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Comparative Evaluation of Different Properties of Zirconia and Peek Abutments in Dental Implants: A Systematic Review

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KEYWORDS
Zirconia,
Abutments

ABSTRACT:

Objectives: The aim of this review was comparative evaluation of mechanical and biological properties of zirconia and PEEK abutments in titanium dental implant supported restorations.

Methods: A comprehensive search was done in PubMed and Cochrane library electronic databases. In addition to this, manual search of the references mentioned in the studies and gray literature were done. Published articles in English languages and in vivo studies only included in this review. Keywords used in this study were “zirconia abutment” “PEEK abutment,” “dental implants,” “mechanical properties,” and “biological properties”. Boolean operators (AND, OR) were used with the combination of these keywords.

Result: The literature search yielded total 49 studies through search in electronic databases (PubMed – 45, Cochrane library – 4). Thirty five studies were removed after screening of title and abstracts. Total 6 studies were included for full text reading. Six studies were included in the review. Two out of 6 included studies compared surface roughness of different biomaterials. Fracture resistance and pattern of fracture were evaluated by two studies. Different Biological properties like accumulation of biofilm and different strains of bacteria, inflammatory cytokine level, active matrix metalloproteinase -8 levels, probing depth and marginal bone loss were the other parameters that were checked in these studies.

Conclusion: Overall no significant difference found in terms of mechanical and biological properties in between Zirconia and PEEK abutments. PEEK abutments can be used as an alternative option to zirconia abutments in esthetic region of oral cavity.

Introduction

Important objectives of abutments in any dental implant-supported restorations are to provide mechanical support and to maintain esthetic requirements. Many factors like position, inclination, shape, color of the restoration and peri-implant soft tissue profile are directly related to

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esthetic requirements.[1,2] Implant abutment acts as a connector between osseointegrated implant and superstructure. Keratinized mucosa around abutment is an important barrier for protection of underlying bone. Integrity of soft tissue envelope around abutment and soft tissue response depend on the type of material and biocompatibility of material.[3] Titanium abutment is a widely used dental implant abutment nowadays, because of its excellent biocompatibility and long term success rate. However in case of subgingival installation of abutment greyish discoloration sometimes occur due to colour of titanium. This is one of the disadvantages of titanium especially in case of thin gingival biotypes.[4]

Zirconia abutments have been emerged as an alternative abutment in esthetic zone to counteract this disadvantage. Zirconia abutments also have good biocompatibility and long term success rate as per recent literature.[5,6] Reports from randomized controlled clinical trials have shown zirconia abutments have similar survival , biologic and esthetic outcomes as titanium abutments.[3,4] However, age related decrease in physical properties have been seen in zirconia restorations. One study reported 50% reduction of fracture toughness after simulated aging in aqueous environment.[7] Studies have also shown different wear rates and fracture resistance between the interface of titanium implant and zirconia abutment compared to titanium implant and titanium abutment interface.[8,9] Some authors have also questioned about the long term bond strength of cement interface zirconia and resin cement. According to some reports Chemo-mechanical conditioning and use of 10-methacryloyloxydecyl dihydrogen phosphate (MDP) containing resin cement can improve the bond strength .[10-12]

Polyetheretherketone (PEEK) is high performance polymers which have been used in orthopaedics, medicine and dentistry. Polyetheretherketone (PEEK) has been successfully used in dentistry as a framework for implant-supported prostheses because it has biocompatibility and similar modulus of elasticity to those of alveolar bone.[13-15] PEEK complete-arch implant frameworks are lighter and easier to fabricate in dental laboratories than metal or ceramic frameworks which can reduce occlusal stress on implants. There are many advantages of PEEK material compared to zirconia like less expense, esthetic material and availability in prefabricated and customized form.[13-15]

Ceramic reinforced PEEK is a recent modification of PEEK material with incorporation of ceramic fillers to improve the mechanical properties. Clinically it has been reported that Ceramic reinforced PEEK can be used as a material for endocrowns, removable partial denture and implant supported prosthesis with promising result in 12-24 month follow-up period.[13-15] Clinically PEEK abutment can be used as an alternative to zirconia abutment in esthetic region. However, there is limited information available in literature about properties of PEEK implant abutment compared to zirconia implant abutment. Therefore the aim of this review was comparative evaluation of mechanical and biological properties of zirconia and PEEK abutments in titanium dental implant supported restorations.

