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Fracture Load of Partially Palatal Covered Maxillary Implant Overdentures Denture Base Reinforced by PEEK Framework Versus Nanoparticle Reinforcement

An In vitro Study

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Abstract
Statement of Problem: The biomechanical nature of maxillary implant over denture causing extreme leverage on the implants, to overcome this problem necessitates complete coverage of palate. However, there are obligations requiring partial palatal coverage design with subsequent more liability of denture base fracture.
Objective: The aim of the present study was to compare fracture load tolerated by denture base of partially palatal coverage maxillary overdentures (PMOI) retained by 4 parallel implants using reinforcement framework of Poly ether-ether ketone (PEEK) versus denture base reinforced by nano-particles composite made off zirconium dioxide(Z) and PEEK(P).
Materials and Methods: Four implants were inserted in completely edentulous epoxy resin maxillary model in canine and second molar region with addition of mucosal simulation. The model was duplicated into 15 stone casts on which15 experimental partially palatal covered maxillary overdentures (PMOI) were retained over implants using locator attachments (Light retention). The dentures were divided into 3 groups (5PMOI\each group) that were; group I (G1)

having printed acrylic denture base; group II (G2) printed denture base treated with 1.5% by weight (wt.) Z and1.5% by wt. P composite nanoparticles. group III (G3) printed denture base reinforced with P framework and the fracture load tolerated by three different PMOI base materials were evaluated using universal testing machine. The collected data were statistically analysed.
Results: The mean value of fracture load of PMOI denture base reinforced with peek framework was the highest followed by that treated by nano-particles; while denture base of G1 tolerated the least fracture load.
Conclusion: Within limitations of this study, PMOI denture base treated with nano-particles tolerated fracture loads comparable to that reinforced by peek framework.

Keywords
peek framework, nanoparticales, fraction load

INTRODUCTION

Implant retained maxillary overdenture remains a viable treatment option for completely edentulous patients; as it provides good retention and stability comparable to that of fixed restorations. It is mainly indicated in cases where lip support is required by labial flange of removable overdenture[1] .

Sadowsky[2] concluded that a number of four implants was the minimum to support a maxillary overdenture and recommended six implants in case of compromised bone. There are several attachments that may be used to retain implant overdentures including either splinted bars or unsplinted solitary attachments like locators[3] . The solitary attachments are preferred over splinting bars, as they can be used with reduced horizontal and vertical space with subsequent decrease of denture bulkiness[4].

The horseshoe (palate-less) design of the maxillary implant overdenture is well-accepted by the patients due to greater comfort resulted from reduction of tissue coverage in contrast to complete palatal coverage[5]. Removal of the palate also improves maintenance of oral sensation and function[6], indicated for patients with a hyperactive gag reflex, psychological or emotional problems, or if maxillary tori exist[5].

The use of attachments over implants enhances the fracture of unreinforced denture base that is considered the most common prosthetic complication of overdentures[2,5]. The weakening and deformation of denture base are aggravated by palate-less design of maxillary implant overdenture[7]

Polymethyl methacrylate acrylic resin (PMMA) is the most widely used denture base material because of its favorable working characteristics, processing ease, accurate fit, stability in the oral environment, superior esthetics, simplicity in repair and the use with inexpensive equipment. However, it has inherent drawback of low fracture resistance that causes ease of fracture on falling down or fatigue from long use[8,9]. There is a necessity for improvement in the fracture resistance of PMMA[9,10] , this is looks very important with maxillary implant overdenture with palate-less design where the denture base deformation with liability of fracture has become more prominent and represent prosthetic disaster that should be overcome . Reinforcement of the maxillary implant overdenture was reported to improve the rigidity of the denture base and minimize base deformation[10]

It has been reported that reinforcements of the denture base with metallic (cobalt chromium) and non-metallic (such as polyethylene, polyaramid, and glass fibers)[11]. Unfortunately metal reinforcement has some drawbacks like bad esthetics and lack bonding ability of metal to acrylic denture base materials[12]

Poly ether-ether ketone (PEEK) is a high-performance polymer that can serve as a metal alternative in prosthetic restorations providing reinforcement. It offers a high strength-to-weight ratio, corrosion resistance, biocompatibility, radiolucency (so it does not interfere with radiographic assessment), low plaque accumulation, and strong chemical stability[13-15]. It also exhibits minimal creep, excellent wear resistance, and effective shock absorption[16,17]. In addition, PEEK's low specific weight enables the fabrication of lighter prostheses, enhancing patient comfort and satisfaction during function.

