The evaluation of the marginal and internal adaptation in metal-ceramic and all-ceramic restorations made by traditional and cad/cam methods

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Sayın yazar, makalenizin son kontrolünü yapınız. Eserinizin yayınlanabilmesi için PDF dosyasının son halini onayladığınıza dair eposta, ING KISA BAŞLIK, CHART 1,2,3 ALT YAZI secretary@jcam.com.tr adresine gönderiniz.

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Abstract
Aim: Lack of good marginal adaptation in dental restorations over time tends to dissolve the cement in the oral cavity, which leads to the accumulation of plaque, tooth decay, pulp contention, gingivitis, periodontal diseases and ultimately treatment failure. The aim of this study is to evaluate and compare the internal and marginal adaptation in metal-ceramic and all-ceramic restorations made by traditional and CAD/CAM methods. Material and Method: 1. Preparation of working cast and die 2. Preparation of restorations: In this study, the samples were divided into six groups of 10, which are as follow; Group A: metal-ceramic restorations without collar made by manual method (traditional and conventional). Group B: metal-ceramic restorations without a metal collar, in which the wax coping was made of special blanks by CAD/CAM method, and the rest of process is manual. Group C: metal-ceramic restorations without a metal collar, in which their frame was made by using dry milling method and Sintron technology and the rest of process was done manually. Group D: E.max-Press all-ceramic restorations (lithium disilicate). Group E: All-ceramic restoration with Core Zirconia prepared by CAD/CAM method and porcelain layering. Group F: Trans-Lucent zirconia (solid) all-ceramic restorations as full-contour by CAM/COD method. 3. Measuring the amount of the gap: Replica technique was used for this purpose. Results: The lowest mean gap in marginal and internal restorations was in group B, and the highest amount was in Group C and D, respectively, and altogether there was a significant difference between 6 study groups (P<0.001). The mean marginal gap in all groups (except group B) was more than 120 microns, which is not clinically acceptable. The best marginal and internal adaptation was observed in Group A and B. Discussion: Based on the findings of this study, traditional spruing technique, investment, wax removing and alloy injection still provide the best marginal adaptation, and in general comparison, metal-ceramic restorations are preferred over all-ceramic restorations.

Keywords
Marginal; Internal; Restoration; Metal-Ceramic; All-Ceramic

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Introduction

The milling of abutment teeth is one of the main steps of crown fabrication. Milled parts should be covered completely and accurately to prevent onset or recurrence of tooth decay. This is only possible by good adaptation of crown edges with finishing line of teeth milling. Lack of good marginal adaptation in crowns over the time tends to dissolve the cement in oral cavity and provide a way for penetration of microorganisms and toxins caused by their activities, it also leads to plaque accumulation, recurrent caries, pulp contention, and onset of inflammation in periodontal tissue around the finishing line of teeth milling and ultimately restoration failure [9, 10, 11]

Restorations are divided into two categories: 1- metal-ceramic and 2- all-ceramic. Metal-ceramics melt at relatively low temperature (800 C). Today, with the changes that have been done on a metal frame, there has been an attempt to restore the beauty and natural property of metal-ceramics by using investment techniques and very thin coping (2.0 to 3.0 mm) [7]. In a classification system by America Dental Association (ADA) metals used in metal-ceramics are divided into three categories: 1- High noble metals, having more than 60% noble metal (like gold–palladium). 2- Noble alloys (35% to 45%) with a small amount of gallium. 3- Alloys that have less than 25% noble metal. Selecting a suitable alloy depends on the factors such as price and stiffness, pouring capability, easy finishing and polishing, resistance to corrosion and compatibility with porcelain. Suitable compounds include gold (44% to 55%) and palladium (35 to 45%) with a small amount of gallium [7]. Metal-ceramic restorations still are the gold standard in fixed denture [16, 17].

All-ceramic restorations (without metal) are increasingly being prescribed to patients, which is due to the high aesthetic functionality and great histocompatibility features. To improve the usability as a dental material and to improve the strength and stiffness, from 1980 up to now, various ceramic materials and manufacturing techniques were introduced, which lithium disilicate, alumina, and zirconia can be named [9, 10, 11]. The method used to build an all-ceramic crown is simple, but to create a beautiful, harmonious, and functional structure, great skill is required. Of all the all-ceramic systems, Inceram is the best way that has all of these factors. This material has the best mechanical properties (almost three times more flexural strength compared to other systems, except Porcera system), Spinell core, which is composed of $MgAl2O3$, has natural teeth translucency. Inceram margins fit well (marginal gap depth of 10-40 mm), core transparency is able to cover the undesirable reflection in the oral cavity. The problem of using this system is that they require special equipment [6].

