Brazilian Dental Science
unesp
UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE

DOI: https://doi.org/10.4322/bds.2023.e3775

The effect of different framework's material on strain induced in distal abutment in mandibular Kennedy's class II: an in-vitro study

O efeito de diferentes materiais de estrutura na deformação induzida na distal do pilar da classe II de Kennedy mandibular: um estudo in vitro

Noha Mohamed EL HUSSIENY FAYAD[1], **Dina Essam BAHIG**[1]

1 - Oral and Maxillofacial Prosthodontics Department, Ain Shams University. Cairo, Egypt.

How to cite: El Hussieny Fayad NM, Bahig DE. The effect of different framework's material on strain induced in distal abutment in mandibular Kennedy's class II: an in-vitro study. Braz Dent Sci. 2023;26(3):e3775. https://doi.org/10.4322/bds.2023.e3775

ABSTRACT

Objective: This study aims to compare the strain induced in the supporting structures of unilateral mandibular removable partial denture frameworks retained by extra-coronal attachments fabricated with three different materials. **Material and Methods:** Three mandibular class II digitally designed and printed acrylic models with detachable abutments were used to fabricate three removable partial denture framework with extra coronal attachments from three different materials. A total of 33 models were prepared for strain testing (n=11). Models were divided into three groups according to framework's material: porcelain fused to cobalt chromium (PFM), polyetherketoneketone (PEKK) and polyetheretherketone (PEEK) group. Unilateral load of 60 N was applied in the three groups and strains were measured around the main abutment and saddle area using strain gauge. **Results:** Statistical analysis was performed using Shapiro-Wilk's test and by checking data distribution. Data were found to be non-parametric and were analysed using Kruskal-Wallis test followed by Dunn's post hoc test with Bonferroni correction. PFM group showed significantly the highest strain values around abutment, slot 1 (1mm distal to the socket of the last abutment) and slot 2 (1 cm away from slot 1) respectively (843.00±23.08, 91.00±6.52 and 1274.00±65.71) than the other tested groups ($p<0.05$) at same tested sites respectively followed by PEKK group (384.00±37.48, 81.00±2.24 and 135.00±0.00) and PEEK group (29.00±4.18, 63.00±4.47 and 52.00±5.70). **Conclusions:** PEEK and PEKK for partial denture framework with extra coronal attachments are adequate alternative to PFM due to their good mechanical response applying less strain on supportive structures in free-end cases. PEEK induces lower strain magnitude on the supporting structures when compared to PEKK.

KEYWORDS

Denture precision attachment; Dental stress analysis; Partial denture; Polyetheretherketone; Removable partial denture.

RESUMO

Objetivo: Este estudo tem como objetivo comparar a tensão induzida nas estruturas de suporte de estruturas de próteses parciais removíveis mandibulares unilaterais retidas por encaixes extracoronários fabricados com três materiais diferentes. **Material e Métodos:** Três modelos mandibulares de classe II digitalmente projetados e impressos em acrílico com pilares destacáveis foram usados para fabricar três estruturas de próteses parciais removíveis com encaixes extracoronários de três materiais diferentes. Um total de 33 modelos foram preparados para testes de deformação (n=11). Os modelos foram divididos em três grupos de acordo com o material da estrutura: porcelana fundida com cobalto-cromo (PFM), poliétercetonacetona (PEKK) e polieteretetercetona (PEEK). Carga unilateral de 60 N foi aplicada nos três grupos e as deformações foram medidas em torno do pilar principal e área de sela usando medido de tensão. **Resultados:** A análise estatística foi realizada por meio do teste de Shapiro-Wilk e com a verificação da distribuição dos dados. Os dados mostraram-se não paramétricos e foram analisados pelo teste de Kruskal-Wallis seguido pelo de Dunn com correção de Bonferroni. O grupo PFM mostrou significativamente os maiores valores de tensão ao redor do pilar, slot 1 (1mm distal do último pilar) e slot 2 (1 cm de distância do slot 1) respectivamente (843,00±23,08, 91,00±6,52 e 1274,00±65,71) do que os outros grupos testados (p<0,05) nos mesmos locais testados, respectivamente, seguido pelo grupo PEKK (384,00±37,48, 81,00±2,24 e 135,00±0,00) e grupo PEEK (29,00±4,18, 63,00±4,47 e 52,00±5,70). **Conclusão:** PEEK e PEKK para estrutura de prótese parcial com encaixes extracoronários são alternativas adequadas ao PFM devido à sua boa resposta mecânica aplicando menos tensão nas estruturas de suporte em casos de extremidade livre. O PEEK induz menor magnitude de deformação nas estruturas de suporte quando comparado ao PEKK.