Materials and methods:

Information search strategy:

In vivo and in-vitro studies were searched for comparative evaluation of different qualities of zirconia abutment and PEEK abutments in dental implants. A comprehensive search was done in PubMed and Cochrane library electronic databases. In addition to this, manual search of the references mentioned in the studies and gray literature were done. Published articles in English languages and in vivo studies only included in this review. Keywords used in this study were “zirconia abutment” “PEEK abutment,” “dental implants,” “mechanical properties,” and “biological properties”. Boolean operators (AND, OR) were used with the combination of these keywords. Two independent reviewers conducted the literature search and any disagreements between reviewers were solved by discussion and Kappa statistics was used for inter-rater reliability.

Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) [16] guidelines were used and the following checklist was followed in this systematic review.

Population, intervention, control, outcome, study design (PICOS) strategy was followed

P: Patients who were rehabilitated with dental implants and experimental models with dental implants

I: Zirconia abutment was used as a choice of abutment material

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C: PEEK abutment was used as a choice of abutment material

O: Mechanical properties and biological properties of both abutment materials

S: Randomized controlled clinical trials, Prospective studies, retrospective studies, In-vitro studies.

Focus question:

"What is the difference between zirconia abutment and PEEK abutment in terms of different mechanical properties and biological properties in in-vitro and in-vivo studies with dental implants?"

Study design:

Study designs used in this review were In-vivo randomized controlled clinical trials, prospective, retrospective studies and in-vitro studies.

Eligibility criteria:

Inclusion criteria were:

1. Published in-vivo and in-vitro studies with dental implants as an interventional procedure
2. Zirconia abutment and PEEK abutment were used as a choice of abutment material for prosthetic support
3. Evaluation of mechanical and biological properties should be used as outcome variables in the study.
4. Published articles in English language.
5. Randomized controlled clinical trials, prospective studies, retrospective studies and in-vitro studies.

Exclusion criteria were:

1. Literature reviews, animal studies.
2. Studies in non-English language.
3. Case reports and case series.
4. Studies with incomplete data.

Data analysis:

The data were extracted by two independent reviewers from all the included studies. Extracted data were filled into predetermined form, consisted of the following information: study, year, country, study design, sample description and interventional procedure. Any disagreements between the reviewers were solved by discussion and Kappa statistics was used for inter-rater reliability.

Assessment of risk of bias :

Assessment of risk of bias of the included in-vivo studies were done according to The recommendations of the consolidated standards of reporting trials statement (CONSORT) by using Cochrane tool for systematic reviews of interventions.[17] The assessed domains were sequence generation, allocation sequence concealment, blinding, incomplete outcome data, selective outcome reporting, and other sources of bias. Bias scores low, unclear, or high were used to assess the overall risk of bias. The risk of bias for each entry recording was scored as "no" to indicate a high risk of bias, "yes" to indicate a low risk of bias, and "unclear" to indicate either a lack of information or uncertainty over the potential risk of bias. The extracted data were stratified and tabulated in chronological order in a summary like format. . Overall, the studies were considered 'high' quality if all conditions met, 'low' quality if ≥1 condition did not meet, or 'unclear' quality if ≥1 condition was partly met. The Newcastle–Ottawa Scale was followed to assess the risk of bias of the In-vivo prospective studies.[18] The methodological quality was based on selection, comparability, and outcome domain. The study was classified to be of good quality if "3 or 4 stars in selection domain," "1 or 2 stars in comparability domain," and "2 or 3 stars in outcome/exposure domain" are obtained. The study was considered to be of fair quality if it secured "2 stars in selection domain," "1 or 2 stars in comparability domain," and "2 or 3 stars in outcome/exposure domain." The quality of the study was considered poor when it obtained "0 or 1 star in selection domain," "0 stars in comparability domain," or "0 or 1 stars in outcome/exposure domain.". Risk of bias assessment of the included In-vitro studies were assessed as per the Cochrane guidelines. [17] Methodological quality assessments was done according to the risk of bias of the articles was assessed as following parameters: selection bias, sample-size calculation, presence of a clearly defined control group, blinding of the operator or examiner, and other bias.

