





Systematic Review

Insufficient Evidence to Ascertain the Long-Term Survival of PEEK Dental Prostheses: A Systematic Review of Clinical Studies

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Abstract: Introduction: Polyetheretherketone (PEEK) is a polymer that is used in the construction of orthopaedic and dental implants. It is also used to construct removable and fixed dental prostheses due to its superior mechanical and esthetic properties compared to conventional materials. This systematic review aims to analyse and appraise the literature concerning PEEK dental prostheses critically. Methods: The following focused question was constructed ‘Are dental prostheses made of PEEK inferior to those made of other materials in terms of clinical- and patient-reported outcomes?’. The CONSORT (Consolidated Standards of Reporting Trials) tool was used for the quality assessment of the randomised clinical trials. The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) quality assessment tool was used to assess the quality of observational studies and the case reports were evaluated using the CARE (Case Report) guidelines. Results: A total of 12 studies were included in this review. Two case studies received an overall grade of medium and the overall quality of six studies was graded as ‘low’. All three observational studies and the only randomised controlled trial received scores of ‘medium’. Conclusion: PEEK-based dental prostheses may provide a viable and more esthetic alternative to conventional prosthodontic appliances. However, within the limitations of this study is the evidence to ascertain the long-term viability of PEEK-based dental prostheses. Future studies should focus on conducting large-scale, multicenter trials to compare the survival rate of PEEK prostheses to that of conventionally available prosthodontic appliances.

Keywords: polyetheretherketone; dental prostheses; prosthodontics; dental implants; obturators



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1. Introduction

Removable and fixed dental prostheses are used for interim and long-term oral rehabilitation of completely and partially edentulous individuals [1,2]. Polymeric and metallic frameworks are used to construct prosthodontic appliances. Acrylic (polymethylmethacrylate; PMMA) remains the most popular, esthetic and least expensive option for the construction of complete dentures [3] and metallic frameworks offer improved strength and longevity in comparison [4]. Obturators, also mostly constructed of acrylics, are prosthodontic appliances constructed to occlude an oronasal fistula which may exist due to a cleft palate or surgery [5]. Outcomes of dental prosthetic treatment may be reported in the clinic (e.g., retention, occlusal stability, debonding of the base material from the framework, implantitis etc.) or by the patient (e.g., esthetics, masticatory function, fractures, etc.).

The materials used to produce these prosthodontic appliances have several disadvantages. Firstly, acrylics have limited strength and may undergo dimensional change during processing [3,6]. On the other hand, although metallic denture frameworks have improved mechanical properties, they are unesthetic and the metallic framework may debond from the overlying acrylic or porcelain [7,8]. Furthermore, acrylic and some metals may also cause allergic reactions in some individuals [9,10]. Moreover, long-span fixed porcelain-fused-to-metal (PFM) prostheses may fracture more easily and, therefore, are contraindicated in patients with inadequate or periodontally compromised abutment teeth [11]. Other major drawbacks of currently used materials are the long processing time and several appointments needed for the clinical procedures. Therefore, recent research was focused on finding a cost-effective alternative to these materials that is not only esthetic but offers more longevity.

