Marginal Adaptation of Implant Prostheses Fabricated by Different Materials in Excessive Crown Height Space Before and After Veneering

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Article Info	A B S T R A C T
Article type: Original Article	**Objectives:** This study aimed to investigate the marginal adaptation of implant-supported three-unit fixed restorations fabricated in excessive crown height by various frameworks namely zirconia, nickel-chromium (Ni-Cr) alloy, and Polyetheretherketone (PEEK) before and after veneering.
	Materials and Methods: A basic model with two implant fixtures was made to receive posterior three-unit fixed partial dentures (second premolar to second molar) in 15 mm crown height. A total of 30 frameworks were fabricated using Ni-Cr, zirconia, and PEEK (n=10). All specimens were veneered and vertical marginal discrepancy was evaluated before and after veneering using a stereomicroscope (×75). The effect of framework material and veneering on marginal discrepancy was evaluated by repeated-measures and one-way ANOVA, and paired t test (α=0.05).
* Corresponding author: Department of Prosthodontics, School of Dentistry, Arak University of Medical Sciences, Arak, Iran Email: nazari.vahideh@yahoo.com	**Results:** There was a significant difference between the groups (P<0.001) before and after veneering. The vertical marginal discrepancy of zirconia frameworks was significantly lower than that of other groups both before and after veneering (P<0.001). Statistical analysis revealed that the veneering process had a significant effect on marginal adaptation (P<0.001). **Conclusion:** In implant prostheses with excessive crown height, zirconia had the greatest marginal adaptaion significantly, followed by Ni-Cr. Veneering caused a significant increase in marginal discrepancy of all the materials. **Keywords:** Dental Marginal Adaptation; Dental Veneers; Polyetheretherketone; Zirconium Oxide

INTRODUCTION

Over the past 30 years, implant-supported prosthesis has become a frequent and reliable rehabilitative option for replacement of the missing teeth with a success rate of over 90% [1,2]. However, mechanical or biological factors might affect the success of this treatment modality [1]. Excessive crown height space (CHS) is a mechanical factor that could influence the clinical outcome both biologically and technically [1,3]. However, there are compromised situations when the clinician is obliged to fabricate the prosthesis in increased CHS. One of the proposed options to reduce the load in such cases is to choose restorative materials with shock-absorbing capacity to decrease the forces and tensions applied to the implant system [4].

Polyetheretherketone (PEEK) is a semi-crystalline thermoplastic polymer with such capacity [5,6] that is noteworthy for application in dentistry due to optimal biocompatibility, natural tooth-colored appearance, excellent mechanical character-istics, chemical constancy, high strength and toughness, and acceptable fatigue resistance [7]. The low elasticity coefficient of PEEK (4Gpa) and the resultant shock-absorbing effect make it a suitable material for implant prostheses in high-load situations such as excessive CHS [4, 8]. However, this material calls for further research to determine whether PEEK properties could compete with the commonly used materials in implant-supported fixed prostheses namely nickel-chromium (Ni-Cr) or zirconia-based restorations, and whether this material may be routinely used in challenging situations like excessive CHS that can negatively affect the prerequisites of a successful treatment. Marginal adaptation has a critical importance in long-term serviceability of implant prostheses, and could be used to evaluate the accuracy and quality of fixed restorations [9]. Ill-fitting implant restora-tions might cause mechanical or biological failures [10]. Many studies have evaluated the marginal adaptation of zirconia and conventional Ni-Cr frameworks [9,11-17], and the effect of veneering process on marginal adaptation of fixed prostheses [18-26]. However, there is no study on marginal adaptation of PEEK-based prostheses fabri-cated in excessive CHS, or the effect of veneering procedure on such compromised situations.

This in vitro study aimed to investigate the marginal adaptation of posterior implant-supported three-unit fixed prostheses made from zirconia, Ni-Cr, and PEEK in excessive CHS before and after veneering. According to the null hypothesis, there would be no difference in marginal adaptation among different materials before or after veneering.

MATERIALS AND METHODS

Manufacturing the model: An aluminum reference model (40x25x20mm) with two parallel separate holes (18mm apart) was prepared using a computerized numerically controlled machine. Two implants (Dentium, Seoul, South Korea), 12mm in height and 4.5mm in diameter, were secured in, using auto-polymerizing acrylic resin (Technovits, HeraeusKulzer GmbH & Co., Wehrheim, Germany). Two straight abutments (Implantium; Dentium, Seoul, South Korea), 5.5mm in height and 4.5- and 5.5-mm in platform diameter, were selected for the second premolar and second molar implants, respectively, and tightened to 35N/cm based on the manufacturer's recommendations.