Results:

Study selection:

The literature search yielded total 45 studies through search in electronic database PubMed and 4 studies in Cochrane library. Among all the studies, 8 duplicate records were removed. Thirty five studies were removed

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after screening of title and abstracts. Total 6 studies were included for full text reading. Six studies were included (One randomized controlled clinical trial, three in-vitro studies and two in-vivo prospective studies) in the review. [20-25] Study selection procedure was done by two independent reviewers and any disagreements between the reviewers were solved by discussion and Kappa statistics was used for inter-rater reliability. Study selection procedure has been shown in (Figure-1).

Quality of the included studies:

Included randomized controlled trial mentioned about allocation concealment and adequate sequence generation procedure during randomization. Blinding procedure was clearly mentioned in the study. Pre-specified outcome criteria, attrition and exclusion of patient with proper reason were mentioned in the study. Overall the included study had low risk of bias (Table 1). The quality of the included prospective studies was determined by Newcastle–Ottawa Scale. Among the included studies, both the studies obtained three stars in the selection domain, two stars in the comparability domain, and three stars in the outcome domain. Quality assessment of In-vitro studies showed low risk of bias for all the included studies (Table 2,3).

Characteristics of the included studies:

Characteristics of the included studies have been tabulated in Table-4. Two out of 6 included studies compared surface roughness of different biomaterials.[20, 25] Fracture resistance and pattern of fracture were evaluated by two studies.[21, 22] Different Biological properties like accumulation of biofilm and different strains of bacteria, inflammatory cytokine level, active matrix metalloproteinase -8 level, probing depth and marginal bone loss were the other parameters that were checked in these studies.[20, 23-25] There was no significant difference found in terms of biological parameters in between zirconia and PEEK abutments in the studies. In evaluation of fracture resistance pattern Dental crown was found to be the weakest link in PEEK abutments whereas commonest fracture site in zirconia abutment was implant-abutment junction.[21]

Discussion:

Materials used for Implant-based restorations must meet specific mechanical and biologic properties for survivability. Titanium, nickel, zirconia, ceramic, and gold are commonly used materials as abutments in Implant dentistry. Zirconia/ All ceramic abutments were developed alternative to titanium abutments to improve esthetics in peri-implant region. Other advantages were to prevent leaching of metal particles in peri-implant region due to corrosion in metallic abutments. Previous studies have reported good survival rates, technical outcomes and biological outcomes regarding the use of zirconia abutments to support all-ceramic crowns for single implant replacements.[26, 27]

Poly Ether Ether ketone (PEEK) is a recently developed biomaterial. Dental implant abutments made of PEEK can be easily removed if any complications occur. Due to its low modulus of elasticity, PEEK abutments can withstand greater stresses and forces. Other advantages of PEEK biomaterial abutments are high biocompatibility, low allergic reactions, esthetics and high polishability.[28, 29]

Mechanical overloading and biological failures of Dental implant supported restorations are the two most common complications. There are different factors which causes biomechanical overloading are poor implant position/angulation, poor mechanical properties of the material, inadequate available bone and the presence of excessive forces due to the parafunctional habits.[30, 31] Abutment screw loosening and fracture of abutment/crown are commonest biomechanical complication.[32]

Biological failures consist of microbial plaque deposition, bacterial infections, progressive bone loss, and neurosensory disturbances. Complications from biological cause can be categorized into early implant failure and late implant failure. Early implant failures occur due to improper aseptic measures during placement. Late implant failures occur due to Bacterial plaque which develops Peri-implantitis.[33,34]

In this systematic review Out of six studies, five studies found no significant differences between zirconia and PEEK abutments in terms of different biological and mechanical properties.[20-24] Only one study found higher biofilm formation in PEEK biomaterials compared to zirconia which can lead to more susceptibility to Peri-implantitis in case of PEEK abutments.[25]

