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Research Article

EVALUATING THE MARGINAL FIT OF GALVANOCERAMIC INLAYS: IS IT CLINICALLY ACCEPTABLE?

Özlem ÇÖLGEÇEN [1,*], Zekiye EROĞLU [2], Ayşegül GÜLERYÜZ [3]

[1] 1 Department of Prosthodontics, Faculty of Dentistry, Izmir Kâtip Celebi University, Izmir, TURKIYE
[2] Department of Prosthodontics, Faculty of Dentistry, Nevşehir Hacı Bektaş Veli Univercity, Nevşehir, TURKIYE
[3] Department of Prosthodontics, Faculty of Dentistry, Erciyes University, Kayseri, TURKIYE
*Correspondence: ozlemalan@yahoo.com

ABSTRACT

Aim: The aim of this study was to investigate the marginal adaptation of galvanoceramic inlay comparing two different ceramic inlays used in dental practice.

Materials and methods: Class II inlay cavity was prepared on an ivorine mandibular left first molar and a metal master die was produced from stainless steel. Using electroforming machine, fifteen galvanoformed copings were produced firstly, and then galvanoceramic inlays were obtained by firing feldspathic porcelain on them. For comparison with ceramic inlays, two different groups were prepared from lithium disilicate and alumina ceramic. The absolute marginal discrepancy of galvanoformed copings and three different inlay restorations were measured onto the master die in described 16 different reference points by scanning electron microscope. Data obtained from the measurements were statistically analysed using paired t-test and two-way analyses of variance (α=.05).

Results: The galvanoceramic inlays showed a significantly higher marginal discrepancy than other ceramic inlays (P<.001). The mean marginal discrepancy was 379±153µm for galvanoceramic inlays, whereas other inlays had marginal gaps under 200µm. Galvanoformed copings had lowest marginal gap, but the adaptation of these copings was failed after porcelain firing.

Conclusion: Galvanoformed copings have superior marginal fit than other ceramic inlays, but the marginal gaps increased after porcelain firing and marginal adaptations became clinically unacceptable. Clinical usage of galvanoceramic inlays is questionable due to their marginal discrepancies.

Keywords: Inlay; Marginal Discrepancy; Galvanoceramic; Electroforming

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INTRODUCTION

Ideally, dental restorations should provide an excellent marginal fit to ensure their long-term success. Poor marginal fit increases the potential for microleakage and plaque retention, which in turn elevates the risk of recurrent caries and periodontal disease (1,2). The marginal fits of inlay/onlay and partial crown restorations are more critical than that of full crown restorations because they have longer margins than the crowns. Therefore, factors affecting the marginal fit of these restorations should be evaluated to achieve desirable clinical outcomes. Many studies have indicated that restoration material and fabrication techniques affect marginal integrity, leading to dimensional changes in the final restoration (3,4). Even the marginal integrity of the restoration may become clinically unacceptable due to these dimensional changes.

Minimal invasive approach in dentistry has resulted in the development of numerous ceramic inlay systems. To produce ceramic inlays, there are both conventional methods such as using pressable ceramics and modern methods such as computer aided design and manufacturing system (CAD/CAM)(3,4). Additionally, there is also galvanoceramic restoration manufacturing technology which incorporates the positive properties of both gold and ceramics (5,6). CAD/CAM systems have become widespread today, but they cannot offer the positive effects that gold can provide at the restoration margin. Gold, a noble metal, is known for high chemical resistance and reduces microorganism adhesion to surface due to its oligodynamic effect and reduces microleakage in margins due to its burnishable structure. The incidence of microleakage and marginal caries is lower in gold restorations compared to others because of these favourable properties. However, gold inlays are losing their widespread usage in today dentistry due to the increase in gold prices and its yellow appearance. However, this does not change the fact that it is biologically more advantageous.

Galvano ceramic restoration manufacturing technology uses electroforming system that combines porcelain and gold, so making both aesthetic and hygienic restorations possible. Since the amount of gold used is not too much, it does not increase the cost excessively. According to literature, galvanized gold has a range of advantages such as biocompatibility, endurance, aesthetic appearance of warm yellow hue of pure gold, bacteriostatic features, better periodontal health, energy saving of electroplating (less than 1% of the energy required for conventional casting) (5–7).