The ideal prosthetic or implant material should be biocompatible, possess adequate mechanical properties to withstand occlusal forces, have favourable esthetic attributes and should not exert forces detrimental to the surrounding hard and soft tissues. Polyetheretherketone (PEEK) is a polymer produced by the step-growth dialkylation reaction of bisphenolates [12]. PEEK was used for the construction of spinal fusion devices and other surgically placed implants [13]. In dentistry, the polymer was used in the construction of dental implants, orthodontic wires and dental prostheses [14]. Studies reporting the use of PEEK in spinal implants indicate that the material has excellent biocompatibility [13]. Because of their excellent mechanical strength, surface-modified PEEK implants were also studied for their potential to replace titanium as the material of choice [14]. Besides being esthetic, a major advantage of PEEK is that has physical properties comparable to that of human bone [15]. Therefore, it was suggested that PEEK appliances distribute forces more favourably than acrylics and metals [16]. More recently, modified forms of PEEK were produced that have antimicrobial and bioactive properties [17]. Given these favourable attributes, PEEK-based prosthodontic appliances [18] and obturators [19] were studied to overcome the drawbacks of conventional prosthodontic materials. There are several ways to process PEEK-based appliances. These include computer-aided design/computer-aided manufacture (CAD–CAM) workflows [20], conventional lost-wax casting [21] and injection moulding [22]. Of these processes, CAD–CAM PEEK prostheses have the unique advantage of being able to be constructed in a single appointment which is more convenient and time-saving for patients as well as the dental practitioner [23]. Studies also suggest that PEEK-based dental prostheses may have survival rates higher than 90%, which is comparable to that of other CAD–CAM materials such as titanium [24]. Moreover, *in vitro* laboratory studies have indicated that CAD–CAM dentures are more accurate and hence have a better fit when compared to conventionally processed prostheses [25]. However, to date, no systematic review has analysed the currently available evidence regarding the use of PEEK-based dental prostheses. Hence, the aim of this systematic review is to not only summarise the currently available evidence but also to critically analyse the literature that has focused on dental prostheses constructed with PEEK.

2. Materials and Methods

2.1. Focused Question and Protocol Registration

Using the Participant, Intervention, Control and Outcomes (PICO) principle provided in the Preferred Reported Items for Systematic Reviews and Meta-analyses (PRISMA) statement in Figure 1 [26], the following focused question was constructed ‘Are dental prostheses made of PEEK inferior to those made of other materials in terms of clinical- and patient-reported outcomes?’. Outcomes such as implant-related complications, fractures, debonding of material stability were classified as clinical and those such as appearance and masticatory function were classified as patient-reported. The protocol for this review was registered on PROSPERO under the registration number CRD42021290311.

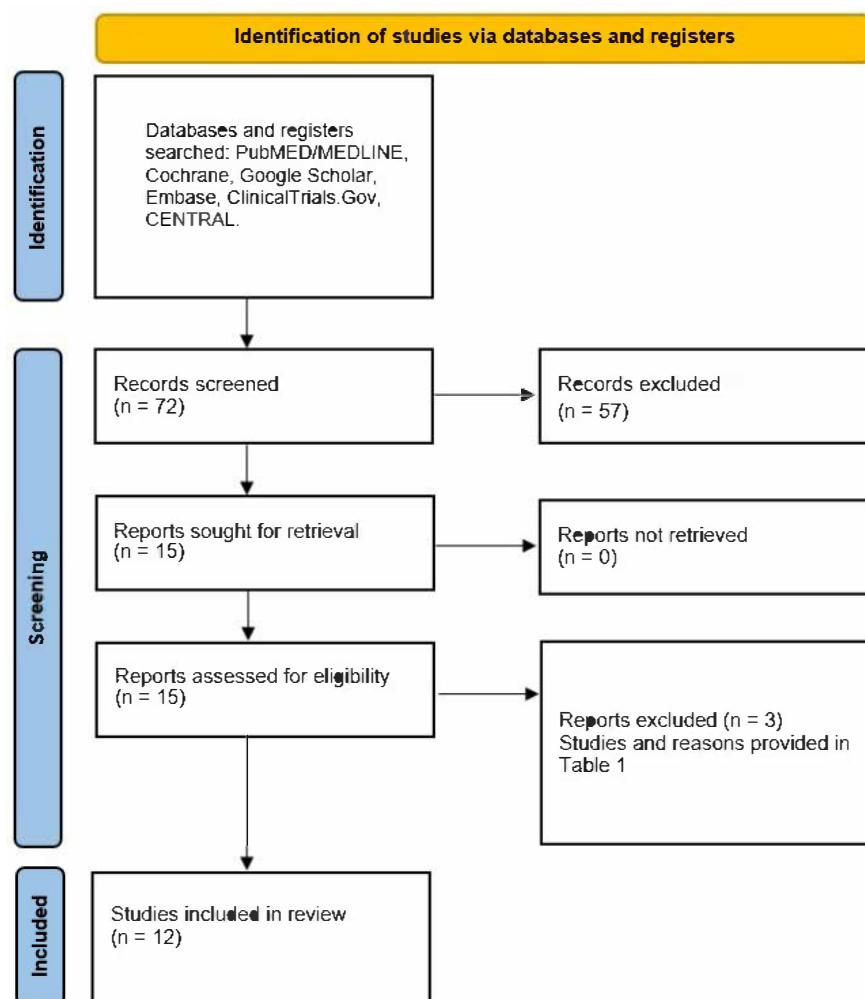


Figure 1. PRISMA flow diagram of the search methodology employed for this review.

