Effect of 2 Load-Absorbing Crown Materials on The Peri-Implant Supporting Structures: A 1- Year Prospective Clinical Study

Shimaa Eltantawy[1], Mahmoud Shakal[1], Sherif Sultan[1,2], Sherif Elsharkawy[1]

1. Fixed prosthodontics, University of Tanta, Tanta, Egypt.
2. Department of prosthetic dental sciences, Jouf university, Sakakah, KSA.

Abstract

Clinical studies assessing the effect of load absorbing crown materials on the peri-implant supporting structures are lacking. So, the aim of this study was to evaluate the effect of two load-absorbing crown materials on the peri-implant supporting structures. Thirty participants aged between 20 and 45 years received a single implant in the maxillary premolar area. 10 implants were restored with metal-ceramic (MC) crowns, 10 implants with polyether ether ketone (PEEK) crowns, and 10 with resin-ceramic (RC) crowns. The crestal bone loss (CBL) and certain clinical parameters were evaluated at baseline (at cementation of the definitive crown), at 6 months, and at 12 months. The clinical parameters assessed were probing depth (PD), modified plaque index (MPI), and modified sulcus bleeding index (MSBI). The tested clinical parameters did not show a significant difference at different follow-up times. The reported CBL in all groups was within the clinically accepted levels (< 0.459 to 0.55 mm at 12 months of implant placement). Regarding the intra-group comparisons of CBL results, In the MC group, there was a statistically significant difference (P <0.05) between 12 months and baseline.

Clinical article (J Int Dent Med Res 2023; 16(1): 164-170)

Keywords: Marginal/Crestal bone loss, PEEK, resin- ceramic, implant-supported CAD/CAM crowns.

Received date: 28 July 2022 **Accept date:** 30 August 2022

Introduction

The precise reasons for the success or failure of implant therapy are difficult to determine, as there are lots of factors involved, including surgical methods and materials used.[1,2] Dental implants are primarily evaluated in terms of the stability of the supporting peri-implant hard and soft tissues. The peri-implant hard tissue is usually evaluated by measuring crestal bone loss (CBL).[3] The loss of bone around dental implants may be caused by a variety of factors, including the implant characteristics, patient age, general health, prosthetic materials, and some peri-implant periodontal parameters.[4] The most common occurrence of CBL occurs shortly after implant placement. Historically, an early CBL of about 1.0 to 1.5 millimeters is considered normal for the first year after implant placement, but more recent data suggest CBL of about 0.459 to 0.55 millimeters throughout the first year after implant placement.[5] In most studies, periapical radiographs are used to measure peri-implant CBL.[6]

The clinical outcomes of implants had been described in the form of clinical parameters like modified plaque index, modified sulcus bleeding index, and probing depth.[4] Successful implants usually allow approximately 3 millimeters of probe penetration.[7] If the pocket depth is less than 3 mm, plaque presence and bleeding tendency should also be considered.[7] Patients' ability to perform oral hygiene procedures correlates directly with plaque index values, and poor oral hygiene is a risk factor for peri-implant lesions Since dental plaque is the primary cause.[8]

Metal-ceramic (MC) crowns have been considered as the gold standard for the restoration of teeth over the past five decades,[9] however, due to the shift toward metal-free restorations, resin-based materials like resin-ceramics (RC) and Polyether-ether ketone (PEEK) are currently used. [10-12]

A natural tooth's periodontal ligament

Corresponding author:
Shimaa Eltantawy,
Assistant lecturer of fixed prosthodontics, University of Tanta, Tanta, Egypt.
E-mail: shaymaa_tantawy@dent.tanta.edu.eg

absorbs shocks, provides tactile sensitivity, and sends proprioceptive motion feedback to the brain through periodontal mechanoreceptors, but implants place direct pressure on surrounding bone because mastication forces directly affect the implant itself.[13] It could be argued that reducing occlusal loads on Osseointegrated implants by selecting a resilient material that can absorb some of the excessive force may prove to be a crucial factor in long-term implant success.[14]