Crown restorations produced by galvanoforming technology have excellent marginal or internal adaptation and high biocompatibility. Additionally, the electroforming system has been made practical for use in small dental laboratories. In the literature, although a large number of galvanoceramic crown studies exist (8–10), there are limited data about galvanoceramic inlays (7,11). In the literature, it is reported that galvano-inlays are clinically advisable, but no detailed study has been found investigating their marginal fit.

The purpose of this in vitro study was to investigate the marginal fit of galvanoceramic inlays and to compare two different all-ceramic inlays. The null hypothesis was that no differences in the marginal adaptation among all three inlays and also, between the galvanoformed coping and galvanoceramic inlay.

MATERIALS AND METHODS

Inlay Preparation Design

A standard class II (mesio-occlusal) inlay cavity was prepared on an ivorine mandibulary left molar teeth using a diamond coated bur (Columbia Dentaform Corp., Long Island City, NY). Occlusal depth was prepared to 3 mm from the oclusal margin, the occlusal width was 5 mm, and proximal depth was 4 mm in central fossa and 3 mm in other areas. The proximal box was extended 1.5 mm above from the cervical line and the taper between the cavity walls was 6 degrees. All internal cavity angles were rounded. A butt-joint margin preparation was made at the all margins and no bevels were utilized in the preparation to obtain accurate measurements. To control of the cavity preparation was used a paralleling device which reduced operator error (Paraskop, Bego Bremer Goldschlagerei Wihl., Hebst GmbH&Co., Germany). In this way, the cavity was cut accurately with the 6° taper determined by the taper of the bur. An impression of the cavity was made using a polyether impression material (Impregum 3M Espe, Germany). The master die model for SEM analysis was prepared by pouring carbonizes acrylic resin (Pattern Resin LS, GC Dental Products Corp., Japan) into this impression. The master model was fabricated with a base metal alloy (Nicor, Schütz Dental, Germany), and the surface was smoothed using diamond impregnated green stone wheels to remove metal casting burrs. The polishing process of the master model was performed using a medium-grit green hard rubber polisher (Dentauram, Germany), a fine-grit gray soft rubber polisher, a felt buff with pumice slurry, and a felt buff with green polishing compound (Degussa, USA), respectively.

Table 1. Inlay materials used in this study

Inlay type	**Material**	**Manufacturer**	**Chemical composition**
All-ceramic inlay	Alumina based all-ceramic	Turcom-Ceramics, Kuala Lumpur, Malaysia	99.15% Al_2O_3 (52.93%Al , 47.07% O)
All-ceramic inlay	Lithium disilicate-reinforced all-ceramic	Ivoclar Vivadent, Schaan, Liechtenstein Gramm Technique, Heimerdingen, Germany	SiO_2 57-80%, Li_2O11-19%, Al_2O_3 0-5%, $La_2O_3$0.1-6%, ZnO 0-8%, K_2O 0-13%, MgO 0-5%, P_2O_5 0.5-11%, Additives 0-6%, Colorants 0-8%
Galvanoceramic inlay	24-K Gold Feldspathic porcelain	VITA Zahnfabrik, Bad sackingen, Germany	99.99% of pure gold SiO_2 60-64%, Al_2O_3 13-15%, K_2O 7-10%, Na_2O 4-6%, TiO_2 <0.5%, CeO_2 <0.5%, ZrO_2 0-1%, CaO 1-2%, B_2O_3 3-5%, BaO 1-3%, SnO_2 0.1%, Oxides of Mg, Fe <0.5%

Stereomicroscopic evaluation (Zeiss S100, Carl Zeiss Surgical GmbH, Oberkochen, Germany) with 25× magnification was conducted to check the marginal integrity of the master die. Impressions for fabricating of each inlay restoration were taken using a polyether impression material (Impregum 3M Espe, Germany) and cast in Type IV stone.