Chemical modification of PMMA by incorporation of nanoparticles is also a method to enhance fracture resistance of denture base materials[18,19] . Nanomaterials added to polymer matrix have been improved optical and mechanical properties of denture base. Zirconium dioxide ($ZrO2$) and PEEK nanoparticles[20] are from nanomaterials that have been added increase fracture resistance of PMMA denture base material. Hyprid nano- mixture of PEEK and zirconia has been added to the polymer matrix with variable percentages and they enhanced mechanical properties of resin specimens[20-22].

Up to our knowledge , many literatures have investigated the addition of these nanoparticles to the PMMA polymer powder that was processed conventionally[22,23] or even CAD\CAM printed[24,25] into specimens having standardized dimensions , but there are no literatures dealing with addition of these nanoparticles to denture base materials that are processed into real denture base of PMOI exposed to large leverage.

The aim of the present study was to investigate the fracture load of conventional PMAA denture base of PMOI with that one's reinforced with either Poly ether-ether ketone (PEEK) framework or reinforced by nano-peek and zirconium particles. The null hypothesis was that no significant difference in fracture load that can be tolerated by both types of denture reinforcement and the conventional denture base.

MATERIALS AND METHODS

Sample size and grouping

The sample size was selected based on power analysis directed using finding of a previous study in which authors applied a similar study design[26] to give a 95% power (effect size =3.01, α two-tailed=.05). Accordingly , fifteen experimental maxillary overdentures were used and divided equally within the 3 groups (5 dentures\ each) . First group maxillary overdentures base was made of printed acrylic resin , maxillary overdenture base of 2nd group was printed acrylic resin reinforced by nan-particles of 1.5% by wt. zirconium dioxide and 1.5% by wt. peek while that of 3rd group was supported by denture base reinforced by peek framework.

Construction of experimental model

A complete edentulous maxillary stone cast poured from actual clinical maxillary impression . Acrylic resin trial denture base having complete arrangement of artificial teeth was constructed, the trial denture was processed into a clear guide template using heat cured acrylic resin. The stone model was duplicated into epoxy resin using heat cure acrylic resin (Acroston b) . Implant installation in the acrylic model was performed by the aid of clear template guide marking parallel implant insertion at canines and second premolars bilaterally using a parallometer milling machine (Milling unit BF 2, Bredent, GmbH&Co, KG, German).

Four laboratory implants (TioLogic, Dentaururm, Ispringen, Germany, 4.2 mm in diameter and 12 mm in length) were attached in the canine and second premolar areas bilaterally using auto-polymerized acrylic resin to simulate osseointegriation[27]. Oral mucosa was simulated on the residual ridge and palate using resilient liner having thickness 1.5 mm[28]. Female locator abutment ((Dentium, South Korea) of 3mm gingival height were screwed to the implants using torque of 20 Ncm and then locator male matrices with their processing inserts were fixed on the female abutments .

Construction of printed denture bases

The acrylic model was duplicated into 15 stone casts that was scanned using extra-oral scanner (InEos® X5; Sirona Dentsply, York, USA), STL file was imported to the software of CAD\CAM program(Exocad, Darmstadt, Germany) .

The trial maxillary overdentures of G1 and G2 were made by adaptation of two layers of base plate wax (Cavex Modeling Wax, Netherlands) on each one of 5 stone cast with 2.5 mm thickness on the crest of ridge covering sites of locators and partially extended on the palate in the form of horse shoe, wax occlusion blocks were attached to the waxed denture bases parallel to the crest of the ridge[26] . The ten casts were scanned again to transmit STL files that overlapped previously made within Exocad program to design G1 and G2 overdentures that were printed using PMMA(NextDent Netherland), but resin of G2 was modified by addition of nano-composite Z and P particles to the resin powder before printing.