PEEK has an elastic modulus which is about 3.5 GPa, its young's modulus and tensile properties are comparable to that of human bone, enamel, and dentin.[15,16] Its capacity to absorb and distribute loads would enable bone to be stimulated favoring remodeling without overloading, so, it had been recommended to be used in patients with severe bruxism.[17] Resin-ceramics or polymer infiltrated ceramics are made from a resin ceramic combination, which exhibits the positive characteristics of both materials.[18] The combination of ceramics and polymers has been shown to give these materials hardness, elasticity, and flexural strength similar to natural teeth.[19] A good example of this type of material is Vitaenamic. A unique feature of this computer-aided design and computer-aided manufacturing (CAD-CAM) material is that it does not require sintering after milling.

Although clinical evidence for the impact of overloading on peri-implant bone loss is limited,[20] controlling the forces applied to the implant-bone interface seems important from a biomechanical perspective.[21] The laboratory evidence of the shock-absorbing ability of resin-based materials like PEEK and resin-ceramic is currently evident,[22] however, there are not enough clinical studies or international standardization about their clinical and radiographic behavior when used over implants.

To the author's knowledge, the first introduced resin-ceramics to the dental market were Lava Ultimate by 3 M ESPE in 2011 and Vita enamic by VITA in 2013. As described by the manufacturers, both materials are suitable for single implant-supported crowns. In 2020 Panadero et al[23] published a 5-year prospective clinical study that evaluated Lava Ultimate versus metal-ceramic (MC) implant-supported crowns, they concluded that the MC crowns showed superior mechanical behavior and the peri-implant tissue biological response was independent of the prosthetic crown material, however, during this study, the manufacturer of Lava Ultimate confirmed that it was no longer suitable for crowns. This 1- year prospective clinical study was conducted to evaluate the effect of load absorbing implant-supported PEEK and RC crowns on the supporting structures compared to MC crowns. The null hypothesis was, that the PEEK and RC crowns will not show a significant difference in the crestal bone loss (CBL), or the clinical parameters assessed compared to MC crowns.

Materials and methods

This study was conducted as a prospective, randomized clinical trial. Ethics approval for the study was granted by the Research Ethics Committee, Faculty of Dentistry, Tanta University, Egypt No. FP-11-19-2. The sample size was estimated by using the following formula: - Sample size $= (Z^{2*}(P)^{*}(1\text{-}P))/C^2$, where z= z value (1.96 for 95% confidence level), p=percentage picking a choice, expressed as a decimal, c= confidence interval, expressed as a decimal. The purpose was explained to the participants and informed consent was obtained. It was calculated that 10 implants per group would provide 95% power with a significance level (0.05). This study was conducted from January 2021 to April 2022 at the out clinics of the faculty of dentistry, Tanta University, Egypt. Thirty participants (16 females and 14 males) aged 20-45 years with a missing maxillary premolar received 30 two-piece implants. The clinical outcomes (probing depth; PD, modified plaque index; MPI, and modified sulcus bleeding index; MSBI) and the radiographic outcomes (crestal bone loss; CBL) were recorded at cementation of the definitive crown(baseline), at 6 months, and 1 year.

Of the 30 implants; 10 were restored with metal-ceramic crowns (MC group), 10 with polyether ether ketone (PEEK group), and 10 with resin-ceramic crowns (RC group). To avoid bias, an online random selection generator was used. Each implant was randomly restored with either MC, PEEK, or RC crowns. Based on random numbers, the generator selected numbers for restorations with PEEK and RC crowns and numbers for restorations with MC crowns until the number of crowns allotted for each group was completed.

Inclusion criteria

Age 20-45 years, medically free, the ability to read and sign the informed consent, bone quality (D2 or D3), and quantity (bone remaining around implant not less than 1.5 mm), bite force within normal values, ability to maintain meticulous oral hygiene, and ability to return for follow-up. Full mouth plaque scores less than 25%.