2.2. Eligibility Criteria

Prior to beginning the literature search, eligibility criteria for research pertinent to this review were established. Randomised controlled trials (RCT), cohort studies, case-control studies and case reports that focused on reporting clinical and patient-reported outcomes of dental prostheses constructed with PEEK frameworks or major connectors were included. Laboratory studies, animal studies, commentaries, reviews, letters to the editor and studies not in English were excluded. Excluded studies along with reasons for exclusion are listed in Table 1.

Table 1. A list of the full texts excluded along with reasons for exclusion.

Study	Reason for Exclusion
Ye et al. [27]	Only workflow; PEEK denture not delivered to patient
Yue et al. [28]	PEEK framework not used
Ichikawa [29]	PEEK framework not used

2.3. Literature Search

Three investigators (ZK, BMN and RM) conducted an electronic literature search via PubMed/MEDLINE, Google Scholar, EMBASE and ISI Web of Science using the following medical subject heading (MeSH) keywords: ((polyetheretherketone) OR (PEEK)) AND ((denture) OR (prosthodontic) OR (bridge) OR (denture framework) OR (dental prosthesis) OR (partial denture) OR (complete denture) OR (fixed denture) OR (removable dental pros-

thesis) OR (fixed dental prosthesis)) and the above-mentioned eligibility criteria for studies published between January 1990 and April 2022. Furthermore, with the assistance of the remaining two investigators (SB and SN), the reference lists in the complete texts of possibly eligible papers were examined to locate other studies that could fit the inclusion criteria.

2.4. Data Extraction

Using the PICO principle, the data from each study were independently extracted by the two investigators using a pre-decided data collection form. Any disagreements were solved by discussion. Briefly, data corresponding to the following categories was extracted: the type of study, number of patients, type or brand of PEEK, the mean age or range of the age of the patients, rehabilitation and study group details, the fabrication details, dental implant details (number and dimensions), duration of the studies (follow-up) and the outcomes. The data categories, along with extracted data, are listed in Table 2 and the outcomes are provided in Table 3.

2.5. Quality Assessment of Included Studies

For the quality assessment of the randomised clinical trials, the CONSORT tool [30] was used. STROBE quality assessment tool was used to assess the quality of observational studies [31] and the case reports were evaluated using the CARE guidelines [32]. Each study was given a relative grade of 'low', 'medium' and 'high' depending on the assessment criteria fulfilled by each study. The topics or sections evaluated in the included studies are presented in Tables 4–6.

Table 2. General characteristics of studies included in this review. PEEK: polyetheretherketone; N/A: not application; CAD: computer-aided design; CAM: computer-aided manufacture.