Possible errors during the construction of the restorations by CAD/CAM, including the process of scanning, designing by software, milling by machine and contraction during sintering affects the amount of marginal integrity [12-15]. The new technology of using designing technology and computer-aided manufacturing (CAD/CAM) for making crowns, laminates and 3-unit anterior fixed partial dentures require precise teeth preparation and molding, to be used as a prosthetic repair with margins. This technology often allows us to complete various cases, even single tooth restoration, in collaboration with numerous specialist, without the need for direct contact with the patient and through electronic communication and memory structures. 4.0 and 6.0 mm coping with a different crowning ability and two different materials (zirconia and alumina) and multiple liners can be outlined as features of all-ceramic CAD/CAM crown [8].

The marginal adaptation is one of the essential factors to achieve long-term success for each restoration. As there is not always a precise definition for marginal adaptation, it can be said that the best way to check it is by measuring non-adaptation of different areas of prepared teeth to the edge of the crown [1-5]. Lack of marginal adaptation can be due to inaccuracies in the fabrication of crown, lack of full sitting during cementation of it or a combination of both. The aim of this study is to evaluate and compare the marginal and internal adaptation in metal-ceramic and manual all–ceramic (conventional) and CAD/CAM restorations.

Material and Method

In this experimental study to prepare the cast and die, first two maxillary dental arches were selected and first molar tooth above it was prepared for similarity with clinical conditions with a shoulder milling with a depth of approximately 1 mm for full crowning and the tooth was examined with a surveyor to ensure that there is no undercut. Then template was prepared from the maxillary, and mandibular arches by two perforated metal trays and additive silicone impression material (BONASIL, DMP, Greece) and working cast was obtained by stone gypsum (dentona, dentona AG, Germany) and under vacuum, in which the die was prepared after trimming and sawing (cutting) steps. The above steps were repeated for the preparation of each restoration. 6 groups of 10, a total of 60 restorations (crowns) were created. The restorations of groups A, B and C were metal-ceramics and the restorations of D, E and F were all-ceramics. It should be noted that Group A is the control group in the study. In order to provide restoration of Group A, after preparing the die, the two layers of Die spacer (mega-Stumpflack, megadental GmbH, Germany) were placed on it, the thickness of each layer is 15 microns and is extended up to 1 mm of margin. Cement space for all the samples whether manual or CAD/CAM was considered as 30 microns. Then the wax-up coping was done, and the labial margin wax was removed. After completing the waxing-up, spruing and investing, the cylinder was filled with investment gypsum (CODENT/PODENT, Dandiran, Iran) and cylinders were placed inside the removing wax furnace (SUNNYTHERM-1, KFP, Iran). Then the inductive centrifuge machine (DUCATRON, KFP, Iran) was used for melting and casting of molten chrome-cobalt alloy (NEW CAST, YAMAHACHI DENTAL MFG, Japan) into the productive space and then it was allowed to become cool. Clean investment gypsum and sandblasting were used for the final cleanup. Feldspathic porcelain layering (Super porcelain EX-3, NORITAKE CO, Japan) was done according to its routine. Placing of opaque layer, shoulder porcelain (initial, GC, E.U) with Direct Lift technique (direct removal of restorations from top of die and direct placement of shoulder porcelain), dentin and enamel and finally firing the porcelain in the special furnace (Programat P500, IVOCLAR VIVADENT, Liechtenstein) were completed and then contacts and occlusions were set according to the opposite arc and adjacent teeth. Wax copings from special wax blanks for milling with COD/CAM (Ceramill wax, Amann) were used to prepare the restorations of the Group B. Casts were scanned with Scanner (Ceramill map400, Amann Girrbach, Austria) and processes of CAD/CAM designing were done in computer software. After preparation of wax copings of CAD/CAM milling, (imes-icore GmbH, Germany imes-icore 550 i) the rest of process was similar to group A. Sintron technology was used to prepare the restorations of group C. First the casts were scanned by a scanner. Coping was milled by CAD/CAM machine from soft blanks and gypsum such as chrome-cobalt alloy (Ceramill Sintron, Amann Girrbach, Austria) and then were placed inside of sinter furnace to sinter and they were put under argon gas pressure (Ceramill Argotherm, Amann Girrbach, Austria) and they have strength comparable to manual and conventional types. It should be noted that the CAD/CAM milling used in study groups were from soft milling zirconia types (dry milling). To prepare the restorations of group D which are E.max-Press (lithium disilicate or glass-ceramic), a full wax-up was done on samples of this group, and then they were placed in wax removal furnace to achieve the productive space. Then Ingots for E.max (IPS e.max, IVOCLAR VIVADENT, Liechtenstein) in the furnace for Press (Programat EP 3000, IVOCLAR VIVADENT, Liechtenstein) were casted into the productive space by a special plunger, after cleaning the plaster investments, an all-ceramic full-contour restoration was obtained. The restorations of group E are Zircon. To prepare the samples of this group, first scanning of casts and processes of CAD/CAM designing were carried out. Then a core zirconia was milled by CAD/CAM from blanks for zirconia (Ceramill Zi, Amann Girrbach, Austria). Binder was put on it, and then special porcelain layering was carried out, and porcelain shoulder specific for zirconia was placed in the area of buccal margin and zirconia was put inside of sintering furnace. To prepare the restoration samples of group F, first scanning of casts and processes of CAD/CAM designing were carried out. Name of the restorations of this group is Zolid, which is a translucent zirconia and it was obtained as full-contour from Zolid soft blanks (Ceramill Zolid, Amann Girrbach, Austria) by CAD/CAM milling and then was put in the furnace for sintering the zirconia.