Exclusion criteria

Patients with periodontitis, severe bone resorption, clenching or bruxism, heavy smokers, drug abusers, and bad oral hygiene, pregnant women, when implant surgery is contraindicated, bisphosphonate therapy or chemo/ radiotherapy to head and neck region, and uncooperative subjects.

Pre-operation examination

Cone-beam computed tomography (CBCT) was done for each patient to evaluate the quality and quantity of the alveolar bone at the implant site, and its relation to anatomical structures. The optimal positions of implants were planned in 3D software considering both the alveolar process and the prosthetic demands (figure 1).

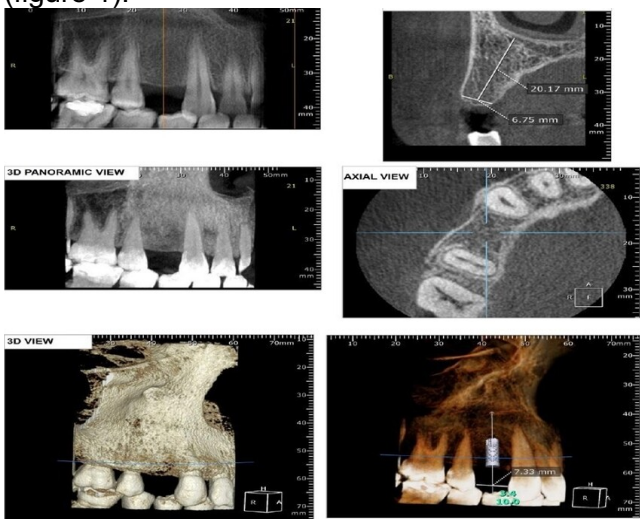

Figure 1. Implant position planning using On Demand 3D software.

Surgical phase

All surgeries were completed in a complete aseptic condition under local anesthesia and following the standard drilling protocol as per the manufacturer's instructions. All implants were placed using implant surgical guides. The implants used in this study were internal hex connection implants (bone-level Nucleoss T6; Europe GmbH). An appropriate dose and duration of postoperative antibiotic, anti-inflammatory, and 0.12 % chlorhexidine mouth wash were described.

The prosthetic phase

To make sure that the implant is ready for loading, an adequate value of implant stability quotient (ISQ) was confirmed 4 months after implant placement. An implant level open-tray polyether impression (Bonasil A^{+} VPS; DMP) was made to select/adjust the prosthetic straight stock abutment extra orally. The selected/adjusted stock abutment was torqued intraorally, a provisional CAD-CAM restoration was then constructed and cemented for 2 weeks to allow for a better emergence profile and adequate healing of peri-implant soft tissues. Two weeks later, the provisional crown was removed, an abutment level impression was made for the construction of the definitive crowns, and the provisional crown was recemented. In the MC group, the crowns were fabricated by a conventional lost wax casting technique and conventional porcelain build-up. In the PEEK group, the implants were restored with pressed polyether ether ketone crowns (PEEK; Bredent GmbH) veneered with veneering composite resin (Visio.lign, Bredent GmbH). In the RC group, the implants were restored with CAD-CAM procedures from milled resin- ceramic (Vitaenamic; VITA Zahnfabrik). All crowns in the 3 groups were finished according to the respective manufacturer's instructions. The provisional crown was then removed, and the definitive crowns were cemented. To decrease the amount of excess cement, the cement was applied only to the occlusal half of the intaglio surface of crowns.[24] Complete seating intraorally was verified using a digital radiograph and the excess cement was removed. Non-eugenol provisional cement (temp-Cem NE cement; Nexobio) was used so that the crowns can be easily removed and cleaned during recall visits.

To exclude the effect of poor oral hygiene on the assessed clinical parameters the participants were taught and instructed to maintain meticulous oral hygiene.