Biological properties of PEEK abutments showed no significant change compared to zirconia abutment. In one

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in-vivo study after 3 months of open healing condition there was no significant increase found in cytokine concentration and degrading enzyme (Matrix metalloproteinase, collagenase) concentration around PEEK abutments. Although zirconia abutments layered with feldspar ceramics showed least mononuclear inflammatory cell infiltration in peri-implant mucosa, no significant change was found in terms of marginal bone loss, pocket probing depth around PEEK abutments.[24] Other two studies also found no significant change in biofilm formation around PEEK abutments due to less surface roughness and high surface energy. . In contrast to previous studies, one prospective study using specimens with a standardized surface roughness below 0.2 µm (Threshold level) found high biofilm formation in PEEK materials compared to titanium and zirconia (Biofim accumulation in PEEK - 19.7%, titanium- 11.1%, and zirconia- 6.5%. Therefore this study concluded that the measured differences in biofilm formation are most likely influenced by the material and not by general surface characteristics.[25]

Atsu et al found no significant difference in fatigue strength level and fracture resistance in between zirconia abutments and PEEK abutments in their in-vitro study. Although titanium abutments were superior to both these materials in terms of these properties but fracture resistance and fatigue level of zirconia and PEEK abutments were compatible with intraoral environment. All specimens in this study were exposed to 4.8×10^5 loading cycles using 100 N dynamic loading and 1.6 Hz chewing efficiency.[21]

Most samples in Titanium group showed screw fracture and deformation of the implant connection segment with abutment but no crown fracture. Samples of zirconia showed simultaneous abutment and crown fracture, screw fracture and deformation in implant-abutment connection. Whereas commonest fracture that occurred in PEEK abutments was crown fracture. There was no biomechanical reason found in terms of these fracture patterns in different abutments. In another study 5-year survival rate was 100% for both zirconia and PEEK abutments without any fracture or abutment loss.[22]

Limitations of the present review were less number of included articles in accordance to the inclusion and exclusion criteria and selected articles were only in English language. Heterogeneity was present in between the articles. Heterogeneity in between the studies limited the scope of performing Meta-analysis of the studies. Three of the included studies were In-vitro studies, two studies were randomized controlled clinical trials and one was prospective study.

Conclusion:

Overall no significant difference found in terms of mechanical and biological properties in between Zirconia and PEEK abutments. PEEK abutments can be used as an alternative option to zirconia abutments in esthetic region of oral cavity.

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Study	Adequate sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective outcome reporting	Other risk of bias	Overall risk of bias
Ayyadanveettil P et al (2021)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Low**

Table 1: Assessment of risk of bias in Randomized clinical trials

Study	Representativeness of the exposed cohort (star)	Selection of the nonexposed cohort (star)	Ascertainment of exposure (star)	Demonstration that outcome of interest was not present at the start of the study (star)	Comparability of cohorts on the basis of the design or analysis controlled for confounders (star)	Assessment of outcome (star)	Was follow-up long enough for outcomes to occur (star)	Adequacy of follow-up of cohorts (star)
Enkling N et al (2022)	**1**	**1**	**1**	**-**	**2**	**1**	**1**	**1**
Wiessner A et al (2023)	**1**	**1**	**1**	**-**	**2**	**1**	**1**	**1**

Table 2: Assessment of risk of bias in Prospective studies

Study	Selection bias	Sample-size calculation	Presence of a clearly defined control group	Blinding of the operator or examiner	Absence of other risk of bias
Hahnel S et al (2014)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Atsu SS et al (2018)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

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Barbosa-junior SA et al (2020)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Table 3: Assessment of risk of bias of the in-vitro studies