Substructure fabrication: Three groups of three-unit posterior mandibular restorations, each 15 mm in crown height, were constructed (n=10 for each group). Two experimental frameworks were manufactured by the computer-aided design/computer-aided man-ufacturing (CAD-CAM) system from pre-sintered zirconia (VITA In-ceramYZ; VITA Zanfabrik, Bad Sackigen, Germany), and PEEK (Bio-HPP; Bredent GmbH &Co.KG, Senden, Germany) using a digital scanner (3Shape D810; Copenhagen, Denmark) and a milling system (CORiTEC450i, GmbH, Eiterfeld, Germany). To standardize the design, a silicon index was made from the first zirconia framework to be used as the wax-up mold for Ni-Cr frames. The control group was fabricated by the conventional waxing of the anatomical frame. Preheated liquid inlay wax (GEO, Renfert, Hilzingen, Germany) was added by the dip wax technique and shaped by an electric waxing instrument. The wax patterns were cast using Ni-Cr alloy.

The cement space was considered 30μm up to 1mm from the finish line. For the control group, the abutments were coated with two layers of 12-15-μm die spacer (PICO-FIT, Renfert, Hilzingen, Germany). The supported anatomical design with a 3-mm collar height in lingual and proximal surfaces was used for frames to obtain a uniform veneer thickness (1.5 mm in occlusal, and 0.8 mm in axial surfaces). After fabrication, the internal fit of all frameworks was examined using vinyl polysiloxane disclosing paste (Fit checkerII; GC Corporation, Tokyo, Japan). No adjustment was needed for the frameworks.

Table 1. Mean±standard deviation (µm) of vertical marginal discrepancy of the three groups (n=10)

Group	Before veneering	After veneering	Magnitude of change after veneering	P-value
Zirconia	16.02±3.27	33.39±6.49	17.37±6.12	<0.001
Ni-Cr*	51.40±14.74	86.53±13.44	35.13±7.53	<0.001
PEEK**	95.07±19.70	140.96±23.45	45.89±12.63	<0.001

* Nickel-Chromium, ** Polyetheretherketone

Assessment of marginal fit: The marginal discrepancy was measured at 24 different points marked on the model. The frameworks were seated and fixed on the master model using Fit checker II (GC Corp., Tokyo, Japan) [27]. An image analysis software (DinoCapture 2.2; Dino-Lite, Netherlands) in combination with a stereomicroscope (×75) (DMBH; BOECO, Hamburg, Germany), and a camera (5MP Edge AM7115MZT; Dino-Lite, Almere, Netherlands) were used to analyze the marginal fit. The specimen was located perpendicular to the ocular axis of the microscope, and the pre-veneering marginal fit was recorded.

Veneering process: One of the zirconia substructures was veneered (VITA VM9; Zahnfabrik, Bad Säckingen, Germany) using the conventional layering technique, and a second silicone index was fabricated for use as a guide. Ni-Cr substructures were veneered by feldspathic ceramic (VITA VMK Master, Zahnfabrik, Bad Säckingen, Germany). For PEEK veneering, the frameworks were sandblasted by 110-µm aluminum oxide particles; afterwards, light-cure adhesive (Visio link; Bredent, Senden, Germany) was applied on the surface, polymerized for 90 s (Lumamat 100, Ivoclar Civadent, Schaan, Liechtenstein), and the specimens were veneered by composite resin (visio.lign; Bredent GmbH& Co KG, Senden, Germany). The post-veneering marginal fit was assessed.

Statistical analysis: The mean vertical marginal discrepancy was calculated. Repeated measures ANOVA was used to evaluate the effects of materials (zirconia, Ni-Cr, PEEK), surfaces (lingual, buccal), abutments (molar, premolar), and the time of assessment (before/after veneering) on marginal discrepancy by entering all three or two factors simultaneously (the level of significance was 0.20). Significant interactions were observed. One-way ANOVA was applied to compare the vertical discrepancy among the groups before and after veneering. The marginal discrepancy was compared among different groups at the same measurement time by one-way ANOVA, Levene's test, and Tukey or Games-Howell post-hoc test. Paired t-test was applied to compare marginal adaptation within a group at different time points. The level of significance was set at 0.05.

RESULTS

The mean and standard deviation of marginal discrepancy before and after veneering are presented in Table 1. The zirconia frameworks showed significantly lower discrepancy compared to other groups before and after veneering, with mean values of 16.02±3.27µm and 33.39±6.49µm, respectively. Repeated-measures ANOVA showed a significant interaction between the restorative material and the veneering process on marginal discrepancy (Table 2).