Data collection and follow up

The marginal bone level (MBL) was measured by 2 experienced radiologists who were not informed about the study groups. To avoid examiner bias, inter-and intra-examiner's reliability was calculated, and a strong level of agreement was achieved. The MBL was evaluated on the mesial and distal implant

surfaces (figure 2) by a standardized periapical digital radiograph using a long cone paralleling technique with a sensor positioning device (Rinn XCP-DS FIT dentrek module; Dentsply).

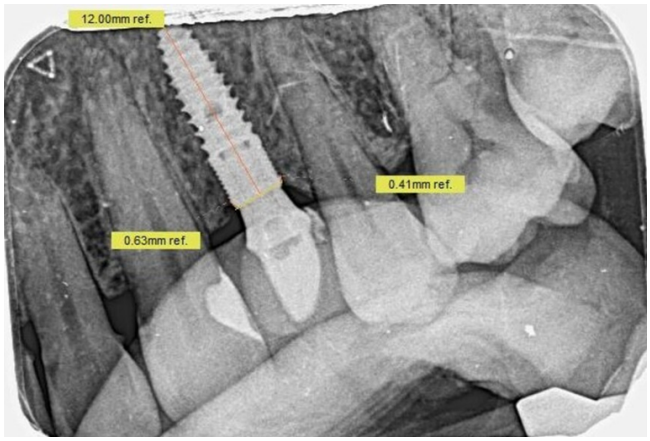

Figure 2. Measurement of Crestal bone loss using 2.6x SIDEXIS-XG software.

The bite block part of Rinn XCP system was modified with an acrylic resin key ensure exact repositioning in future measurements. All radiographs and exposure times followed a standard radiologic setup. The marginal bone levels were evaluated using a software program designed to take measurements from images (2.6x SIDEXIS-XG software; Sirona).[25] The most coronal edges of the implant platform mesially and distally were chosen as the reference point. The length of the implant as provided by the manufacturer, from the apex to the implant platform, was used as a reference to calibrate the measurements.[26] The mesial and distal distance from the implant platform to the first point of bone-implant contact was measured for each implant. The mean MBL (MMBL) per implant at a certain time was considered as the mean of the mesial and distal MBL measurements at that time. CBL has been calculated according to the following formula, CBL (at a certain time) = (MMBL at that time-MMBL at baseline).[27]

The clinical parameters were measured by 2 experienced periodontists who were blinded to the study groups. The PD measurements were taken at 6 points, distobuccal, distolingual, mesiobuccal, mesiolingual, mid buccal and midlingual using HZ plastic prob (HELMUT ZEPF, Medizin Technik GmbH). PD was measured as the longest distance between the gingival sulcus base and the gingival margin. The MPI was measured according to the following records, no plaque detected = score 0; when plaque is detected with probe only = score 1, score 2 is given when plaque can be detected by the naked eye; and score 3 = plentiful plaque. The MSBI was recorded as per the following scores: score 0 = bleeding is not detected; score 1 = separated bleeding spots; score 2 = confluent bleeding; score 3 = abundant bleeding.[28]

Statistical analysis

It was performed using Statistical Package for Social Sciences (SPSS version 26), the data of radiographic (CBL) and clinical parameters (PD, MPI, and MSBI) at baseline, 6 and 12 months were analyzed so that numerical variables were expressed by descriptive statistics as mean and standard deviation. After homogeneity of variance and normal distribution of errors have been confirmed, repeated measures ANOVA followed by Tukey post hoc tests; in case of significant difference; were used for intra-group comparisons of parameters at 6 months against baseline, and at 12 months against baseline. One way ANOVA was used for inter-group comparisons of means of the parameters at 6 and 12 months. P-value ≤0.05(*) was considered a significant difference.

Results

One participant showed a significant increase in CBL at 6 months, and he was removed from the study. No prosthetic failures were recorded. The intragroup comparisons of the clinical parameters tested at the follow-up times (6 months versus baseline and 12 months versus baseline) showed in (Table 1).