Incorporation of nano-zirconia and peek composite into printable acrylic resin powder[29]

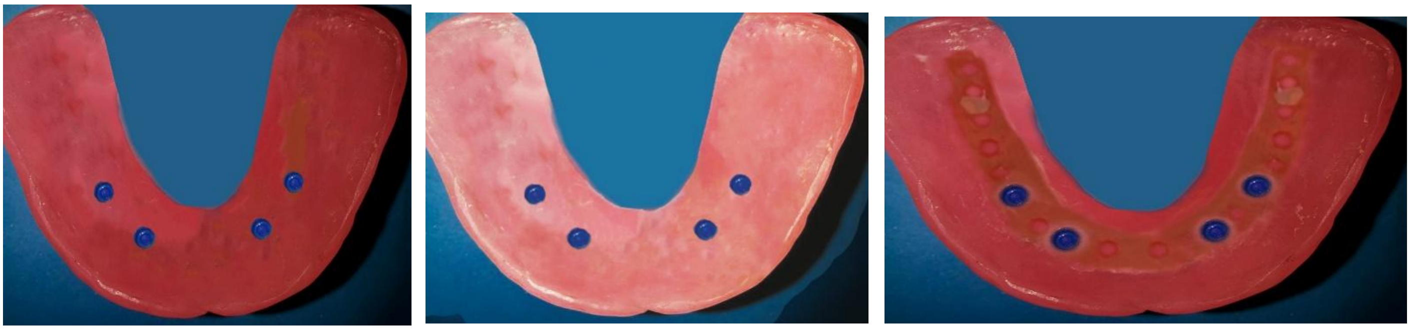
A 2 wt.% solution of Triethoxy(octyl)silane (TTOS) was used as the silane coupling agent to introduce reactive functional groups onto the nanoparticle surfaces. (Sharma, Konica, M. K. Malik 2023). This surface treatment was carried out to improve the dispersion and wettability of the nanoparticles within the resin matrix, thereby promoting uniform distribution and stronger interfacial adhesion between the filler particles and the polymer.

Following surface modification, the silanized zirconia and peek nanoparticles were incorporated into the 3D-printed acrylic resin (HARZ Labs Dental Pink, HARZ Labs LLC, Russia) at concentrations of 2.5by weight for both of them180 _C. Accurate weighing of both the liquid resin and zirconia - peek nanoparticles was performed at using an electronic analytical balance (Model KB360-3N, Germany). The mixture was initially homogenized using a mechanical homogenizer (DAIHAN Scientific, Korea) for 1.5hrs to ensure uniform dispersion. The prepared mixture was homogenized using a DAIHAN Scientific homogenizer for consistent nanoparticle dispersion. Then resin mixtures were transferred to a hotplate magnetic stirrer (Model UC152, Stuart, France) and stirred at 60 °C for 30 minutes to reduce viscosity and promote uniform distribution of the nanoparticles. Stirring was then continued at ambient room temperature for an additional 8 hours to obtain a consistent and homogeneous resin blend suitable for the subsequent 3D printing process.

Construction of reinforcing peek framework (G3)

Five peek frames of G3 were designed on exocad with 1mm thickness[24] over crest of ridge and attachment .and then milled using modified peek blocks (BioHPP, high-performance polymer, Bredent GmbH & Co.KG, Weißenhorner Str. 2, 89250 Senden, Germany) with milling machine (COR I-TEC 350i Loader PRO (imes- icore ® GmbH, 16 Leibolzgraben, 36132 Eiterfeld, Germany). The reinforcement frames of G3 were tried over their opposing stone casts and attached to the implants via locator attachments.

Stone casts of G3having reinforcing frames, were similarly covered by2.5 mm of base plate wax to be waxed up, then were scanned to be printed using the same PMMA resin similar to G1 and G2 (Fig. 1).



Gr 1 Gr2 Gr3

Fig. 1

Adaptation of maxillary overdentures

Fifteen maxillary overdentures with partial palatal coverage and the same thickness were ready to be adapted on their corresponding acrylic models (fig 1), where self-cure acrylic resin was used for pickup of locator male matrices to be inserted in the fitting surfaces of overdentures.

Evaluation of Fracture Loads

Horizontal metallic bar of universal testing machine (GUNT HAMBURG) was fixed at the area of first molar area of occlusion rim bilaterally, vertical compression load was applied at the middle portion of metallic bar using a crosshead speed of 10mm/min (Fig. 2), the force was continued to be applied until catastrophic fracture of denture base occurred. Record block was constructed without denture teeth for measurement as the position of the loading pin over inclined cusps of the posterior teeth will result in slippage of the pin and application of non-axial loading (oblique, horizontal and lateral) on the occlusal surface of the denture[30] (Fig. 2).