Study	Study Design	Country	Sample description	Interventional procedure
Hahnel S et al (2014)	In-vitro	Germany	Specimens were made from three different implant abutment materials (titanium, zirconia, and polyetheretherketone (PEEK). Polymethylmethacrylate (PMMA) made specimens were used for reference. Silicon carbide paper was used for surface polishing.	Surface roughness was measured using profilometry, and contact angle measurements were used for surface free energy calculation. Viablity and incubation time of Streptococcus gordonii, Streptococcus mutans, Actinomyces naeslundii, and Candida albicans species were checked in all biomaterials after stimulating salivary pellicle formation.
Atsu SS et al (2018)	In-vitro	Turkey	Thirty six CAD-CAM Monolithic lithium disilicate crowns were luted on three different types of abutments (Titanium, zirconia and ceramic reinforced PEEK) with Panavia V5 cement.	Fracture resistance and type of fracture patterns were evaluated with Universal testing machine after dynamic loading and thermocycling.
Barbosa-junior SA et al (2020)	In-vitro	Brazil	Forty morse-taper implants were mounted in epoxy resin. Monolithic crowns of Zirconia/Lithium Disilicate were luted on Customized abutments of zirconia and PEEK. Specimens were randomly allocated into four groups.	Specimens undergone mechanical fatigue test with increasing load. Load at failure, failure pattern, and survival possibilities and specimen displacement were calculated.
Ayyadanveettil P et al (2021)	Randomized controlled clinical trial	India	Forty participants (age 20 to 50 years) who had undergone implant placement in maxillary anterior and premolar region were divided into 2 groups. Participants of Group 1 had PEEK abutments and group 2 had	Pocket probing depth, plaque control record, bleeding on probing and marginal bone loss was evaluated at baseline and at 1, 3, and 5 years. Colour change of peri-implant tissue and the restoration was also evaluated with spectrophotometer.

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			zirconia abutments. Both groups were restored with pressed lithium disilicate ceramic crowns.	
Enkling N et al (2022)	Prospective study	Switzerland	Forty abutments of 4 different materials (titanium, zirconia, zirconia layered with feldspar, PEEK) were mounted on bone level implants in 20 participants (split-mouth study design).	Inflammatory cytokine mRNA-concentrations and histological analysis were done after 3 months of open healing. In addition, Periodonto-pathogenic bacteria counts and active MMP-8 levels were also checked from peri-implant sulcular fluid.
Wiessner A et al (2023)	In-vivo prospective study	Germany	Specimens of four different materials (titanium, zirconia, PEEK, and modified PEEK (PEEK-BioHPP) were mounted on removable acrylic splints. Splints worn by 20 healthy participants for 24 hours.	Widefield confocal microscopy was used for determining surface roughness. Biofilm accumulation was evaluated by fluorescence microscopy. No significant difference was found regarding surface roughness in between the materials and surface roughness was <0.2 µm for all the materials. Lowest biofilm formation occurred in zirconia followed by titanium, PEEK, PEEK-BioHPP. There was significant difference between all the materials except the PEEK materials.

Table 4: Characteristics of the included studies

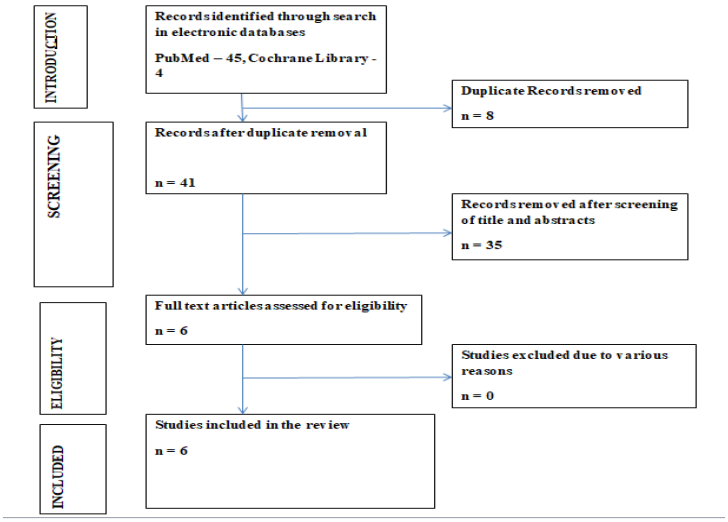

Figure 1: Study design.