mendeley Reference Manager, which enabled independent and blinded assessment by all authors. During the first phase of screening, titles and abstracts were carefully examined to identify potentially eligible studies, and any records not meeting the inclusion criteria were excluded. In the second phase, full-text articles of the shortlisted studies were thoroughly reviewed to determine their final eligibility for inclusion in the analysis.

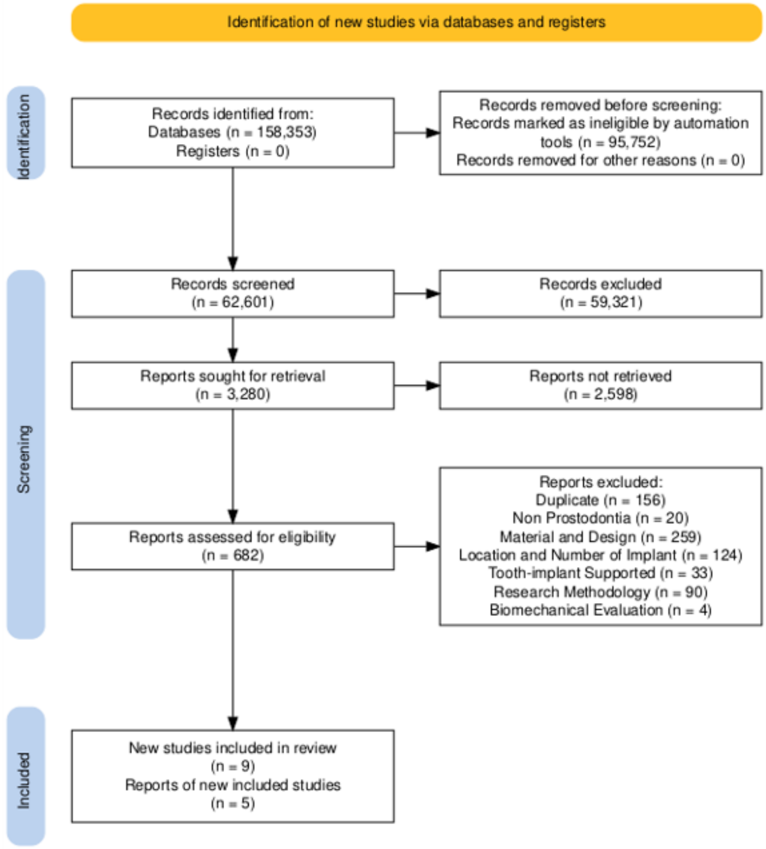

Figure 1. Flowchart of study selection process.

Results

Study Selection and Data Charting

The literature search process for this systematic review was concluded on July 4, 2025. The initial search, conducted using a keyword strategy formulated according to the PICO framework, yielded a total of 158,353 articles. Following subsequent filtering based on publication period (2020–2025), document type, English language, and open-access availability, the number of eligible articles was reduced to 682 for further assessment. The first stage of screening, performed by evaluating article titles, identified 117 potentially relevant publications. Thereafter, a comprehensive abstract screening was conducted, resulting in 19 articles deemed relevant and suitable for full-text review.

After the final evaluation for compliance with the predefined inclusion and exclusion criteria, five studies met all eligibility requirements and were ultimately included in the final analysis, as detailed in table 2. To ensure transparency and methodological rigor in the selection process, the PRISMA 2020 flow diagram was employed to illustrate the identification, screening, eligibility assessment, and final inclusion stages. The screening process adhered strictly to the predetermined inclusion and exclusion criteria, while also considering methodological appropriateness and topical relevance to the review's objectives.

Quality Assessment

The methodological quality assessment of finite element modeling was performed on the five studies included in this systematic review using a 12-item appraisal tool specifically designed for in silico studies based on Finite Element Analysis (FEA) (21). Each item was scored on a scale of 0 (not reported), 1 (partially reported), and 2 (fully reported), with a maximum total score of 24, as presented in table 3. The five evaluated studies demonstrated good methodological quality, with total scores ranging from 20 to 23. The study by Alberto et al. (2022) achieved the highest score (23/24) due to comprehensive model validation and robust sensitivity analysis, whereas the study by Aboelfadl et al. (2023) obtained the lowest score (20/24) owing to insufficient reporting of model validation and sensitivity analysis. Figure 2 illustrates the distribution of total quality assessment scores across the included studies. Score Description: 2 = Fully addressed; 1 = Partially addressed or unclear; 0 = Not addressed.