Fig. 2

Statistical Analysis

The data was tested for normal distribution using Kolmogorov-Smirnov and Shapiro-Wilk tests that explored parametric normal data spreading. The results were analyzed using ANOVA and *t*-test to determine the significant differences between tested groups at a significant level ($P<0.05$). Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Table (1) results showed significant differences between the three types of denture bases, where the printed denture base reinforced with P framework (G3) tolerated the highest significant force until fracture, followed by that of PMMA of nano- reinforced printed denture base (G2), while that of G1 fractured at the least force. Printed denture base reinforced by nanoparticles (G2) expressed significantly less fracture load than that tolerated by G3 ($p=0.014$), on the other hand it tolerated highly significant fracture load as compared to that of G1($P=0.001$).

Table 1 Comparison of registered fracture load measured in (N)

Groups	Number	Mean	SD
G1 Printed Denture base	5	294	80.2
G2 Nano-Reinforced printed Denture base	5	420	56.7
G3 Peek Framework Reinforced Printed Denture base	5	640	87.4
P-Value		0.001	

DISCUSSION

There was significant difference in the fracture load of the three groups, hence the null hypothesis was rejected. Denture base should have better mechanical properties to resist catastrophic failure under masticatory cyclic loading. Flexural strength and hence fracture load are especially important in PMIOD having greater leverage arm and partial coverage of palate enhances liability of deformation and fracture. Quality of polymerization by use of CAD\CAM is effective method of reducing maxillary denture deformation and denture strains[31].

Mechanical reinforcement of denture base using P framework designed over the implants and crest of ridge increases the rigidity of base with subsequent distribution of stresses between implants and residual ridge[11]. Moreover, P is as elastic as bone reducing the masticatory forces transferred to the denture base and hence palatal framework may compensate for lower rigidity caused by a partial palatal coverage[32]. Hence, P framework enhanced the fracture load as compared to nonreinforced printed PMMA. This is also in line with Muhsin *et al.*[33]who reported that P material is resistant to notch concentration, so P material could be used for denture frameworks having notches at labial or buccal frenum without fracture.

Chemical reinforcement of denture base using Z and P nanoparticles attained significantly higher fracture load than that of G1, this is in line with Gad *et al*.[34] who reported that PMMA resin reinforced with Z and glass fibers increased flexural strength by 45% as compared to that of nonreinforced PMMA. The observable increase of fracture load of G2 that became comparable to that of G3, could be attributed to the synergistic reinforcement of Z and P nanoparticles[23]. Zirconia particles are crystals having high flexural strength of 166 MPa with more resistance of crack propagation and more uniform stress distribution and so it is used to enhance mechanical properties of dental materials[35]. While P particles are semi-crystalline linear polycyclic aromatic polymers having high flexural modulus of 140-170 MPa and high tensile strength, hence it is used for making partial dentures frameworks[36,37]

It is worthy to mention that Z and P nanoparticles reinforcement of PMOI denture base tolerated comparable fracture load to that expressed by PMOI denture base strengthened by P framework. However, according to Barapatre D[23] et al who found that the increase of nanoparticles percentage by 6% by wt to be 3% Z and 3% P decreased significantly the tolerated fracture load. Alrais S.[38] et al demonstrated that addition of 5% by wt ZP composite nanoparticles to the PMMA of denture base improved significantly fracture load as compared to that reinforced by either Z or P nanoparticles alone. This debate in percentage of ZP nanoparticles could be attributed to difference in nanoparticle techniques.

CONCLUSION

Within the limits of this invitro study, zirconia and peek nanoparticles mixed in the powder of printed PMMA reinforced the denture base is recommended for reinforcement of partially covered palate maxillary implant overdentures. However, reinforced P framework has still higher fracture load, hence improvement of nano-techniques is required to increase fracture strength of printed denture base and save the excess costs of CAM making peek framework.