The replica technique was used for measuring the internal and marginal gap. This means that the restoration was filled with additive silicon with light body consolidation (BONASIL, DMP, Greece) and was put on the respective die. Immediately and with caution additions of impression material was cleaned and the restoration was held for 2 minutes with finger pressure (for similarity with clinical conditions). After setting of the impression materials, restoration was removed from the respective die. Thin layer of light body silicon is attached to the inner surface of the restoration, which is indicative of the gap in different parts of restoration and in order to strength it and make it examinable, we fill the inside of restoration with Injectable additive silicone with medium or heavy consolidation (BONASIL, DMP, Greece) and let it be set. Then we remove the silicone from inside of restoration and saw whether the light body silicone layer is attached to amplifier silicone, now according to figure this silicone block is milled with a milling razor. Eight cuts are used to examine the points, and the middle area does not use. The marginal gap is measured at 8 points and internal gap measured at 4 points (cervical, middle of the axial level, axial occlusal line angle, and center of the occlusal surface). Light body silicone layer thickness, which is equal to the amount of the existing gap, is photographed by stereomicroscope (Dino-Lite, Taiwan) with a magnification of 60 times and then it was calculated and declared using Dino Capture 2.0 software. Tables and appropriate statistical charts were used for describing the data, and one-factor variance analysis test or its non-parametric equivalent was used for data analysis. The sample size for two independent groups was determined based on the study by Kim Ki-Baek et al. (2014) with 85% power and ten samples in each group [22].

Results

In this study, three variables of internal, marginal, and buccal marginal adaptations were examined between six groups as well as between metal-ceramic and all-ceramic restorations. The normality of the data was evaluated using the Shapiro-Wilk test, and it was determined that the data for some variables and some groups are not normally distributed. The results showed that for the internal adaptation, the range of data changes of group 4 is much greater than the other groups. The lowest value observed belongs to group 6 and the highest values belong to group 4. The lowest mean belongs to group 2, and the highest mean belongs to group 4, the lowest mean value belongs to group 1, and the highest mean value belongs to group 3. In total, the distributions among six groups are significantly different from each other (P<0.001), which in a pairwise comparison of groups with each other, it was determined that groups 1, 2 and 3 were significantly lower than groups 3 and 4. Group 6 was significantly lower than group 4; group 3 was also significantly lower than group 4. There was no significant difference between the other groups (Table 1).

In total, the distributions among six groups are significantly different from each other (P <0.001), which in a pairwise comparison of groups, it was determined that group 2 is significantly lower than other groups. Group 1 was significantly lower than group 3, 5 and 6. There was no significant difference between the other groups (Table 2).