Outcome	Parameter	Groups	M±SD at follow up times			P-Value	
			Baseline	6 months	1 year	6 months	1 year
Clinical	PD	MC	2.31±0.28	2.24±0.25	2.17±0.17	0.275	0.345
		PEEK	2.32±0.15	2.21±0.12	2.11±0.09	0.333	0.321
		RC	2.18±0.12	1.92±0.12	1.32±0.17	0.125	0.123
	MPI	MC	1.34± 0.41	0.81± 0.34	0.74± 0.39	0.323	0.312
		PEEK	1.34 ± 0.43	0.81 ± 0.53	0.64 ± 0.30	0.444	0.521
		RC	1.33 ± 0.49	0.81 ± 0.44	0.67 ± 0.30	0.453	0.432
	MSBI	MC	0.81 ± 0.85	0.56 ± 0.77	0.78 ± 0.89	0.445	0.646
		PEEK	0.75 ± 0.86	0.71 ± 0.77	0.69 ± 0.83	0.441	0.332
		RC	0.79 ± 0.85	0.77 ± 0.66	0.66 ± 0.89	0.243	0.222

MMBL: Mean marginal bone level. CBL: Crestal bone loss.

Table 1: Comparison of clinical outcomes of the MC, PEEK, and RC groups.

The intragroup comparisons of the radiographic parameters (CBL) at the follow-up

times (6 months versus baseline and 12 months versus baseline) showed in (Table 2). In all groups, the reported CBL at 12 months was within the clinically accepted levels (< 0.459 to 0.55 mm at the first year). There were no significant differences in all the clinical parameters evaluated. However, there was a significant difference in the CBL in the MC group between baseline and 12 months measurements (Table 3).

Group	MMBL	CBL		P-Value	
	(Baseline)	6 months	1 year	6 months	1 year
MC	0.51±0.12	0.13±0.25	0.43±0.35	0.122	0.001*
PEEK	0.59±0.05	0.03±0.07	0.07±0.06	0.311	0.324
RC	0.61±0.11	0.07±0.14	0.11±0.12	0.245	0.453

MMBL: Mean marginal bone level. CBL: Crestal bone loss

Table 2. Comparison of radiographic outcomes of the MC, PEEK, and RC groups.

Groups	6 months versus baseline	12 months Versus baseline
MC	0.059	0.001*

Table 3. Pairwise comparisons of CBL measurements in group MC.

Regarding the intergroup comparisons (MC versus PEEK, MC versus RC, and PEEK versus RC), there was no significant difference in all the clinical parameters assessed at the 3 follow-up times (baseline, 6 months, and 12 months). There was no significant difference in the CBL between all groups at baseline and 6 months. However, there was a significant difference in CBL between MC&PEEK and between MC& RC at 12 months. Also, there was no significant difference in CBL between PEEK, RC groups at 12 months (Table 4).

Groups	Mean± S. D	Min-Max	ANOVA		Multiple comparisons (Tukey)
			F	p-value	
MC	0.43±0.35	0.15-1.39	21.036	0.00*	MC& PEEK≥0.00*
PEEK	0.07±0.06	0.02-0.33			MC& RC≥0.00*
RC	0.11±0.12	0.05-0.50			PEEK & RC≥0.843

Table 4. Multiple comparisons of CBL measurements of all groups at 12 months.

Discussion

The causes of early excessive peri-implant CBL are multifactorial; however, they are not fully understood. Among the main theories are the infection theory, advocated by periodontists, and the overload theory, advocated by prosthodontists.[5] Assuming that the infection of the peri-implant tissues can be controlled by maintaining meticulous oral hygiene, the effect of prosthetic material on the peri-implant bone loss can be studied clinically. Therefore, the goal of this study was to assess the impact of 2 load-absorbing implant-supported crown materials on supporting structures.