No.	Study—Author(s) and Year	Type of Study	Patient (s) (n)	Age (Mean/Range)	Type/Brand of PEEK	Rehabilitation Details and/or Study Groups	Fabrication	Implants Placed (n)	Implant Dimensions (mm)	Duration of Study
1	Costa-Palau et al., 2014	Case report	1	58 years	PEEK-Optima	Maxillary obturator.	Mechanical duplication of old obturator.	0	N/A	6 months
2	Zoidis and Papathanasiou, 2016	Case report	1	52 years	BioHPP PEEK	Interim fixed implant-supported 3-unit prosthesis.	Digital scanning of wax pattern and injection molding.	2	L = 11.5 D = 4	4 months
3	Hahnel et al., 2017	Case report	1	76 years	Ceramill PEEK	Interim maxillary all-on-four implant-supported PEEK fixed prosthesis.	Conventional wax pattern. CAM	4	NR	3 months
4	Zoidis 2017	Case report	1	65 years	BioHPP PEEK	Definitive maxillary fixed all-on-four implant-supported PEEK framework and PMMA base and veneers.	Conventional impression. Lost-wax and casting.	4	L = 11.5 D = 4	2 years
5	Sinha et al., 2017	Case report	1	32 years	PEEK-Optima	FPD. Upper and lower incisors replaced with canine–canine abutments. PEEK framework with resin composite veneers.	Conventional impression. Lost-wax and casting.	0	N/A	6 months
6	Zoidis 2018	Case report	1	85 years	BioHPP PEEK	Removable mandibular PEEK framework and PMMA base retained by high noble ball attachments on both canines.	Conventional impression. Lost-wax casting.	0	N/A	Not reported
7	Harb et al., 2018	Case report	1	56 years	CeraMill PEEK	Removable PEEK mandibular Kennedy class I framework and PMMA base to replace first and second molars.	Conventional impressions. Digital scanning of a wax pattern. CAM.	0	N/A	Not reported
8	Mangano et al., 2019	Prospective cohort	15	68.8 ± 4.7 years	Not recorded	Each patient received one removable maxillary overdenture supported by 4 implants and PEEK bar.	CAD–CAM replication of a relined denture. CAD: Meshmixer, Autodesk CAM: 3500 PD 3D printer, DWS	60	L = 8–14 D = 3.3–4.8	1 year
9	Tasopoulos et al., 2020	Case report	1	47 years	BioHPP	Two-piece PEEK maxillary obturator; Kennedy Class II (canine to second molar). Acrylic supported by PEEK framework.	Material: BioHPP Construction of 3D model using wax pattern. CAD: 3Shape Dental CAM: External laboratory	0	N/A	1 year
10	Wang et al., 2021	Retrospective cohort	43	59.8 years	BioHPP	Full-mouth FDP, 6 implants per arch (n = 60): Group I: PEEK framework and PMMA veneers (n = 29) Group II: Titanium framework and PMMA veneers (n = 31).	CAD: D2000 3D Scanner, 3Shape A/S CAM: 308 B, Willemin-Macodel (Ti), D3608, Sirona (PEEK) Dental Systems	331	N/A	5 years

Table 2. Cont.

No.	Study—Author(s) and Year	Type of Study	Patient (s) (n)	Age (Mean/Range)	Type/Brand of PEEK	Rehabilitation Details and/or Study Groups	Fabrication	Implants Placed (n)	Implant Dimensions (mm)	Duration of Study
11	Sharaf and Eskandar 2021	Randomised control trial	18	Not stated	Dental Direkt	Group I: Attachment-retained obturator with PEEK framework (n = 6) Group II: Attachment-retained obturator with metallic framework (n = 6) Group III: Conventional clasp-retained obturators with metallic framework (n = 6)	Conventional impressions. Digital scanning of wax pattern. CAM: Exocad GmbH	0	N/A	12 months
12	Russo et al., 2021	Case-control	16	46–72 years	Not specified	Group I: RPD (n = 10) Group II: Untreated partially edentulous (n = 6) Changes in residual ridge investigated for 1 year.	CAD: TRIOS 3, 3Shape A/S CAM: SmilesPeek	0	N/A	1 year

Table 3. Implant and prosthodontic outcomes of studies included in this review. PEEK: polyetheretherketone; BOP: bleeding on probing; TMJ: temporomandibular joint; VBL: vertical bone loss.