PALAVRAS-CHAVE

Análise de tensão dentária; Encaixe de precisão para próteses; Polieteretercetona; Prótese parcial; Prótese parcial removível.

INTRODUCTION

Kennedy class I and II free end saddle cases are one of the most challenging prosthetic clinical situations due to absence of posterior abutments and variable compressibility of supportive dental and saddle area [1]. Different treatment options for these cases have been introduced in literature including the insertion of distal dental implants with an implant supported prosthesis or a properly designed classic removable partial denture (RPD). RPD in distal extension cases represents a great challenge due to multiple factors. These factors include dental, patient and RPD design aspects. RPD is a biomechanical device. Its components are exposed to various loads and forces which are consequently transferred to the supportive dental and saddle structures during function as well as during insertion and removal of RPD [2-6].

Load within the physiological limit of the abutments and supportive saddle area leads to the torsional force of abutments as well as less destructive bone resorption effect on the saddle area. But, even with controlled application of load in free end saddle cases, they are still subjected to stresses during function that affect the support as well as stability of RPD leading to the need for frequent relining [2,7]. Good clinical prognosis of RPD in classic Kennedy class II requires optimal design of RPD on solid biomechanical principles. In such instances the selection of a suitable retainer becomes a critical component to control stresses applied on the supportive abutments [8-11].

Attachment retained RPD is the treatment modality that can facilitate both an aesthetic and functional replacement of missing teeth and oral structures [12]. Elimination of labial or buccal clasp arms increases the patient's psychological acceptance of the denture [8-13]. Extra coronal attachments as direct retainers that extend from the full coverage crown of abutments can provide a rigid, movable, or resilient connection between abutments and RPD [8-14]. Proper materials selection of RPDs' framework fabrication affects stresses transmitted to the supportive structures [11].

RPD framework fabrication material may be metallic or non-metallic. Cobalt-chromium (CoCr) alloy is the most commonly used metallic material for casting or printing RPD framework material. Many drawbacks are detected with metallic RPD framework fabrication materials where aesthetics and metallic taste are of major concern. Non-metallic RPD framework materials with polymeric nature provide a wide range of physical and chemical properties that have solved many of the major problems encountered with metallic RPD framework materials [15,16].

Poly aryl ether ketone (PAEK) family is a thermoplastic polymeric material which has been used in the engineering field since 1980s with excellent mechanical properties and chemical resistance. PAEK family includes two polymeric material polyetheretherketone (PEEK) and polyetherketoneketone (PEKK) [17,18]. PEEK was the first version of PEAK family that was widely applied in many dental fields including implantology, prosthetics and maxillofacial fields [11,19].

PEKK is the latest generation of the PAEK family showing higher quality. Unlike PEEK, PEKK shows both amorphous and crystalline material properties which gives PEKK unique interesting mechanical, physical and chemical properties [11,20]. Digital workflow for the fabrication of RPD from polymeric material as PEEK & PEKK provides RPD frameworks with dimensional accuracy and adaptation to the underlying structures leading to good retention and support [11,21,22].

Mechanical behaviour of variable materials in the dental field can be measured with different techniques including photoelasticity measurement, strain gauge-based measurements, optic measurement, and computational finite analysis [15,23]. A strain gauge is a tool designed to measure the strain of an entity [3,4,8,10]. Strain gauge evaluation is a method for measuring micro-strains, by measuring electrical resistance [8,13,24].

Strain induced by partial dentures on the supporting structures can be detrimental. The goal of this study was to assess how partial denture frame work with extra coronal attachment fabrication materials affects the biomechanical behaviour using strain gauge analysis. The null hypothesis was that different fabrication materials for partial denture with extra coronal attachment would result in different outcomes.

MATERIALS AND METHODS

Construction of 3D model of lower class II

A mandibular 3D educational acrylic model simulating mandibular Kennedy class II with the first premolar as the principal abutment was used for this study. It was scanned using desktop scanner (DOF swing scanner, DOFlabs, Seoul, South Korea) for designing and modifying the virtual model.

Designing & modification of virtual model and virtual abutments preparation

Virtual abutment preparation was done separately after removal from their sites in the virtual model to obtain separate STL files for the detachable abutments designed (Exocad Dental CAD, Exocad Inc. Darmstadt, Germany). For mucosal simulation, two mm cut back was done virtually on a 3D model for creating space for mucosal simulation material to be injected using a printed mucosa key index.