The results of the current study indicated that RC and PEEK single implant-supported crowns have a significantly lower CBL value compared to MC crowns at the first year of implant insertion. However, the clinical outcomes of the 3 crown materials did not differ significantly. Therefore, the null hypothesis was partially accepted

The selection of superstructure materials for the implant is of important concern as it directly affects the health of peri-implant tissues.[29] Currently, there is increased clinical use of metal-free restorations, however, there is a lack of clinical research on their effectiveness over implants. In this study, 2 shock-absorbing metal-free crown materials were compared with the gold standard MC implant-supported crowns to assess the impact of crown material on hard and soft tissues around the implant. To standardize clinical factors related to soft tissue around implants, strict oral hygiene instructions were given to participants and therefore maintaining the periodontal indices without significant change during the study course, this was confirmed by the normal range of values obtained for PD, MBI, and MSBI as previous studies.[30-32]

Most of the studies conducted on RC and PEEK implant-supported crowns before starting our study were in vitro or finite element analysis studies. Consequently, we found it difficult to compare our results with similar studies. The highest mean CBL value reported in this study after 1 year was 0.43 mm in MC crowns which was in accordance with the mean CBL value reported in a 15 year follow up study published in 1996 by Lindquist et al.[33] The mean CBL values reported for PEEK and RC crowns were 0.66 and 0.72 mm which was in accordance with the same values reported in recently published studies.[3,26]

Results of the present study showed higher values of CBL in MC than in PEEK and RC crowns. The CBL in MC crowns at 12 months was 0.43±0.35. For PEEK crowns, it was

0.07±0.06, and for RC crowns it was 0.11±0.12. So, there was a significant difference between MC and the other two groups, this may be due to the lower elastic modulus of PEEK and RC compared to MC crowns.[15,34] and consequently reducing the stresses transmitted to crestal bone. These results are consistent with the study performed by Akanksha et al, who concluded that PEEK crown produced lesser stress than MC crown under vertical and oblique loading and that straight abutment along with PEEK crown could be given in patients with bruxism to reduce the stress concentration in bone.[35] Also, this result agreed with an invitro study by Rosenstiel et al.[22] who studied the effect of different combinations of crown materials and cements on the shock absorbing capacity of implant-supported crowns. They concluded that resin-based materials have higher shock absorption capacity compared to ceramics and the best force damping behavior was recorded for PEEK.

However, the outcome of this study didn`t agree with a finite element analysis study comparing implant-supported MC and resin-modified ceramic crowns and found no significant differences in peri-implant bone loss between them.[36] This difference in the result might be because of difference in study type and method of CBL evaluation.

The outcome of this study is not in accordance with the study of Panadero R et al.[2] that evaluated the mechanical and clinical behavior of implant-supported resin-modified ceramic (RMC) crowns compared with that of metal-ceramic crowns and concluded that RMC (Lava Ultimate) crowns are not suitable for use over titanium implant because of mechanical failure although matched CBL values to our study were obtained.

Digital periapical 2D radiographs were used to assess the marginal bone loss changes as they are used in most studies.[6] and easy to standardize for repeated measurements of single implant-supported crowns.

There was no significant difference between all groups at all durations for the tested clinical parameters, this may be because the patients were given instructions to maintain meticulous oral hygiene measures, and this was confirmed and checked over short-term recall visits.

The limitations of this study include the short-term follow-up and not considering the mechanical complication of these load absorbing restorations; studies may be recommended to evaluate both biological and mechanical aspects of these materials over a long-term follow-up time.

Conclusions

Based on the present results, Accordingly, we have drawn the following conclusions:

1. In all groups, the reported crestal bone loss was within the clinically accepted levels (< 0.459 to 0.55 mm at 1 year).
2. Implant-supported metal-ceramic crowns showed more crestal bone loss than polyether ether ketone and resin-ceramic crowns.
3. Considering the peri-implant crestal bone loss, polyether ether ketone and resin-ceramic may be recommended as single implant-supported crowns when compared to metal-ceramic.