Table 2. Repeated-measures ANOVA for the effect of material and veneering on vertical marginal discrepancy

Variable	df	F	P-value
Veneering	1	123.33	<0.001
Framework	2	234.94	<0.001
Veneering* Framework	2	6.83	0.002

* Interaction between veneering and framework

Pairwise comparisons showed significant differences in the vertical marginal adaptation among the groups before and after veneering (P<0.001 in all comparisons).

Table 3. Mean±standard deviation (μm) of vertical marginal discrepancy for the premolar and molar abutments

Groups (N=10)	Abutment	Before veneering	After veneering	P-value Difference before veneering	P-value Difference after veneering
Zirconia	Premolar	16.1±3.2	31.2±9	0.82	0.34
	Molar	15.8±4.5	35.5±9.1		
Ni-Cr*	Premolar	53.3±19.4	80.7±16.2	0.32	0.16
	Molar	49.4±11.4	92.3±19.8		
PEEK**	Premolar	94.6±24.7	139.5±21.9	0.92	0.74
	Molar	95.4±21	142.3±30.7		

∗ Nickel-Chromium, ∗∗ Polyetheretherketone,

Table 3 demonstrates the means values of the vertical discrepancy of the two abutments before and after veneering. No significant interaction was seen between the effects of veneering and abutment (P=0.15). The mean values of marginal discrepancy in buccal and lingual surfaces are reported in Table 4. There was a significant interaction between the veneering and surface (P=0.001). Paired t-test showed no significant differences in marginal adaptation between surfaces before veneering; but after veneering, there was a significant difference between surfaces in all groups (P<0.001).

DISCUSSION

This study examined the marginal adaptation of three groups of implant-supported posterior three-unit restorations fabricated from zirconia, Ni-Cr, and PEEK in excessive CHS before and after veneering. All samples were made directly on the original model to eliminate the effects of other factors such as the impression technique, dimensional stability of the impression material, and fabrication of the reference cast on the results [11].

The results rejected the null hypothesis, since significant differences were observed in comparison of the marginal adaptation before and after veneering.

The adaptation of frameworks may vary depending on the measurement methods [12,28]. Direct observation by a stereo-microscope does not require any additional processes for sample preparation, is less expensive, faster than other techniques such as cross sectioning or replica techniques, reduces the risk of error accumulation [29,30], and can be done at different stages of sample preparation. Jemt and Hjalmarsson [28] compared the physical and virtual methods and stated that assessments of the adaptation may vary depending on the chosen method for the measurements. Also, the materials, structure designs, manufacturing or mea-suring methods, type of prosthesis (cement-retained or screw-retained), and even the concept of discrepancy itself vary in the literature, and must be considered when comparing the mean marginal discrepancy values reported in different studies [12].

Table 4. Mean±standard deviation (μm) of marginal discrepancy in the buccal and lingual surfaces

Group	Surface	Before veneering	After veneering	Magnitude of change after veneering	P-value Difference before veneering	P-value Difference after veneering
Zirconia	Buccal	23.8±6.6	41.3±12.9	<0.001	0.14	0.014
	Lingual	19.5±6.4	23.7±12.6	0.38		
Ni-Cr*	Buccal	52±21.1	97.9±19	<0.001	0.46	0.014
	Lingual	58.6±16	78.4±25.3	0.014		
PEEK**	Buccal	97.9±19.1	156.0±19.1	<0.001	0.53	0.001
	Lingual	101.7±27.1	121.0±29	0.06		

* Nickel-Chromium, ** Polyetheretherketone

The lack of unification in study designs is a major reason for the disagreements between different studies [12].

In the present study, the marginal adaptation of zirconia frameworks before the veneering was significantly higher than that of Ni-Cr frameworks. The results agreed with those of Zaghloul and Younis [16] and might be related to the higher accuracy of the CAD-CAM procedure in fabrication of frameworks specially in special situations like excessive CHS. Casting of Ni-Cr alloy is more technique-sensitive due to the alloy's high melting point, base metal oxidation, and the errors related to the fabrication stages (wax-up, investing, casting, divesting, and finishing) [31-33]. All these technical sensitivities could be intensified in case of excessive volume or height of a restoration.