Two slots for strain gauge were designed on the virtual model where the first slot was 1mm distal to the socket of the last abutment and the second slot was 1cm away from the first slot.

Digital printing for the modified virtual model and detachable prepared abutments

Three models with their detachable abutments were printed (Form 2 3D printer, formlabs, Somerville, Massachusetts, United States). Mucosal simulating material (Gingisil, Soft Endharte Shore a 45,dent-e-con e.k, Germany) was injected through printed mucosa key index around the roots of the dies and into saddle area of the printed casts Figure 1.

Splinted crowns and attachments fabrication

Printed models with detachable dies were rescanned to obtain STL files to design two splinted on the two main detachable abutments with I-rod extra coronal attachments using the three different materials Figures 2-4.

Figure 1 - Digital printed lower-class II model with detachable abutments with mucosal simulating material and two slots for strain gauge.

Figure 2 - Splinted porcelain fused to metal crowns with metallic extra coronal attachment.

Figure 3 - Splinted PEKK crowns with PEKK extra coronal attachment.

Figure 4 - Splinted PEEK crowns with PEEK extra coronal attachment.

Figure 5 - Group I porcelain fused to CoCr metal attachment and RPD.

Study grouping

PFM group: Eleven porcelain fused to cobalt chrome partial denture frame works with extra coronal attachments were fabricated with conventional casting lost wax technique.

PEKK group: Eleven PEKK chrome partial denture frame works with extra coronal attachments were fabricated with milling technique for PEKK blank.

PEEK group: Eleven PEEK chrome partial denture frame works with extra coronal attachments were fabricated with milling technique for PEEK blank.

Partial denture framework fabrication

Splinted crowns with extra coronal attachments in the three groups were cemented to the abutments of the printed models then rescanned to design the partial denture frame works virtually. Three different materials were used to fabricate the splinted crowns with extra coronal attachments in the three groups.

Design of partial denture frameworks

The scanned model was virtually surveyed to adjust the proper path of insertion with butterfly clasp design on the intact side for cross arch stabilization with occlusal rests on the second premolar and first molar designed (Exocad Dental CAD, Exocad Inc. Darmstadt, Germany). The designed STL file was imported to the milling machine to mill the two frame works of PEKK &PEEK while the casted conventional frame work was fabricated after printing a wax pattern to be used in lost wax technique to fabricate conventional CoCr partial denture frame work.

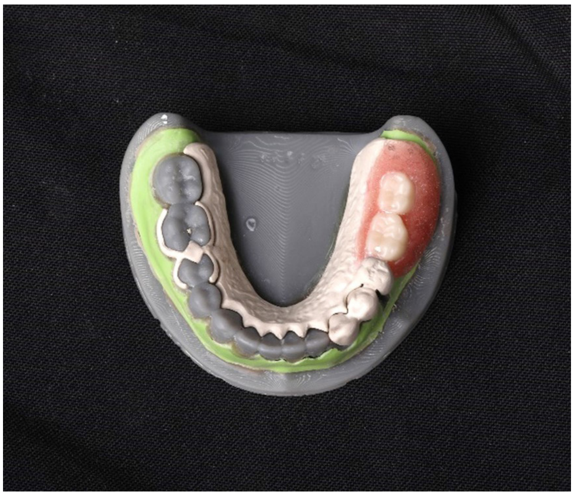

Figure 6 - Group II PEKK attachment and RPD.

Figure 7 - Group III PEEK attachment and RPD.

Artificial teeth were set and waxed up on a duplicated cast then final denture bases were fabricated for the three frameworks in the three groups from conventional heat cured acrylic resin and pick up for the female part of extra coronal attachment was done with cold cured acrylic resin as showed in Figures 5-7.

Strain analysis

Strain gauges installation and load application

Three strain gauges (KFGS-2N-120-C1-11L1M2R, Kyowa electronic instruments co., Japan) were glued using cyanoacrylate adhesive on the cast around the distal abutment on the buccal surface of the socket in respective slot and in the two pre planed slots one and two (Figures 8 and 9). The ends of the strain gauge wires were inserted into four channel strain meters (Kyowa, kyowa Electronic Instruments Co, Ltd, Tokyo, Japan) to calculate the micro strains induced by the applied load [25].

Each model was fixed to the lower metal plate of the universal testing machine (Lloyd LRX; Lloyd Instruments Ltd., Fareham, UK) where calibration was done by applying load from 10-60N load five times in 10N steps at a speed of at speed 100 mm/s in a progressive manner until full magnitude of load was reached. Unilateral 60 N load was applied using I bar load applicator (8mm in diameter and 22 cm in length) perpendicular to and centralized over central fossa of the first molar as showed in Figure 10.