The box chart below shows the distribution of data for internal and marginal adaptation with separation of study groups. As it can be seen, there is an extensive distribution in groups of 1, 3 and 4, and there are large outlier values in the data for marginal adaptation of groups 3 and 5 (chart 1).

Table 1.

Group	Numbers	Mean	Standard deviation	Lowest	Highest	Median	Kruskal-Wallis test result
1	320	113.77	52.44	30.61	329.63	98.21	
2	320	112.40	53.44	43.44	336.71	99.23	X2=153.04
3	320	149.85	99.66	43.44	792.80	159.18	
4	320	172.25	115.76	54.30	1650.76	139.26	
5	320	117.80	46.84	46.07	314.92	127.29	P<0.001
6	320	120.72	53.39	26.02	292.40	131.21	

Table 2. The mean, standard deviation, minimum, maximum, and median of data for marginal adaptation of the study groups and the statistical test result

Group	Numbers	Mean	Standard deviation	Lowest	Highest	Median	Kruskal-Wallis test result
1	80	135.42	69.34	49.79	372.33	106.91	
2	80	92.49	54.80	39.15	369.38	72.85	X2=122.36
3	80	195.17	123.33	54.30	680.33	152.41	
4	80	155.92	73.70	69.53	607.05	136.71	
5	80	181.05	85.55	65.16	602.08	179.86	P<0.001
6	80	168.72	54.11	87.56	347.67	165.04	

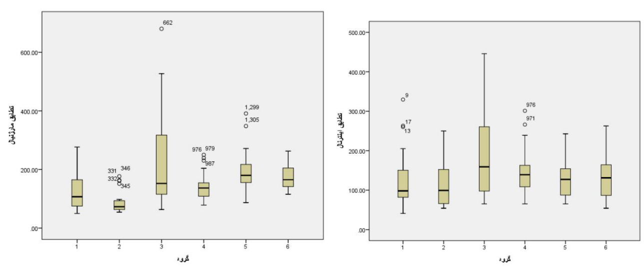

Chart 1.

The range of data changes in buccal marginal adaptation data for groups 5 is higher than other groups. The lowest value belongs to group 2, and the highest belongs to group 5. The lowest mean belongs to group 2, and the highest belongs to group 5, the lowest median value belongs to group 2, and the highest belongs to group 3. In total, the distribution among six groups are significantly different from each other (P <0.001), which in a pairwise comparison of groups, it was determined that group 2 is significantly lower than other groups. There was no significant difference between the other groups (Table 3).
The box chart below shows the distribution of data for buccal marginal adaptation with separation of study groups. As it can be seen, there are large outlier values (chart 2).
The results of the marginal adaptation data indicated that range of data changes in the all-ceramic group is lower than the metal-ceramic group. The lowest and the highest value observed belongs to the metal-ceramic group. The lower mean and median belongs to the metal-ceramic group, and the higher mean belongs to the all-ceramic group. The difference between the two groups was statistically significant (P <0.001) (Table 4).
As shown in Table 5, the range of data changes in the all-ceramic group is higher than the metal-ceramic group. The

Table 3. The mean, standard deviation, minimum, maximum, and median in the study groups and the statistical test results

Group	Numbers	Mean	Standard deviation	Lowest	Highest	Median	Kruskal-Wallis test result
1	30	155.21	81.45	61.21	372.33	121.48	
2	30	96.22	58.97	39.15	342.18	82.31	
3	30	174.43	87.98	54.30	414.65	169.11	X2=33.37
4	30	144.42	51.42	69.53	262.65	148.48	
5	30	183.21	118.36	65.16	602.08	152.99	
6	30	158.62	34.37	87.56	222.81	159.03	P<0.001