REFERENCES

1. Slot W, Raghoebar GM, Vissink A, Huddleston Slater JJ, Meijer HJ. A systematic review of implant-supported maxillary overdentures after a mean observation period of at least 1 year. J Clin Periodontol. 2010;37:98-110.
2. Sadowsky SJ. Treatment considerations for maxillary implant overdentures: a systematic review. J Prosthet Dent. 2007;97:340-8.
3. Kobayashi M, Srinivasan M, Ammann P, Perriard J, Ohkubo C, Muller F, et al. Effects of in vitro cyclic dislodging on retentive force and removal torque of three overdenture attachment systems. Clin Oral Implants Res. 2014;25:426-34.
4. ELsyad MA, Errabti HM, Mustafa AZ. Mandibular Denture Base Deformation with Locator and Ball Attachments of Implant-Retained Overdentures. J Prosthodont. 2016;25:656-64.
5. Ochiai KT, Williams BH, Hojo S, Nishimura R, Caputo AA. Photoelastic analysis of the effect of palatal support on various implant-supported overdenture designs. J Prosthet Dent. 2004;91:421-7.
6. Tanino F, Hayakawa I, Hirano S, Minakuchi S. Finite element analysis of stress-breaking attachments on maxillary implant-retained overdentures. Int J Prosthodont. 2007;20:193-8.
7. Mizuno Y, Takahashi T, Gonda T, Maeda Y. Mechanical analysis of a palateless denture. Int J Prosthodont. 2013;26:419-22.
8. Meng TR Jr, Latta MA. Physical properties of four acrylic denture base resins. The Journal of Contemporary Dental Practice. 2005 Nov;6(4):93-100. DOI: 10.5005/jcdp-6-4-93. PMID: 16299611.
9. Nejatian, T., Johnson, A., & Van Noort, R. Reinforcement of Denture Base Resin. Advances in Sci. and Techn. (2006). 49, 124–129
10. Tandon R, Gupta S & Samarth KA: Denture base materials: From past to future. Ind J Dent Sc. 2010; 2: 33-9.
11. Gibreel MF, Khalifa A, Said MM, Mahanna F, El-Amier N, Narhi TO, et al. Biomechanical aspects of reinforced implant overdentures: A systematic review. J Mech Behav Biomed Mater. 2019;91:202-11.
12. Rached RN, de Souza EM, Dyer SR, Ferracane JL. Dynamic and static strength of an implant-supported overdenture model reinforced with metal and nonmetal strengtheners. J Prosthet Dent. 2011;106:297-304.
13. Hahnel S, Wieser A, Lang R, Rosentritt M. Biofilm formation on the surface of modern implant abutment materials. Clin Oral Implants Res. 2015;26:1297-301.