No.	Study—Author(s) and Year	Implant Outcomes	Prosthodontic Outcomes
1	Costa-Palau et al., 2014	No implants placed	No complications reported
2	Zoidis and Papathanasiou, 2016	No complications reported	No complications reported
3	Hahnel et al., 2017	No complications reported	No complications reported. OVD increased successfully on final follow-up
4	Zoidis 2017	No complications reported	No complications reported
5	Sinha et al., 2017	No implants placed	No complications reported
6	Zoidis 2018	No implants placed	No complications reported
7	Harb et al., 2018	No implants placed	No complications reported
8	Mangano et al., 2019	Peri-implantitis developed around 2 implants	20% of the dentures failed due to inadequate passive fit. 2 fractured dentures had to be repaired.
9	Tasopoulos et al., 2020	No implants placed	No complications reported
10	Wang et al., 2021	BOP: PEEK: 13.8%; Ti: 16.1% Soft tissue inflammation: PEEK: 3.4%; Ti: 3.2% TMJ disorders: PEEK: None; Ti: 6.5% VBL: PEEK: 0.70 mm; Ti: 0.96 mm	5-year survival rate of PEEK and titanium overdentures comparable (93.1% and 93.5%, respectively).
11	Sharaf and Eskandar 2021	No implants placed	Group I and II exhibited lesser bone loss and greater patient satisfaction than Group III. No statistical difference between Groups I and II.
12	Russo et al., 2021	No implants placed	No significant differences between residual ridge changes in both groups

Table 4. Quality assessment results of the case reports included in this review.

Study Characteristics	Study							
1. Title	Costa-Palau et al., 2013	Zoidis and Papathanasiou, 2016	Hahnel et al., 2017	Zoidis 2017	Sinha et al., 2017	Zoidis 2017	Harb et al., 2018	Tasopoulos et al., 2020
The diagnosis or intervention of primary focus followed by the words “case report”	Yes	Yes	Yes	Yes	No	Yes	Yes	No
2. Keywords								
2 to 5 keywords that identify diagnoses or interventions in this case report, including “case report”	No	No	No	No	Yes	Yes	Yes	No
3. Abstract								
Introduction	No	No	Yes	Yes	Yes	Yes	No	No
Symptoms/findings	No	No	No	No	No	No	No	No
Diagnoses and prosthodontic outcomes	No	No	Yes	No	No	No	No	No
Conclusions	Yes	Yes	Yes	Yes	No	No	No	Yes
4. Introduction								
One or two paragraphs summarising why this case is unique	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5. Patient information								
De-identified patient information	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chief concerns and symptoms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Medical, family, psycho-social history, genetic information	Yes	No	No	Yes	No	No	No	Yes
Relevant past interventions with outcomes	Yes	No	Yes	Yes	No	No	Yes	Yes
6. Clinical findings								
Oral examination and important clinical findings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7. Timeline								
Historical and current information from this episode of care organised as a timeline	No	No	No	No	No	No	No	No
8. Diagnostic Assessment								
Oral examination	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Previous denture history	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Oral hygiene/periodontal status	No	No	No	No	Yes	Yes	No	

Table 4. Cont.

Study Characteristics	Study								
9. Prosthodontic rehabilitation									
Clinical procedures (impressions, intraoral scanning, surgery, etc.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Laboratory procedures (wax-up, casting, fabrication, etc.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prosthesis design	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10. Follow-up and outcomes									
Follow-up time period	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
Patient-reported outcomes	Yes	Yes	Yes	Yes	No	No	Yes	No	No
Prosthesis and/or implant outcomes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Complications/adverse effects	No	Yes	Yes	Yes	Yes	No	No	No	No
11. Discussion									
Strengths and limitations	No	No	No	No	No	No	No	No	No
Review of relevant literature	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
The scientific rationale for any conclusions	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
12. Conclusion	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13. Informed consent	No	No	No	No	No	No	No	No	No
Overall quality	Low	Low	Medium	Medium	Low	Low	Low	Low	Low

Table 5. Quality assessment of the observational studies included in this review.