Declaration of Interest

The authors report no conflict of interest.

References

1. Wittneben JG, Joda T, Weber HP, Brägger U. Screw retained vs. cement-retained implant-supported fixed dental prosthesis. Periodontol 2000. 2017;73(1):141-51.
2. Agustín-Panadero R, Soriano-Valero S, Labaig-Rueda C, Fernández-Estevan L, Solá-Ruíz MF. Implant-supported metal-ceramic and resin-modified ceramic crowns: A 5-year prospective clinical study. J Prosthet Dent. 2020;124(1):46-52.
3. Geraets W, Zhang L, Liu Y, & Wismeijer D. Annual bone loss and success rates of dental implants based on radiographic measurements. Dentomaxillofac Rad. 2014;43(7):34-8.
4. Kim DM, Badovinac RL, Lorenz RL, Fiorellini JP, Weber HP. A 10-year prospective clinical and radiographic study of one-stage dental implants. Clin Oral Implants Res. 2008;19(3):254-8.
5. Saravi BE, Putz M, Patzelt S, Alkalak A, Uelkuemen S, Boeker M. Marginal bone loss around oral implants supporting fixed versus removable prostheses: A systematic review. Int J Implant Dent. 2020;6(1):20-9.
6. García-García M, Mir-Mari J, Benic GI, Figueiredo R, Valmaseda-Castellón E. Accuracy of periapical radiography in assessing bone level in implants affected by peri-implantitis: a cross-sectional study. J Clin Periodontol. 2016;43(1):85-91.
7. Mombelli A, Lang NP. The diagnosis and treatment of peri-implantitis. Periodontol 2000. 1998;17(2):63-76.
8. Martin W, Lewis E, Nicol A. Local risk factors for implant therapy. Int J Oral Maxillofac Implants. 2009;24(6):28-38.
9. Bonfante EA, Suzuki M, Lorenzoni FC, Sena LA, Hirata R, Bonfante G, et al. Probability of survival of implant-supported metal ceramic and CAD/CAM resin nanoceramic crowns. Dent Mater. 2015;31(8):168-77.
10. Rasha A A, Silikas N, Salim NA, Al-Nasrawi S, Satterthwaite JD. Effect of the Composition of CAD/CAM Composite Blocks on Mechanical Properties. BioMed Res Int. 2018;2018(5):1-8.
11. Barizon KT, Bergeron C, Vargas MA, Qian F, Cobb DS, Gratton DG, et al. Ceramic materials for porcelain veneers: part II.