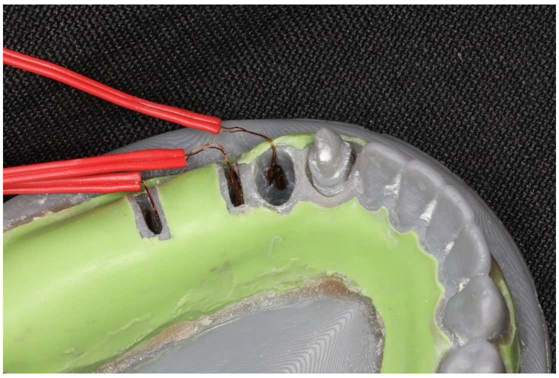

Figure 8 - Strain gauges bonded in their sites.

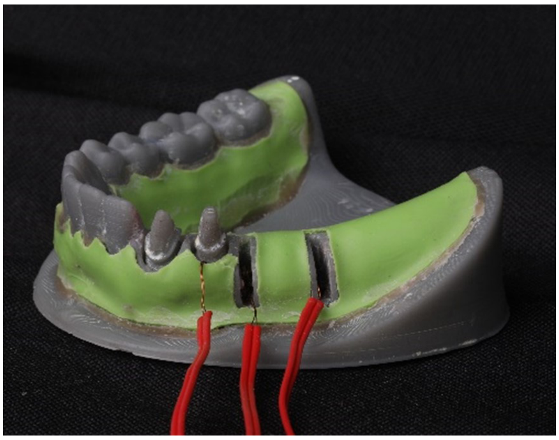

Figure 9 - Three strain gauges bonded on the cast around the distal abutment on the buccal surface of the socket and in the two pre-planned slots (one and two).

STATISTICAL ANALYSIS AND SAMPLE SIZE CALCULATION

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups regarding accuracy. By adopting an alpha (α) and beta (β) levels of (0.05) (i.e. power=95%) and an effect size (f) of (0.733) calculated based on the results of a previous study [26]. The minimal required sample size (n) was found to be (33) samples (i.e., 11 samples per group). Sample size calculation was performed using G*Power version 3.1.9.7.

RESULTS

The results were analyzed using Kruskal-Wallis test followed by Dunn's post hoc test with Bonferroni correction. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.0 for Windows. Numerical data was represented as mean, standard deviation (SD) median and interquartile range values (μm/μm).

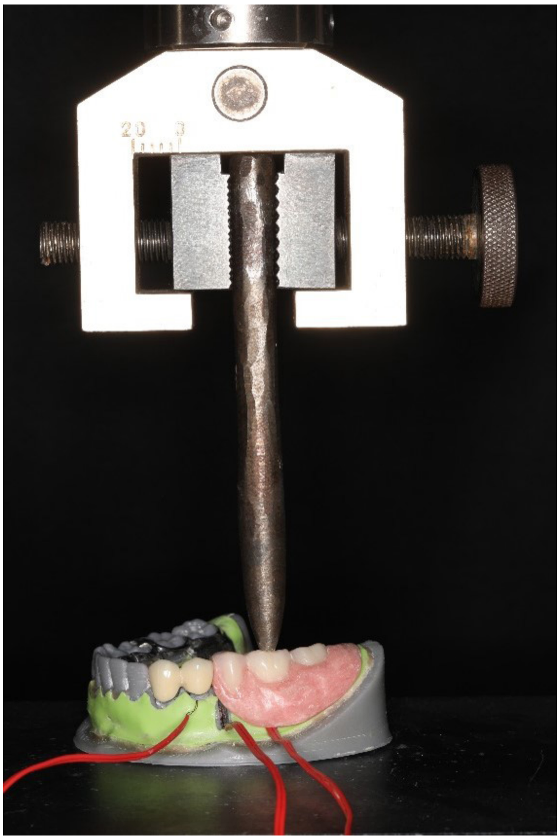

Figure 10 - Unilateral load applied using I bar load applicator.

Results of intergroup comparisons and summary statistics for strain values are presented in Table I. there was a significant difference between the three tested groups with all post hoc pairwise comparisons being statistically significant (p<0.001).

The strain mean values which was the highest value was for the abutment measures in PFM framework group (843.00 ± 23.08^A) followed by PEEK framework (29.00 ± 4.18^B) & PEEK framework group (384.00 ± 37.48^C).