Section/Topic	Mangano et al., 2019	Wang et al., 2021	Russo et al., 2021
1. Title and abstract			
Study design in title	No	Yes	No
Adequate abstract	Yes	Yes	Yes
2. Introduction			
Scientific background and rationale	Yes	Yes	Yes
State specific objectives and hypothesis	Yes	Yes	Yes
3. Methods			
Study design	Yes	Yes	Yes
Recruitment, exposure, follow-up, and data collection	Yes	Yes	Yes
Participants			
Eligibility criteria	No	Yes	No
Number of exposed and unexposed	No	No	No
Variables			
Adequate description of variables	Yes	Yes	Yes
Data measurement			
Sources and methods of measurement	Yes	Yes	Yes
Bias			
Methods to reduce bias (randomisation or blinding)	No	No	No
Study size			
Statistical calculation of sample size	No	No	No
Quantitative analysis			
Description of quantitative variables	No	No	No
Statistical methods			
Description of statistical methods	Yes	Yes	Yes
Subgroup analysis	No	No	No
Handling of missing data	No	No	No
Loss to follow-up	No	No	No
Sensitivity	No	No	No
4. Results			
Participants			
Number analysed	Yes	Yes	Yes
Reasons for drop-out	No	No	No
Flow-diagram for recruitment	No	No	No
Descriptive data			
Demographic, clinical and social data	No	No	No
Missing data	No	No	No
Follow-up time	Yes	Yes	Yes
Outcomes			
Outcome events or summary measures	Yes	Yes	Yes

Table 5. Cont.

Section/Topic	Mangano et al., 2019	Wang et al., 2021	Russo et al., 2021
Main results			
Confidence-interval	Yes	Yes	No
Category boundaries	No	No	No
Translation of relative to absolute risk	Yes	No	No
5. Discussion			
Key results	Yes	Yes	Yes
Limitations	Yes	Yes	Yes
Interpretation	Yes	Yes	Yes
Generalisability	Yes	Yes	Yes
6. Funding details			
Overall quality	Medium	Medium	Medium

Table 6. Quality assessment results of the quality assessment of the randomised controlled trial included in this review.

Section/Topic	Quality Assessment
1. Title and abstract	
Study: Sharaf and Eskandar 2021	
Identification as a randomised trial	Yes
Structured summary of the study	Yes
2. Introduction	
Scientific background and rationale	Yes
Specific objectives or hypotheses	Yes
3. Methods	
Description of trial design	Yes
Changes to methods	No
Eligibility criteria for participants	Yes
Settings and locations where the data were collected	No
The interventions for each group.	Yes
Primary and secondary outcome measures	
Any changes to trial outcomes	No
Sample size calculation	Yes
Method used to generate the random allocation sequence	Yes
Type of randomisation	Yes
Mechanism used to implement the random allocation sequence	Yes
Who generated the allocation sequence, who enrolled participants	No
Blinding of investigators	Yes
Description of the similarity of interventions	No
Appropriate statistics	Yes

Table 6. Cont.

Section/Topic	Quality Assessment
4. Results	
Number analysed	Yes
Losses and exclusions	Yes
Dates of recruitment and follow up	Yes
Why the trial ended or was stopped	No
Demographic and clinical characteristics for each group	No
For each group, number of participants included in each analysis	Yes
Estimated effect size and its precision (such as 95% confidence interval)	Yes
Absolute and relative effect sizes	No
Subgroup analysis	No
Harms or unintended effects in each group	No
5. Discussion	
Trial limitations and addressing sources of potential bias	No
Generalisability of the trial findings	Yes
Interpretation consistent with results	Yes
6. Other information	
Registration number	Yes
Accessible protocol	Yes
Funding	Yes
Overall quality	Medium

3. Results

3.1. Results of the Literature Search

The initial search resulted in 72 items. In total, 57 irrelevant articles were excluded based on titles and abstracts and the full texts of 15 articles were downloaded to deem their eligibility for inclusion in this review. Of these 15 articles, three articles were excluded [27–29]. The reasons for their exclusion are provided in Table 1. Therefore, 12 studies were deemed suitable for inclusion in this review [20,24,33–42]. No additional studies were found upon hand searching, and none was found within the references of the included studies. The inter-examiner reliability (Cohen’s kappa) score was calculated as 0.83.