Effect of material, shade, and thickness on translucency. J prosthet dent. 2014;112(4):864-70.
12. Denry I, Kelly J. Emerging ceramic-based materials for dentistry. J Dent Res. 2014;93(12):1235-42.
13. Skalak R. Biomechanical considerations in osseointegrated prostheses. J Prosthet Dent. 1983;49(6):843-8.
14. Parmigiani-Izquierdo JM, Cabaña-Muñoz ME, Merino JJ, Sánchez-Pérez A. Zirconia implants and peek restorations for the replacement of upper molars. Int J Implant Dent. 2017;3(1):3-5.
15. Garcia-Gonzalez J, Jayamohan SN, Sotiropoulos SH, Yoon J, Cook CR, Siviour A et al. On the mechanical behaviour of PEEK and HA cranial implants under impact loading. J Mech Behav Biomed Mater. 2017;69(2):342-54.
16. Schwitalla A, Müller W-D. PEEK Dental Implants: A Review of the Literature. J Oral Implan. 2013;39(6):743-9.
17. Ponnappan RK, Serhan H, Zarda B, Patel R, Albert T, Vaccaro AR. Biomechanical evaluation, and comparison of polyetheretherketone rod system to traditional titanium rod fixation. Spine J. 2009;9(3):263-7.
18. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. Dent Mater. 2014;30(5):564-9.
19. Swain M, Coldea A, Bilkhair A, Guess P. Interpenetrating network ceramic-resin composite dental restorative materials. Dent Mater. 2016;32(1):34-42.
20. Duyck J, Vandamme K. The effect of loading on peri-implant bone: a critical review of the literature. J Oral Rehabil. 2014;41(10):783-94.
21. Koyano K, Esaki D. Occlusion on oral implants: current clinical guidelines. J Oral Rehabil. 2015;42(2):153-61.
22. 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(1):116–22.
23. Agustín-Panadero R, Soriano-Valero S, Labaig-Rueda C, Fernández-Estevan L, Solá-Ruíz MF. Implant-supported metal-ceramic and resin-modified ceramic crowns: A 5-year prospective clinical study. J Prosthet Dent. 2020;124(1):46-52.
24. Dumbrigue HB, Abanomi AA, Cheng LL. Techniques to minimize excess luting agent in cement-retained implant restorations. J Prosthet Dent. 2002;87(1):112-4.
25. Stacchi C, Lombardi T, Baldi D, Bugea C, Rapani A, Perinetti G, et al. Immediate loading of implant-supported single crowns after conventional and ultrasonic implant site preparation: a multicenter randomized controlled clinical trial. Biomed Res Int. 2018;2018(14):8-15.
26. Nemli SK, Güngör MB, Aydın C, Yılmaz H, Bal BT, Arıcı YK. Clinical and radiographic evaluation of new dental implant system: Results of a 3-year prospective study. J Dent Sci. 2016;11(1):29-34.
27. Smet DE, Jacobs R, Gijbels F, Naert I. The accuracy and reliability of radiographic methods for the assessment of marginal bone level around oral implants. Dentomaxillofac Radiol. 2002;31(3):176-81.
28. Mombelli A, Van Oosten MAC, Schurch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol. 1987;2(4):145-51.
29. Cibirka RM, Razzoog ME, Lang BR, Stohler CS. Determining the force absorption quotient for restorative materials used in implant occlusal surfaces. J Prosthet Dent. 1992;67(3):361-4.
30. Pellicer-Chover H, Peñarrocha-Oltra D, Bagán L, Fichy-Fernandez A J, Canullo L, Peñarrocha-Diago M. Single-blind randomized clinical trial to evaluate clinical and radiological outcomes after one year of immediate versus delayed implant placement supporting full-arch prostheses. Med Oral Patol Oral Cir Bucal. 2014;19(3):295-301.
31. Boynueğri AD, Yalım M, Nemli SK, Ergüder Bİ, Gökalp P. Effect of different localizations of micro gap on clinical parameters and inflammatory cytokines in peri-implant crevicular fluid: a prospective comparative study. Clin Oral Investig. 2012;16(2):353-61.
32. Lachmann S, Kimmerle-Müller E, Axmann D, Gomez-Roman G, Weber H, Haas R. Reliability of findings around healthy implants in association with oral hygiene measures: A clinical, microbiological, and immunological follow-up in edentulous patients. Clin Oral Implants Res. 2007;18(6):686-98.
33. Lindquist LW, Carlsson GE, Jemt TA. prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. Clin Oral Implants Res. 1996;7(4):329-36.
34. Elsaka SE. Influence of surface treatments on bond strength of metal and ceramic brackets to a novel CAD/CAM hybrid ceramic material. J Odontology. 2016;104(1):68-76.
35. Mourya A, Nahar R, Mishra SK, Chowdhary R. Stress distribution around different abutments on titanium and CFR-PEEK implant with different prosthetic crowns under parafunctional loading: A 3D FEA study. J Oral Biol Craniofac Res.2021;11(2):313-20.
36. Sevimay M, Usumez A, Eskitascıoglu G. The influence of various occlusal materials on stresses transferred to implant-supported prostheses and supporting bone: a three-dimensional finite-element study. J Biomed Mater Res B Appl Biomater. 2005;73(1):140-7.