This study demonstrated that the marginal discrepancy of PEEK frames was significantly higher than that of Ni-Cr and zirconia frameworks. Since the fabrication method was similar in PEEK and zirconia frameworks, this difference may be related to the lower elastic modulus of PEEK (4Gpa) compared with zirconia (210Gpa), which makes PEEK frameworks susceptible to distortion by the pressure of milling burs. Furthermore, the heat generated during milling may also cause distortion and reduce the marginal adaptation of PEEK frameworks. Zeighami et al. [34] reported the marginal discrepancy of PEEK frameworks to be 92.40±40.00µm, which was close to the results of the present study (95.07µm). These values are greater than those reported by Bae et al, [35] (62.04µm for the canine and 51.64µm for the molar), and significantly higher than the values reported by Jin et al, [36] (19±4µm) in their study on screw-retained prosthesis with normal height. These findings signify the fundamental effect of prosthesis type, and restoration height (CHS) on the final results. The significant reduction of the adaptation of Ni-Cr frameworks after ceramic veneering agreed with the findings of previous studies [18,19,21, 22,25]. Porcelain veneering also significantly decreased the marginal adaptation of zirconia. This was compatible with the results of Pak et al, [24] Dittmer et al, [20] Kohorst et al, [13] and Regish et al [25]. In the PEEK group, the same scenario was repeated that could be related to

the polymerization shrinkage of composite which affects the substructure. The mean vertical marginal discrepancy after veneering observed in zirconia, Ni-Cr and PEEK groups was 33, 86, and 140µm, respectively. In 1971, McLean and von Fraunhofer [37] clinically proposed 120 µm as the maximum acceptable marginal discrepancy for dental restorations. In the present study, vertical discrepancy of all the groups was below 120µm except the PEEK group. Implant and bone appear to endure a certain amount of marginal discrepancy without adverse biomechanical or biological problems; however, the quantity of this discrepancy has not yet been determined accurately. In 1991, Jemt [38] empirically suggested that misfit of cement-retained implant-supported restorations should be smaller than 150µm. According to their suggestion, the discrepancy in the PEEK group also had an acceptable borderline value (140µm), and may be an alternative for implant-supported restorations in situations with increased stress like excessive CHS. However, considering its potential applications, the improvement in PEEK characteristics should be encouraged.

In the Ni-Cr group, the change in vertical discrepancy after veneering was significant in both surfaces. However, the marginal adaptation after veneering in the buccal surface was significantly lower than that in the lingual surface. This result was consistent with the findings of Lalande et al [39]. More metal volume in lingual surface may play a role in reducing the distortion rate of the framework during porcelain firing cycles. Greater vertical discrepancy in the buccal surface may also be explained by increased possibility of porcelain contamination on intaglio surfaces of the frameworks. The PEEK group (as zirconia, and Ni-Cr groups) showed no significant differences between the buccal and lingual marginal discrepancies before the veneering. However, in PEEK and zirconia groups, the marginal adaptation decreased significantly in the buccal surface after veneering (unlike the lingual surface). Kohorst et al. [23] applied porcelain veneer 0.5mm away from the margin of zirconia four-unit prostheses to eliminate the effect of porcelain contamination, and observed no significant change in marginal adaptation after

veneering. It appears that the effect of porcelain contamination on marginal adaptation might be more pronounced than the porcelain firing cycles. This finding is consistent with the results of Vigolo and Fonzi [26] who showed that the porcelain firing cycles had no significant effect on marginal discrepancy of zirconia four-unit frameworks. When it comes to increased volume of prosthesis in excessive CHS or long-span restorations, the importance of attention to technical details increases.

In this study, there was no significant difference between the abutments before and after veneering in all the groups. This finding agreed with the results of Gonzalo et al [40].

The results of the present study confirmed that in challenging situations of excessive CHS, the application of routine prosthetic materials will provide acceptable accuracy. However, more improvement in PEEK composite characteristics is suggested to take the maximum advantage of a more flexible material in such high-stress situations. clinical trials are recommended to evaluate whether the mechanical properties of shock-absorbing PEEK allow for the application of this material in excessive CHS for implant restorations particularly in the long-term, or further improvements are necessary. Further studies on other important clinical properties of PEEK are also encouraged namely fatigue resistance, color stability, lateral stress resistance, and long-term biological effects in excessive CHS.

CONCLUSION

Given the limitations of this in vitro study, the results indicated that in excessive CHS, zirconia fixed partial prostheses showed the highest marginal adaptation before and after veneering; PEEK restorations showed the lowest. The veneering process significantly decreased the marginal adaptation of zirconia, Ni-Cr, and PEEK frameworks in restorations with excessive CHS. The vertical marginal discrepancies were within the acceptable clinical level (below 150μm) in all tested groups.

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CONFLICT OF INTEREST STATEMENT

None declared.

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