For slot 1 and slot 2 strain values were also found to be the highest for PFM framework group respectively (91.00 ± 6.52^A, 1274.00 ± 65.71^A) but less strain values were detected in PEKK framework group respectively (81.00 ± 2.24^B, 135.00 ± 0.00^B) and the lowest strain values were detected in PEEK framework group (63.00 ± 4.47^C, 52.00 ± 5.70^C).

DISCUSSION

Distal extension RPD abutments along with the saddle supportive tissues act as an important source of support and retention. A disadvantage of the metallic removable partial dentures is the inferior esthetics. This led to the development of attachments whether precision or resilient to help give more esthetic results. The advantage of resilient attachment is that it dissipates forces permitting denture base movement towards the tissues during function leading to a decrease in the torque falling on the abutments [27-29].

The partial denture design and material play a critical role in the dissipation of the masticatory applied load. If the partial denture fails to distribute these stresses equally the tension created will lead to local irritation and excessive bone resorption which will affect RPD stability and function and the health of the supporting structures [15].

The difference in compressibility of the supportive structures in free end saddle cases leads to inevitable tissue ward rotation of the denture. Although actual movement of RPD is minimal, a lever force is created at the terminal abutment leading to an increase in the stress induced [30]. So, proper design and selection of fabrication material is crucial to control stresses induced in the supporting tissues to reduce bone loss [31,32].

The results of this study showed highly significant difference in strain induced around abutment, slot 1 and slot 2 in PFM framework group in comparison to the PEEK framework and PEEK framework groups that showed less strain mean values. Such finding were in line with the study of Fayyad [33] that showed that porcelain fused to CoCr metal might initiate higher strain values around the abutments due to the stiff nature of the material [9,33]. This finding is due to high modulus of elasticity of cobalt-chromium (210MPa) which is more rigid in comparison to the low value of modulus of elasticity of PEKK (15GPa) and PEEK (3.6GPa). PEEK & PEKK are almost like dentine and bone so they are flexible and at the same time elastic with strong damping power to decrease torque and stresses on abutments with the RPD settling. The rigidity of cobalt chromium transmits great rotational and lateral stresses on the abutment. According to the recent literature, the modulus of elasticity and nano-hardness of a material are factors that directly affect the amount of pressure transmitted by the material and the extent of the area to which it is transmitted [11,33].

Results comparing strain induced around abutment showed higher value in PEKK framework group when compared to PEEK framework group which was in line with the findings of Sadek [13] where strain gauge assessment method revealed that, PEEK is the material of choice as it showed the most suitable stress dissemination in all parts particularly throughout the abutment teeth due to its flexure behaviours [13,34-38].

Table I - Intergroup comparisons of strain values

Measurement area		PFM	PEEK	PEKK	h-value	p-value
Abutment	Mean±SD	843.00 ± 23.08^A	29.00 ± 4.18^B	384.00 ± 37.48^C	12.54	<0.001*
	Median (IQR)	$840.00\ (25.00)^A$	$30.00\ (5.00)^B$	$385.00\ (55.00)^C$		
Slot 1	Mean±SD	91.00 ± 6.52^A	63.00 ± 4.47^B	81.00 ± 2.24^C	12.42	<0.001*
	Median (IQR)	$90.00\ (10.00)^A$	$60.00\ (5.00)^B$	$80.00\ (0.00)^C$		
Slot 2	Mean±SD	1274.00 ± 65.71^A	52.00 ± 5.70^B	135.00 ± 0.00^C	12.99	<0.001*
	Median (IQR)	$1270.00\ (85.00)^A$	$50.00\ (5.00)^B$	$135.00\ (0.00)^C$		

Values with different superscript letters within the same horizontal row are significantly different. *significant (p<0.05).

Regarding results at slot 2, PEEK group showed lesser strain value in comparison to PEKK group which was In contrast to the findings of Bagley and Bell [39] and Alsadon et al. [40] who reported that PEKK shows better mechanical values when compared to PEEK (pure and glass-reinforced) in the tensile strength, flexural strength and compressive strength and better stress distribution. Also Lee et al. [41] and Sirandoni et al. [42] reported that the shock absorbing property of PEEK is limited to the site of its presence. But distant sites received higher stresses when PEEK was compared to other rigid materials.

Finally, a limitation of this study was that it was carried out in-vitro, without taking into consideration the effect of individual patient variation regarding the supporting structures for the fabricated prostheses. Thus, future clinical trials should be carried out as such in-vitro researches do not eradicate the requirement for clinical ones. The null hypothesis was rejected as there was significant difference between the three groups in regard to the strain induced on the supporting structures.