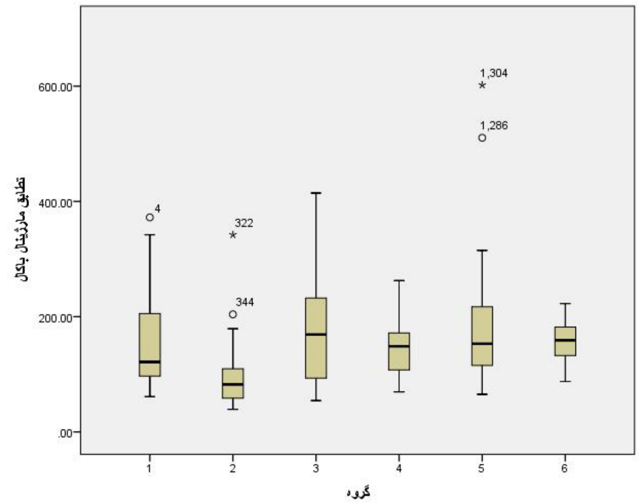

Chart 2.

lowest and highest value observed belongs to the all-ceramic group. The lower mean and median belongs to the metal-ceramic group, and higher mean belongs to the all-ceramic group. The difference between the two groups is statistically significant (P <0.001).
The box chart below shows the distribution of data for internal and marginal adaptation with separation of all-ceramic and metal-ceramic groups (Chart 3)

Discussion

Marginal adaptation is one of the key criteria in successful clinical restorations [4-1]. After clinical examination of over

Table 4. The mean, standard deviation, highest, lowest, and median of marginal adaptation data in metal-ceramic and all-ceramic groups and statistical test result.

Group	Numbers	Mean	Standard deviation	Lowest	Highest	Median	Mann-Whitney test result
Metal-ceramic	240	141.03	96.90	39.15	680.33	105.92	Z=6.93
All-ceramic	240	168.57	70.66	65.16	607.05	155.49	P<0.001

Table 5. The mean, standard deviation, highest, lowest, and median of internal adaptation data in metal-ceramic and all-ceramic groups and statistical test result.

Group	Numbers	Mean	Standard deviation	Lowest	Highest	Median	Mann-Whitney test result
	960	125.34	73.96	30.61	792.80	106.93	Z=5.28
	960	136.92	82.23	26.02	1650.76	121.41	P<0.001

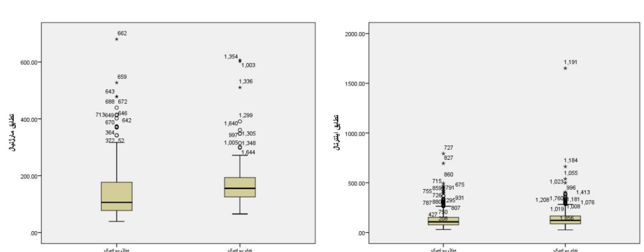

Chart 3.

a thousand metal-ceramic crowns, Mclean & Von Fraunhofer reported that marginal gap of up to a maximum of 120 mµ is acceptable. Other clinicians stated the maximum value as 100 mµ [8]. All-ceramic restorations (without metal) are increasingly being prescribed to patients, which is due to their high aesthetic capability and their excellent histocompatibility properties [9, 10, 11]. Possible errors during the construction of the restorations with CAD/CAM, including process scanning, designing by software, milling by machine and contraction during sintering, affect the amount of marginal adaptation [12 – 15].

The aim of this study was to evaluate and compare the marginal adaptation in metal-ceramic and all-ceramic CAD/CAM restorations. Therefore, in this study, a total of 60 dies created from milled molar teeth were prepared on the arch and dies were divided into 6 groups of 10, in which metal-ceramic restorations for 3 groups and all-ceramic restorations were made in the following order: in group A, all-ceramic restorations were made in the traditional way and this group considered as control group. In group B, wax copings were made from millable wax blocks by CAD/CAM machine, and after making of metal coping, porcelain was done by a conventional method. In group C, Sintron technology was used, in which metal copings are prepared from chrome-cobalt alloys milled by CAM/CAD machine. In group D, E.max press restorations nonparametric. Zircon restorations were made for group E, and Zolid restorations were made for group F and for all of the samples of study, the internal, marginal, and buccal marginal adaptations were measured using gap measuring by Replica technique. The results showed that the best internal, marginal, and buccal marginal were observed in groups 1 and 2. This finding suggests that using traditional techniques of spruing, investment, wax elimination and alloy casting provide the best marginal adaptation. Vojdani et al. (2013) examined the internal and marginal adaptations in metal-ceramic restorations which are made by a traditional method by using CAD/CAM. They prepared 12 copings by CAD/CAM method and 12 copings by traditional method and measured the internal and marginal adaptations in 15 points. In this study, they concluded that the internal and marginal adaptation in metal-ceramic made by traditional method is significantly better than the internal and marginal adaptation in metal-ceramic made by CAD/CAM [23].