3.2. General Characteristics of Included Studies

Eight of the included studies were case reports [20,33–38,40], two studies were cohort studies [24,39], one study was a randomised controlled trial (RCT) [41] and another one was a case-control study [42]. Case reports documented six patients who received single PEEK prostheses [20,33–38,40]. The number of patients in the other studies ranged from 15 to 43 [24,39,41,42]. The age range of the patients ranged from 32 to 85 years [20,24,33–40,42]. The mean age was calculated as 59.96 years [20,24,33–40,42] while, in one study, the age of the patients was not reported [41]. BioHPP PEEK was used to construct prostheses in five studies [24,34,36,38,40]. PEEK Optima was used in the construction of prostheses in two studies [33,37] and Ceramill PEEK was also used in two studies [20,35]. While one study reported the use of the PEEK brand called

Dental Direkt [41], two studies did not specify the type or brand of PEEK used [39,42]. In four studies, removable PEEK dentures were constructed [20,38,39,42] and fixed dental prostheses (FDP) were fabricated in three studies [24,36,37]. PEEK obturators were constructed in three studies [33,40,41] and PEEK was used to fabricate interim fixed in two studies [34,35]. In four studies, CAD–CAM was used for the construction of the prostheses [24,39,40,42] and in three studies, conventional impressions and lost-wax technique were used [36–38]. In one study, a PEEK obturator was constructed via the mechanical duplication of an older acrylic obturator [33]. In three studies, PEEK frameworks were digitally milled upon scanning of a wax pattern [20,34,35,41]. In two studies, conventional impressions were used in combination with CAM [20,41]. Implants were placed to support PEEK dentures in five studies [24,34–36,39] and the number of implants placed in each study ranged from 2 to 331 [24,34–36,39]. Among the five studies that had reported the use of implants, three studies reported the dimensions of the implants; the diameters ranged from 3.3 to 4.8 mm and the lengths ranged from 8 to 11 mm [34,36,39].

3.3. Outcomes of the Included Studies

In the case reports, PEEK dentures were successfully used for the oral rehabilitation of eight patients without any clinical or patient-reported complications [20,33–38,40]. In one cohort study, 20% of the implant-supported PEEK overdentures failed due to loss of passive fit, peri-implantitis developed in two patients and two dentures had to be repaired [39]. On the other hand, in a retrospective study, the 5-year survival rate of PEEK FDPs was reported to be 93.1%, which was statistically similar to the success rate of titanium FDPs which was reported to be 93.5% [24]. In the case-control study, in which the ridge changes of individuals who wore PEEK dentures were compared to those who did not wear any dentures, there was no difference observed between the outcomes of both the groups [42]. In the randomised controlled trial, attachment retained PEEK and metallic obturators exhibited similar bone loss and patient satisfaction but both the materials reported better outcomes when compared to conventional clasp-retained obturators [41]. In one study, 13.8% of the PEEK group and 16.1% of the titanium group exhibited bleeding on probing, soft tissue inflammation was observed in 3.4% of the PEEK group and 3.2% of the titanium prostheses, and temporomandibular disorders were observed in the 6.5% for the titanium group and none in the PEEK prostheses [24]. Furthermore, in the same study, PEEK prostheses resulted in significantly lesser (0.70 mm) vertical bone loss when compared to Ti, which resulted in 0.96 mm of vertical bone loss after 5 years [24].

3.4. Results of the Quality Assessment

Two case studies received an overall grade of medium [35,36] and the overall quality of six studies was graded as ‘low’ [20,33,34,37,38,40]. All three observational studies and the only RCT received scores of ‘medium’ [24,39,41,42]. The detailed results of the quality assessment are presented in Tables 3–5.

4. Discussion

Several materials are used in the construction of dental prostheses. Conventional materials include acrylics (with or without metallic frameworks), alloys and porcelain-fused-to-metal. However, studies suggested that these materials have a high percentage of failure or complications after five years of placement. Systematic review and meta-analysis of 32 studies have suggested that implant-supported fixed dental prostheses may have a failure rate of as high as 33.6% after 5 years [43]. The same study also concluded that the biggest cause of prostheses failure of implant-supported fixed dental prostheses is the fracture of the veneering material (13.5%) followed by peri-implantitis (8.5%) [43]. Conversely, conventional fixed bridges were reported to have a 15-year survival rate of 74% [44]. Acrylic partial dentures, primarily used as interim prostheses, were reported to last 6 to 12 months [45]. On the other hand, removable metal dentures were reported to have a 5-year survival rate of 75% [46]. Although alloy and PFM prostheses were

constructed conventionally to overcome the limited strength and fracture resistance of acrylics, they are unable to prevent alveolar bone loss [47] most likely due to unfavourable stress distribution [48]. Although using dental implants to retain dental prostheses results in lesser bone resorption [49], it does not prevent it completely [50].