To reduce detrimental forces falling on the abutment and free end saddle area in class II Kennedy cases, it is recommended to use a polymeric material for the construction of RPD framework. Apart from their better aesthetics, they have a mechanical advantage and can be used to better preserve the supporting structures.

CONCLUSION

Within the limitations of this study it could be concluded that the use of polymers like PEKK and PEEK for the construction of RPD frameworks can be a promising treatment option when compared to PFM frameworks. Moreover PEEK induces the least strains on the supporting structures due to its resilient nature and ability to dissipate forces effectively.

Author's Contributions

NMEHF: Conceptualization, Methodology, Software, Validation, Writing – Original Draft Preparation, Visualization, Supervision, Project Administration. DEB: Formal Analysis, Investigation, Resources, Data Curation, Writing – Review & Editing.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Regulatory Statement

The approval code for this study is: FDASU-Rec ER112222.

REFERENCES

1. El-Rahman A, Aladdin N, El-Sharkawy AM, Mohy El-Din MH, Saad MS. sStrain evaluation of peek cantilever bars around implants assisted mandibular overdentures (in vitro study). Alex Dent J. 2022;47(3):138-45.
2. Mousa MA, Abdullah JY, Jamayet NB, El-Anwar MI, Ganji KK, Alam MK, et al. Biomechanics in removable partial dentures: a literature review of FEA-based studies. BioMed Res Int. 2021;2021(4):5699962. http://dx.doi.org/10.1155/2021/5699962. PMid:34485518.
3. Lynch CD. Successful removable partial dentures. Dent Update. 2012;39(2):118-20. http://dx.doi.org/10.12968/denu.2012.39.2.118. PMid:22482269.
4. Benso B, Kovalik AC, Jorge JH, Campanha NH. Failures in the rehabilitation treatment with removable partial dentures. Acta Odontol Scand. 2013;71(6):1351-5. http://dx.doi.org/10.3109/00016357.2013.777780. PMid:23834529.
5. Alsharif HN, Ganji KK, Alam MK, Manay SM, Bandela V, Sghaireen MG, et al. Periodontal clinical parameters as a predictor of bite force: a cross-sectional study. BioMed Res Int. 2021;2021:5582946. http://dx.doi.org/10.1155/2021/5582946. PMid:34046498.
6. Bhathal M, Batra J, Attresh G, Sambyal S. A review on stresses-induced by removable partial dentures. Int J Contemp Dent Med Rev. 2015;5:1-15.
7. Costa L, do Nascimento C, de Souza VO, Pedrazzi V. Microbiological and clinical assessment of the abutment and non-abutment teeth of partial removable denture wearers. Arch Oral Biol. 2017;75:74-80. http://dx.doi.org/10.1016/j.archoralbio.2016.11.002. PMid:27825678.
8. Saleh MM, Aldori D. Effects of new modification in the design of the attachments retaining distal extension partial denture on stress distribution around the abutments and residual ridges: an in vitro study. Dent Hypotheses. 2020;11(4):112-7. http://dx.doi.org/10.4103/denthyp.denthyp_38_20.
9. McKenna G, Tada S, Woods N, Hayes M, DaMata C, Allen PF. Tooth replacement for partially dentate elders: a willingness-to-pay analysis. J Dent. 2016;53:51-6. http://dx.doi.org/10.1016/j.jdent.2016.07.006. PMid:27421987.
10. Tribst JP, Dal Piva AM, Borges AL. Biomechanical tools to study dental implants: a literature review. Braz Dent Sci. 2016;19(4):5-11. http://dx.doi.org/10.14295/bds.2016.v19i4.1321.
11. El-Baz R, Fayad M, Abas M, Shoieb A, Gad M, Helal MA. Comparative study of some mechanical properties of cobalt chromium and polyether ether ketone thermoplastic removable partial

denture clasps: an In-vitro Study. Braz Dent Sci. 2020;23(3):6-10. http://dx.doi.org/10.14295/bds.2020.v23i3.1935.