Description of Evaluation Criteria; GM: Geometry Model; CD: Contact Definition; MQ: Mesh Quality; A: Assumptions; MP: Material Properties; MV: Model Validation; ETS: Element Type & Size; SA: Sensitivity Analysis; BC: Boundary Conditions; OV: Output Variables; LC: Loading Conditions; CR: Clinical Relevance.

Synthesis of Results

One of the primary biomechanical parame-

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ters is the elastic modulus, which characterizes the stiffness of a material and influences the stress distribution within the prosthesis. Table 4 summarizes the elastic modulus and Poisson's ratio values of commonly used and analyzed structures in implantrelated prosthodontics. Biomechanical data indicate that materials with a high elastic modulus, such as zirconia frameworks (210 GPa) and monolithic zirconia (200 GPa), exhibit substantially greater stiffness compared with cortical bone (13.7 GPa) and titanium implants (110 GPa). This suggests that zirconia tends to absorb stress within the prosthetic body, thereby providing a clinically beneficial stress-shielding effect on peri-implant bone. Conversely, materials such as PEEK and PEKK demonstrate considerably lower elastic moduli (~3.5–5.1 GPa), values that are closer to those of trabecular bone, implying higher elasticity and potentially greater load transmission to the supporting osseous structures, particularly when used in cantilever designs.

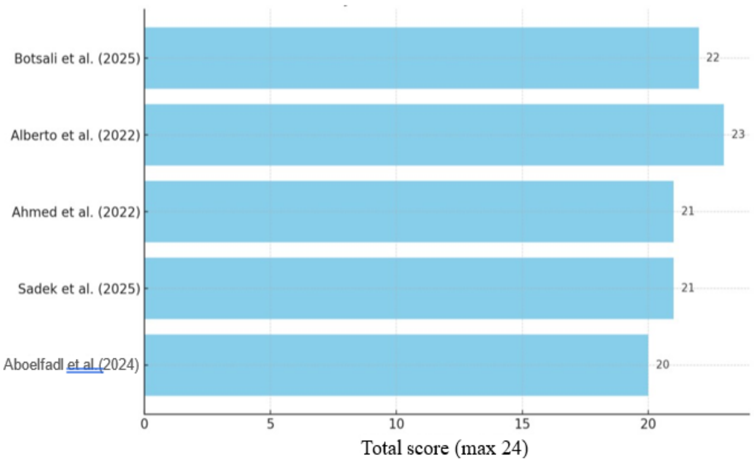

Figure 2. Bar chart of FEA quality assessment results based on total scores (Maximum 24).

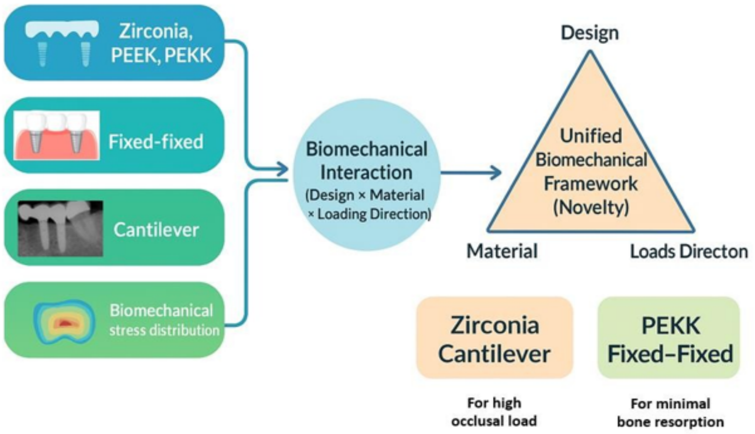

Figure 3. Integrative biomechanical framework linking PICO structure to novelty in posterior implant-supported fixed partial dentures.

VITA Ambria (100 GPa) and enamel (84.1 GPa) exhibit intermediate stiffness, whereas the periodontal ligament, with an elastic modulus of 0.05 GPa, represents the most flexible component which is emphasizing the importance of accurate soft-tissue modeling in FEA simulations. The mismatch in elastic properties among these components directly contributes to the concentration of peak stresses, particularly at the connector regions and abutment interfaces, as illustrated in table 5.