PEEK, with mechanical properties similar to that of cortical bone [15], is currently being studied as an alternative to conventional materials used in the fabrication of fixed and removable dental prostheses [20,24,33–42]. Indeed, PEEK's flexural strength (183 MPa) was shown to be much higher than that of polymethylmethacrylate (PMMA; 84 MPa) in a recent *in vitro* investigation [51]. Similarly, in the case reports reviewed in this systematic review, favourable outcomes in the case reports reviewed in this systematic review suggest that PEEK is a promising material to replace PMMA as the material of choice to construct interim prostheses [34,35]. Nevertheless, a higher cost of PEEK may limit its clinical usage. Furthermore, a lack of randomised clinical trials focusing on PEEK dental prostheses indicates that there is evidence to use PEEK is inconclusive. Other materials such as base alloys and acrylics have been used for a longer time and, hence, are reported in the literature significantly more compared to PEEK.

Fractures at the acrylic–metal interface may account for up to 38% of denture fractures [52]. Perhaps the biggest advantage of PEEK frameworks that reinforce acrylic prostheses is that they may overcome the mismatch between the mechanical properties of metal frameworks and the acrylic components of conventional removable prostheses [20,38,39,42]. Moreover, recent research is being conducted to improve the bonding between PEEK and acrylic to further improve the durability of the PEEK–acrylic interface [53]. Therefore, PEEK–acrylic prostheses hold the potential for constructing durable and cost-effective dental prostheses. Due to PEEK's tensile properties being similar to bone, mechanical properties superior to those of conventional acrylics and due to its non-brittle nature, PEEK-based prostheses supported by dental implants may potentially survive longer than conventional implant-supported dentures. Nevertheless, in the retrospective study by Wang et al., a 5-year survival rate of 93% for implant-supported was reported and none of the 331 implants placed failed [24]. Nevertheless, in the PEEK group, there was significantly lesser vertical peri-implant bone loss observed (0.70 mm) after 5 years compared to the same around the implants placed under titanium prostheses (0.96 mm) [24], which could be due to a reduced level of stress-shielding that was reported in prior finite element analysis (FEA) studies on PEEK prostheses [14]. In the same study, however, there was no significant difference observed between the survival of PEEK and Ti denture frameworks [24]. The results from this study suggest that for implant-supported prostheses, implant outcomes may determine the viability of both, PEEK and Ti denture frameworks [24]. In contrast, Mangano et al. reported a 20% prosthodontic failure rate in a prospective cohort trial and two of the 60 implants placed developed peri-implantitis [39]. Therefore, more long-term clinical trials are required to ascertain the survival of implant-supported PEEK dentures.

The studies included in this review had several limitations. A significant limitation is the lack of clinical trials comparing the survival of conventional prostheses with that of PEEK dental prostheses. Furthermore, most studies included in this review were case reports, and minimal sample sizes were included in those studies. Additionally, due to the nature of these studies, it was not possible to randomise the patients or blind the investigators. Therefore, the resulting bias may have influenced the outcomes of these studies. A major limitation of this systematic review was that it was not possible to conduct a meta-analysis due to the heterogeneous nature of the included studies and a lack of multiple clinical trials. Therefore, the currently available evidence is insufficient to gauge the durability and viability of PEEK-based dental prostheses. Moreover, none of the studies received a high score during the quality assessment, which further undermines the quality of the evidence presented in this systematic review.

5. Conclusions

Within the limitations of this study, the evidence to ascertain the long-term viability of PEEK-based dental prostheses is insufficient. The majority of the evidence regarding the outcomes of PEEK dental prostheses is obtained from case reports and non-randomised observational studies. Therefore, future studies should focus on conducting large-scale, multicenter trials to compare the survival rate of PEEK prostheses to that of conventionally available prosthodontic appliances. Additionally, implant-supported PEEK prostheses should be studied further for their potential to replace conventional materials and designs.

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