12. Makkar S, Chhabra A, Khare A. Attachment retained removable partial denture: a clinical report. Inter J of Clin Dent Sci. 2011;2(2):13-9.
13. Sadek SA. Comparative study clarifying the usage of PEEK as suitable material to be used as partial denture attachment and framework. Open Access Maced J Med Sci. 2019;7(7):1193-7. http://dx.doi.org/10.3889/oamjms.2019.287 PMid:31049106.
14. Alkhodary MA, Class II. Kenn edy implant assisted mandibular removable partial dentures with and without cross arch stabilization: a strain gauge in vitro study. Egypt Dent J. 2020;66(2):1173-82. http://dx.doi.org/10.21608/edj.2020.23987.1010.
15. Chen X, Mao B, Zhu Z, Yu J, Lu Y, Zhang Q, et al. A three-dimensional finite element analysis of mechanical function for 4 removable partial denture designs with 3 framework materials: CoCr, Ti-6Al-4V alloy and PEEK. Sci Rep. 2019;9(1):13975. http://dx.doi.org/10.1038/s41598-019-50363-1 PMid:31562391.
16. Chen J, Cai H, Suo L, Xue Y, Wang J, Wan Q. A systematic review of the survival and complication rates of inlay-retained fixed dental prostheses. J Dent. 2017;59:2-10. http://dx.doi.org/10.1016/j.jdent.2017.02.006. PMid:28212978.
17. Alqurashi H, Khurshid Z, Syed AU, Habib SR, Rokaya D, Zafar MS. Polyetherketoneketone (PEKK): an emerging biomaterial for oral implants and dental prostheses. J Adv Res. 2020;28:87-95. http://dx.doi.org/10.1016/j.jare.2020.09.004 PMid:33384878.
18. Villefort RF, Diamantino PJ, Von Zeidler SL, Borges AL, Saavedra GD, Tribst JP. Mechanical response of PEKK and PEEK as frameworks for implant-supported full-arch fixed dental prosthesis: 3D finite element analysis. Eur J Dent. 2022;16(1):115-21. http://dx.doi.org/10.1055/s-0041-1731833. PMid:34560810.
19. Maharana T, Sutar AK, Routaray A, Nath N, Negi YS. Polyetheretherketone (PEEK): applications as a biomaterial. encyclopedia of biomedical polymers and polymeric biomaterials. 2014;35(1):1701-8
20. Sanath S, Kamalakanth K, Rajesh S, Vidya B, Mallikarjuna R, Abhishek CK. Pekk (Polyetherketoneketone) as a prosthetic material- a review. Int J Recent Sci Res. 2018;9(4):25724-6.
21. Li RW, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: state of the art. J Prosthodont Res. 2014;58(4):208-16. http://dx.doi.org/10.1016/j.jpor.2014.07.003 PMid:25172234.
22. Whitty T. PEEK: a new material for CAD/CAM dentistry. Juvora Dental Innovations. 2014;7(2):123-40.
23. Ahmed MA, Hamdy AM, Fattah GA, Effadl AK. Prosthetic design and restorative material effect on the biomechanical behavior of dental implants: strain gauge analysis. Braz Dent Sci. 2022;25(3):e3380. http://dx.doi.org/10.4322/bds.2022.e3380.
24. Ramadan RE, Mohamed FS, Gepreel MA. Evaluation of implant-assisted mandibular overdenture with new metal to metal interface attachment system (in vitro study). Alex Dent J. 2020;45(1):106-11. http://dx.doi.org/10.21608/adjalexu.2020.79970.
25. Saleh MM, Aldori D. Effects of new modification in the design of the attachments retaining distal extension partial denture on stress distribution around the abutments and residual ridges: an in vitro study. Dent Hypotheses. 2020;11(4):112-29. http://dx.doi.org/10.4103/denthyp.denthyp_38_20.
26. Rady AA, Abdel Nabi N. Stress analysis of two different attachments for a two implant retained mandibular overdenture. Egypt Dent J. 2017;63(4):3447-57. http://dx.doi.org/10.21608/edj.2017.76263.
27. El-Baz R, Fayad M, Abas M, Shoieb A, Gad M, Helal MA. Comparative study of some mechanical properties of cobalt chromium and polyether ether ketone thermoplastic removable partial denture clasps: an In-vitro Study. Braz Dent Sci. 2020;23(3):6. http://dx.doi.org/10.14295/bds.2020.v23i3.1935.
28. Mutto JC, Sato TP, da Silva JM, Borges AL, Uemura ES. Retentiveness comparison of individual clasps made from polyamide, acetate resin and cobalt-chrome for removable partial dentures. Braz Dent Sci. 2019;22(4):483-7. http://dx.doi.org/10.14295/bds.2019.v22i4.1802.