Discussion

In the modern biomechanical approach to implant-supported Fixed Partial Dentures (iFPDs), the focus extends beyond the inherent strength of restorative materials to encompass the stress distribution behavior within the entire bone–implant–prosthesis system. Recent comparative studies evaluating prosthetic designs made of monolithic zirconia and PEKK for implant restorations have demonstrated consistent biomechanical patterns. According to Sadek et al. (2025), monolithic zirconia prostheses exhibited slightly higher stress concentrations within the prosthetic body compared to PEKK, accompanied, however, by a significant reduction in stress values at the implant and cortical bone levels.[22] This trend aligns with the findings of Aboelfadl et al. (2024), in which the MF-Zr model recorded the lowest von Mises stress value of 19.6 MPa in cortical bone under vertical loading conditions.[25]

Conversely, Aboelfadl et al. (2024) reported that the MD-PEKK design demonstrated the highest bone stress value (up to 111.6 MPa), with localized stress concentrations near the distal offset extension an area clinically susceptible to biomechanical overloading. Furthermore, the MD-Zr model showed the highest von Mises stress within the prosthetic body (105 MPa), particularly at the interface between the prosthesis and the abutment adjacent to the offset extension.[25] Although stress concentration was higher within the prosthetic structure itself, this pattern indicates a superior stress-shielding effect for the supporting bone when zirconia is used. In contrast, PEKK, which exhibits lower internal prosthetic stress, tends to transmit a greater portion of the load to the surrounding bone structures, potentially increasing the long-term risk of alveolar bone resorption.

While several studies have emphasized the dominant role of material characteristics in influencing biomechanical stress behavior, emerging evidence suggests that prosthetic design may serve as a more critical determinant of stress distribution patterns, regardless of the material employed. In this context, comparisons among fixed–fixed, separate-crown, and cantilever designs have yielded inconsistent findings, forming a significant research gap that remains insufficiently addressed. Ahmed et al. (2022) reported that prosthetic design exerts a greater impact on stress distribution than the choice of restorative material, with cantilever and separate-crown configurations generating the highest von Mises stress values. Moreover, as the length or complexity of the iFPD (e.g., 3-unit bridge) increases, stress magnitudes also rise, particularly in implant-supported iFPDs subjected to oblique loading.[23] These findings highlight the need for comprehensive biomechanical design considerations in prosthetic planning and encourage a reevaluation of design preferences for posterior regions subjected to high masticatory loads.

Alberto et al. (2022) and Botsali et al. (2025) further contributed valuable insights into the interplay between prosthetic design and material composition on stress distribution within iFPDs. Their studies revealed that both factors exert a significant influence on the biomechanical behavior of three-unit iFPDs. The regions of highest stress concentration were consistently located at the abutment–prosthesis interface and the occlusal surface zones of direct occlusal contact. Correspondingly, maximum stress values were also observed at the connector areas, regardless of the supporting configuration, identifying this region as a biomechanical weak point in the iFPD structure.[24] Other studies similarly reported that zirconia abutments exhibited high peak stress values, particularly at the cervical region on the buccal surface of the mesial abutment and the lingual surface of the distal abutment with stress magnitudes ranging from 56 to 194 MPa, depending on the model configuration.[15] These data collectively underscore that abutment geometry and material composition play pivotal roles in load redistribution, ultimately influencing the long-term durability of both the prosthetic structure and its supporting tissues, as shown in figure 3. Accordingly, this systematic review identifies the biomechanical risk prediction based on the integrative combination of design–material–location parameters, an area that has not been comprehensively explored previously.

Clinical Relevance And Future Direction

These findings underscore the importance of adopting a personalized prosthetic approach. The combination of a fixed–fixed design with PEKK material may be recommended for patients with good bone quality, whereas zirconia is more suitable for highload conditions due to its superior resistance to deformation, tailored to specific clinical conditions such as the need for distal extension, limited supporting bone availability, and patient-specific occlusal conditions (e.g., high lateral loading).

Conclusion

Through Finite Element Analysis (FEA), five studies published between 2020 and 2025 demonstrated that stress distribution is predominantly governed by the interplay among prosthetic design, restorative material, and loading direction. Cantilever designs consistently exhibited the highest von Mises stresses at the connector and prosthesis–abutment interface, while fixed–fixed designs reduced stress concentration, particularly when combined with flexible materials such as PEKK. In contrast, the high stiffness of zirconia provided a stress-shielding effect by retaining loads within the prosthesis.

The novelty of this review lies in its integrative analysis of design, material, and stress location—variables rarely examined together. Clinically, zirconia is recommended for posterior cantilever prostheses under high occlusal load, whereas PEKK suits fixed–fixed configurations with minimal bone resorption. This review highlights connector optimization as a critical factor in mitigating stress concentration, positioning it as a central focus in digital prosthodontic design research through FEA.

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