Inlay Fabrication

A total of 45 inlay restorations were produced by the same laboratory from three different materials and technique. The materials used to fabricate inlays, along with their manufacturers and chemical compositions, are presented in Table 1. Fifteen galvanoceramic inlays were fabricated in two stages; producing of gold galvanoformed coping and adding feldspathic porcelain on it. Galvanoformed copings of 0.25 mm were fabricated by a galvanoforming machine (GES Gold–Electroforming System, Gramm Technique GmbH, Heimerdingen, Germany) produced for dental usage. Fifteen duplicated stone (Type IV Suppen-Sockler G, Picodent Productions und Vertriebs GmbH, Germany) dies were prepared, and covered a thin silver layer and then connected to a copper wire. Thanks to this way, transition of the galvanic current through dies was provided to enable the gold electrodeposition. The dies were immersed into the gold electrolyte solution (Ecolyt SG 100, Gramm Technik, GmbH, Germany) in the beaker. The beaker was placed in the galvanoforming machine (GES Gold –Electroforming–System, Gramm Technique GmbH, Germany) and electrodeposition process was started. After the completion of the electro deposition, the gypsum dies were removed into the gold electrolyte solution and electroformed inlay copings were removed from the dies using gypsum remover (Gips Löser, Gramm Technik GmbH,Germany) in a ultrasonic cleaner. The removed inlay copings were re-cleaned by nitric acid with %5 solution in ultrasonic cleaner. So that, the silver nitrate solution that remained on the inner surface of the inlay copings, was cleaned. After cleaning and adjustments all specimens were examined for integrity under a stereomicroscope magnification x 25 (Carl Zeiss f 170, Carl Zeiss Surgical GmbH, Germany) via the copings were placed one by one on the master metal die. After marginal measurements, feldspathic porcelain application was made on the copings to produce galvanoceramic inlays. The galvano ceramic bonder (GES Galvano-bonder, Gramm GmbH Co. Heimerdingen, Germany), opaque porcelain, dentin porcelain, and enamel porcelain (VMK95; VITA Zahnfabrik, Bad Sackingen, Germany) were applied on these copings, respectively. The firing procedures were performed according to the firing schedule recommended by the manufacturer. Prepared galvanoceramic specimens were placed one by one on the master die to examine their integrity under a stereomicroscope (Carl Zeiss 170, Carl Zeiss Surgical GmbH, Oberkochen, Germany) at 25× magnification.

In this study two different ceramic inlays (lithium disilicate based and alumina based) were used as control groups to compare galvanoceramic inlays. Fifteen lithium disilicate-reinforced all-ceramic inlays (IPS Empress 2; Ivoclar Vivadent, Schaan, Liechtenstein) were fabricated using a high-temperature injection molding technique following manufacturer’s instructions. Fifteen alumina-based all ceramic inlays were also fabricated according to the manufacturers’ direction using the Turkom-Cera technique (Turcom-Ceramics, Sdn Bhd, Kuala Lumpur, Malasia).

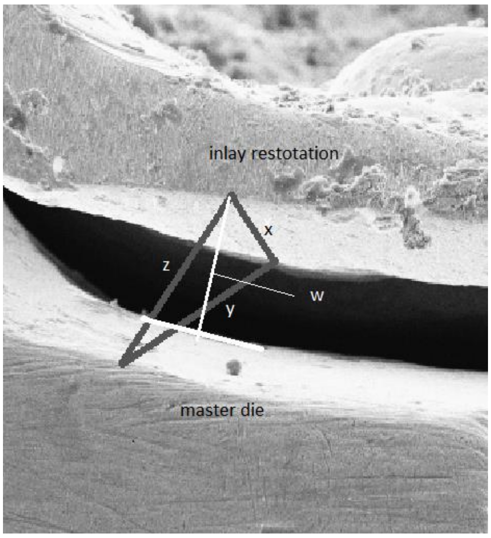

Figure 1. SEM image of a sample. Definition of measuring distances for marginal accuracy. x: horizontal marginal discrepancy; y: vertical marginal discrepancy; z: absolute marginal discrepancy; w: marginal gap.

Marginal Gap Analyses

The absolute marginal discrepancy measurements defined by Holmes (12) were used in this study to evaluate marginal gap analyses. The marginal distance between the external edges of the inlay cavity on the master die and the marginal edges of the fabricated inlays was defined as "the absolute marginal discrepancy". It is the hypotenuse of a right triangle, the sides of which are the vertical and horizontal marginal discrepancies (Figure 1).