14. Wang H, Xu M, Zhang W, Kwok DT, Jiang J, Wu Z, et al. Mechanical and biological characteristics of diamond-like carbon coated poly aryl-ether-ether-ketone. Biomaterials. 2010;31:8181-7.
15. Zoidis P, Papathanasiou I, Polyzois G. The Use of a Modified Poly-Ether-Ether-Ketone (PEEK) as an Alternative Framework Material for Removable Dental Prostheses. A Clinical Report. J Prosthodont. 2016;25:580-4.
16. Conserva E, Menini M, Tealdo T, Bevilacqua M, Ravera G, Pera F, et al. The use of a masticatory robot to analyze the shock absorption capacity of different restorative materials for prosthetic implants: a preliminary report. Int J Prosthodont. 2009;22:53-5.
17. Rosentritt M, Schneider-Feyrer S, Behr M, Preis V. In Vitro Shock Absorption Tests on Implant-Supported Crowns: Influence of Crown Materials and Luting Agents. Int J Oral Maxillofac Implants. 2018;33:116-22.
18. Jordan, J., Jacob, K. I., Tannenbaum, R., Sharaf, M. A. & Jasiuk, I. Experimental trends in polymer nanocomposites—A review. *Mater. Sci. Eng. A* (2005) 393, 1–11 .
19. Qian, C. et al. The effect of CaSiO3 nano-particles reinforced denture polymethyl methacrylate. *Adv. Compos. Lett.* 20, 096369351102000102 (2011).
20. Sodagar, A., Bahador, A., Khalil, S., Shahroudi, A. S. & Kassaee, M. Z. The effect of TiO2 and SiO2 nanoparticles on flexural strength of poly (methyl methacrylate) acrylic resins. *J. Prosthodont. Res.* (2013) 57, 15–19.
21. Abdelraouf, R. M., Bayoumi, R. E. & Hamdy, T. M. Influence of incorporating 5% weight titanium oxide nanoparticles on flexural strength, micro-hardness, surface roughness and water sorption of dental self-cured acrylic resin. *Polymers* (2022) 14, 3767
22. Mustafa, M. A. & Al-Omari, A. W. Evaluating the effect of polyetheretherketone particles addition on water sorption and solubility of polymethylmethacrylate denture base material. *Al-Rafidain Dent. J.* 22, 400–408 (2022).
23. Barapatre, D., Somkuwar, S., Mishra, S. & Chowdhary, R. The effects of reinforcement with nanoparticles of polyetheretherketone, zirconium oxide and its mixture on flexural strength of PMMA resin. *Eur. Oral Res.* 56, 61–66 (2022).
24. Chen, S. G., Yang, J., Jia, Y. G., Lu, B., & Ren, L. (2019). TiO_2 and PEEK reinforced 3D printing PMMA composite resin for dental denture base applications. *Nanomaterials*, 9(7), 1049.
25. Gad, M. M., & Fouda, S. M. Factors affecting flexural strength of 3D-printed resins: A systematic review. *Journal of Prosthodontics,* (2024). *32*(Suppl. S1), 96–110.
26. Gonda, T., Maeda, Y., Walton, J. N., & MacEntee, M. I. (2010). Fracture incidence in mandibular overdentures retained by one or two implants. Journal of Prosthetic Dentistry, 103(3)
27. Elsyad MA, Kabeel A, Elmekawy N. Effect of Implant position and Span Length on Stresses around Implants assisting claspless distal extension partial overdentures. An invitro study. J Oral Implantol. 2017.
28. Elsyad MA, Agha NN, Habib AA. Retention and stability of implant retained mandibular over dentures using different types of resilient attachments. An invitro study. Int J Oral Maxillofac Implants. 2016;31:1040-8.
29. Al-Douri, Y., & Sadoon, Z. Nanotechnology in dental materials: Applications and limitations. *International Journal of Nanomedicine and Dentistry*, (2023). 12(3), 45–58
30. Takahashi T, Mizuno Y, Gonda T, Maeda Y. Metal reinforcement of a complete maxillary denture without a palate: a preliminary report. Int J Prosthodont. 2015;28:188-90.
31. Hada T, Suzuki T, Minakuchi S, Takahashi H. Reduction in maxillary complete denture deformation using framework material made by computer-aided design and manufacturing systems. J Mech Behav Biomed Mater. 2019;103:103514.
32. Suwannaroop P, Chaijareenont P, Koottathape N, Takahashi H, Arksornnukit M. In vitro wear resistance, hardness and elastic modulus of artificial denture teeth. Dent Mater J. 2011;30:461-8.
33. Muhsin SA, Hatton PV, Johnson A, Sereno N, Wood DJ. Determination of polyetheretherketone (PEEK) mechanical properties as a denture material. Saudi Dent J 2019;31:382-91
34. Gad MM, Al-Thobity AM, Rahoma A, Abualsaud R, Al-Harbi FA, Akhtar S. Reinforcement of PMMA denture base material with a mixture of ZrO2 nanoparticles and glass fibers. Int J Dent2019;2019:1-11.
35. Vagkopoulou T, Koutayas SO, Koidis P, Strub JR. Zirconia in dentistry: Part 1. Discovering the nature of an upcoming bioceramic. Eur J Esthet Dent 2009;4:130-51.
36. Zoidis P, Papathanasiou I, Polyzois G. The use of a modified poly ether ether ketone (PEEK) as an alternative framework material for removable dental prostheses. A clinical report. J Prosthet Dent 2015;25:580-4.
37. Skirbutis G, Dzingutė A, Masiliūnaitė V, Šulcaitė G, Žilinskas. A review of PEEK polymer's properties and its use in prosthodontics. Stomatologija 2017;19:19-23.
38. Alrais S. , Alghoraibi I. & Salloum A. In vitro comparative evaluation of the flexural strength of acrylic denture bases reinforced with nano-PEEK and PEEK–zirconia composites. Scien. Rep. (2026) 16:7601