29. Mamdouh RI, El-Sherbini NN, Mady YO. Treatment outcomes based on patient's oral health related quality of life (OHRQoL) after receiving conventional clasp or precision attachment removable partial dentures in distal extension cases: a randomized controlled clinical trial. Braz Dent Sci. 2019;22(4):528-37. http://dx.doi.org/10.14295/bds.2019.v22i4.1819.
30. Sabri LA, Abdulkareem JF, Salloomi KN, Faraj SA, Al-Zahawi AR, Abdullah OI, et al. Finite element analysis of class II mandibular unilateral distal extension partial dentures. J Mech Eng Sci. 2022;236(17):9407-18. http://dx.doi.org/10.1177/09544062221096634.
31. Al-Okl A, Al Samahy M, Amin H, Khashaba U. Stresses induced by integrated and'nonintegrated extracoronal semi-precision attachments for maxillary distal extension bases. Al-Azhar Dent J for Girls. 2018;5(3):297-304. http://dx.doi.org/10.21608/adjg.2018.17195.
32. Ragghianti MS, Greghi SL, Lauris JR, Sant'Ana AC, Passanezi E. Influence of age, sex, plaque and smoking on periodontal conditions in a population from Bauru, Brazil. J Appl Oral Sci. 2004;12(4):273-9. http://dx.doi.org/10.1590/S1678-77572004000400004. PMid:20976396.
33. Fayyad A. Comparison between two different unilateral mandibular partial denture designs retained by extra-coronal attachment: an in-vitro study. Egypt Dent J. 2022;68(3):2479-85. http://dx.doi.org/10.21608/edj.2022.127727.2024.
34. Elgamal M. PEEK versus Metallic Framework for extracoronal attachment mandibular bilateral distally extended Removable Dental Prosthesis (RDP) evaluation of abutments bone height changes and patient satisfaction. A Randomized Clinical Trial. Egypt Dent J. 2022;68(1):631-45. http://dx.doi.org/10.21608/edj.2021.93903.1778.
35. Stawarczyk B, Beuer F, Wimmer T, Jahn D, Sener B, Roos M, et al. Polyetheretherketone a suitable material for fixed dental prostheses? J Biomed Mater Res B Appl Biomater. 2013;101(7):1209-16. http://dx.doi.org/10.1002/jbm.b.32932 PMid:23564476.
36. Schwitalla AD, Spintig T, Kallage I, Müller WD. Flexural behavior of PEEK materials for dental application. Dent Mater. 2015;31(11):1377-84. http://dx.doi.org/10.1016/j.dental.2015.08.151 PMid:26361808.
37. Tekin S, Cangül S, Adıgüzel Ö, Değer Y. Areas for use of PEEK material in dentistry. J. Int. Dent. 2018;8(2):84-92. http://dx.doi.org/10.5577/intdentres.2018.vol8.no2.6.
38. Skirbutis G, Dzingutė A, Masiliūnaitė V, Šulcaitė G, Žilinskas J. PEEK polymer's properties and its use in prosthodontics: a review. Stomatologija. 2018;20(2):54-8. PMid:30531169.
39. Bagley D, Bell M. Method for producing sealing and anti-extrusion components for use in downhole tools and components produced thereby. United States Patent Application US 10/112,172. 2002 Dec 26.
40. Alsadon O, Wood D, Patrick D, Pollington S. Fatigue behavior and damage modes of high-performance poly-ether-ketone-ketone PEKK bilayered crowns. J Mech Behav Biomed Mater. 2020;110:103957. http://dx.doi.org/10.1016/j.jmbbm.2020.103957. PMid:32957248.
41. Lee KS, Shin SW, Lee SP, Kim JE, Kim JH, Lee JY. Comparative evaluation of a four implant–supported poly ether ketone ketone framework prosthesis: a three-dimensional finite element analysis based on cone beam computed tomography and computer aided design. Int J Prosthodont. 2017;30(6):581-5. http://dx.doi.org/10.11607/ijp.5369. PMid:29095963.
42. Sirandoni D, Leal E, Weber B, Noritomi P, Fuentes R, Borie E. Effect of different framework materials in implant-supported fixed mandibular prostheses: a finite element analysis. Int J Oral Maxillofac Implants. 2019;34(6):e107-14. http://dx.doi.org/10.11607/jomi.7255. PMid:31711084.

Noha Mohamed El Hussieny Fayad
(Corresponding address)
Oral and Maxillofacial Prosthodontics Department, Ain Shams University, Cairo, Egypt.
Email: nohafayad@dent.asu.edu.eg

Date submitted: 2023 Mar 03
Accepted submission: 2023 May 21