The mean internal, marginal, and buccal marginal adaptations for teeth in group C were 148.9, 195.17 and 174.4, respectively, which in overall these amounts are indicative of lesser adaptation of restorations made by Sintron technology compare to other restorations. Also, the lowest internal adaptation was related to group D with the mean of 172.2, which shows that glass-ceramic restorations that are made by lithium disilicate casting into mold space have lesser internal adaptation compare to all-ceramic restorations made by CAD/CAM method. But marginal adaptations in E.max restorations were lesser than restorations made by CAD/CAM. From these findings, we cannot make a judgment about the advantage of all-ceramic restorations made by CAD/CAM method over E.max restorations. Among the metal-ceramic restorations, restorations made by Sintron technology had the worst adaptation. But in comparison with restorations of A and B, internal adaptation in these two groups were the same, but a marginal gap in group B, in which wax blocks were made by CAD/CAM technology, was significantly lesser than restorations made by traditional method. These findings could be indicative of a priority of metal copings that their wax pattern is made by CAD/CAM method. Since there is a general agreement among researchers about a clinically acceptable gap of fewer than 120 µm [8, 29], based on the findings of our study, only the adaptations in group B are acceptable. Several studies have examined the different methods of preparing all-ceramic restorations made by CAD/CAM method regarding marginal adaptation. According to the findings of the study by Paolo Vigolo, Seven Reich, and Beuer, different methods of preparing all-ceramic restorations by CAD/CAM have no significant difference regarding marginal adaptation, and in all of these study, a marginal gap was clinically acceptable at the end [24, 25, 26]. In the study by kohorstp et al. (2009), in which they examined the marginal precision of 4-unit zirconia restorations made by different CAM/CAD methods (Digident, Inlab, Everest, Cercon) before and after sintering, it was determined that the marginal adaptation of zirconia is highly dependent on used CAM/CAD system and restorations prior to sintering have better marginal adaptation [27]. Kianoosh Torabi et al. (2011) examined the zirconia copings made by CAD/CAM and Slip–Cast regarding marginal adaptation and suggested that CAD/CAM is competitive with conventional methods and clinically and in vitro has acceptable, marginal adaptation [28]. In a comparison of marginal adaptation of 3-unit restorations with two methods of Laser sintering and Lost Wax which was conducted by Ki-Baek Kim (2013), it was determined that the marginal adaptation of conventional method (Lost Wax) is significantly better and marginal adaptation of Laser sintering method is not clinically acceptable [29]. On the study by Zhuoli Huang et al. (2014), it was determined that Laser–sinter metal-ceramic restorations have better marginal adaptation compare to CAM/CAD method [both zirconia and disilicate system) [20].

Conclusions

In this study, results showed that there is no difference between two methods of preparing all-ceramic restorations by CAD/CAM machine. But in all three groups of all-ceramic restorations, the mean of the internal and marginal gap was more than 120 µm, which according to many researchers is not clinically acceptable. Perhaps we could associate the difference between this finding of our study and some studies [14, 30, 31, 32] with a difference in preparing restorations, as in these studies measuring the gap on restorations were performed before sintering, while in our study, all-ceramic restorations after preparation undergone sintering again. According to the findings of a study by Vigolo, restorations prepared by CAD/CAM technique, before sintering have better adaptation compare to restorations post-sintering. A general comparison of metal-ceramic and all-ceramic restorations was also indicative of the priority of internal and marginal adaptation of metal-ceramic restorations over all-ceramic restorations. The findings of this study, regarding better internal and marginal adaptation of metal-ceramic restorations compare to all-ceramic restorations, were similar to other studies [26, 27, 33, 34].

Comparing the results of different studies conducted on marginal adaptation of restorations is difficult, because these studies have significant differences, for example, some studies have been conducted in vitro, some on clinical samples, some on single-unit restorations and some other on multi-unit restorations. There are considerable differences in the details of laboratory procedures and materials used in these studies, also, different methods of measuring the marginal gap of restoration, itself can be a source of difference between results of different studies.

Competing interests:

The authors declare that they have no competing interests.

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