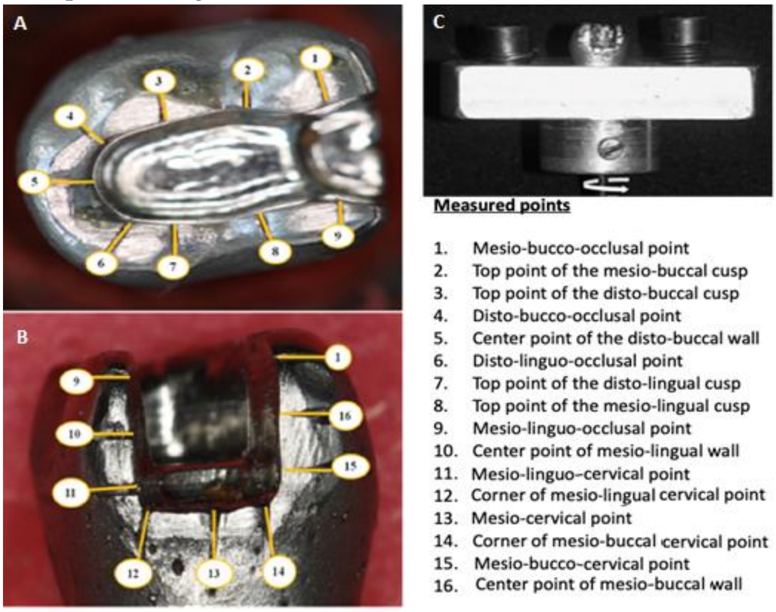

Figure 1. Measurement points on the master die. Occlusal view of the master die is in the picture A, mesial view of the master die is in the picture B. Custom made specimen positioning device is in the picture C.

The sixteen different points were scribed on the master die for standardised measurements without damaging the margins. The master die was mounted onto a custom-made specimen-positioning device that swivels around its axis to observe all measurements points without removing the master die during microscopic investigation (Figure 2). The absolute marginal discrepancies of each inlay were measured at the 16 scribed reference points using scanning electron microscope (SEM) (LEO 440 Computer Controlled Digital, Leica Zeiss, Cologne, Oberkochen, Germany) at an accelerating voltage of 20–30 kV and 100μm bar. Each point was measured twice. A total of 32 marginal adaptation measurements were performed for each specimen. All measurements were performed without cementation. At the galvanoceramic inlay, the measurements were conducted both before and after porcelain application. A total of 1920 measurements of the marginal gap were performed (45 samples×16 points×2 times on inlays; 15samples×16 points×2 times on galvano-copings).

Statistical analyses

The statistical analysis of the data was performed using the SPSS version 22.0 statistical software package program. Shapiro-wilk tests were used to evaluate normal distribution of the data. Levene test was used to determine homogeneity of the variances. The data of the marginal discrepancies were statistically compared among the measurement points and inlay material using two-way analysis of variance (2-side ANOVA). Comparison between galvanoformed copings and galvanoceramic inlays were made using paired t-test. Post-hoc Tamhane T2 test was used for multiple comparisons. The level of significance was set at α=0.05.

RESULTS

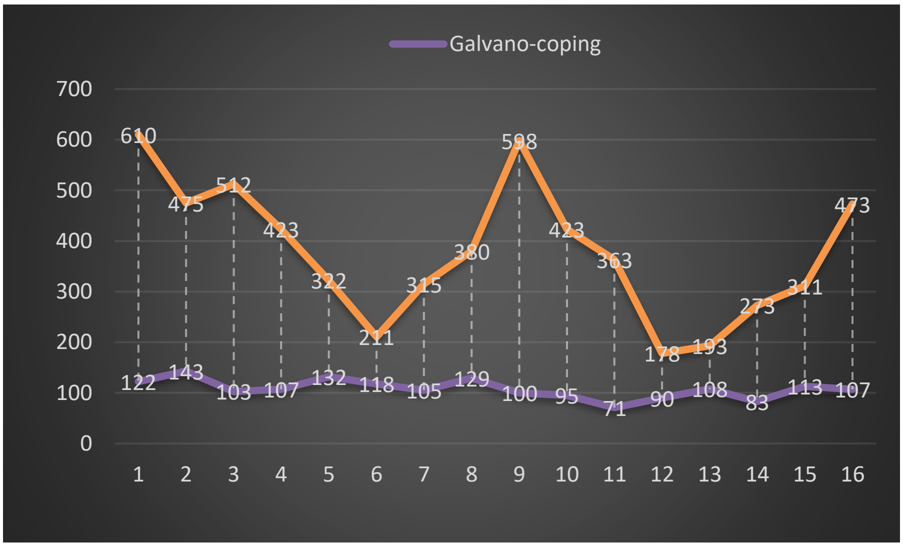

Figure 2. The galvanoceramic inlays exhibited a significantly larger marginal gap at all points (The highest p value belonged to the 13th point. p=0.011).

Marginal gap differences between galvanoformed copings and galvanoceramic inlays at each measurement points are shown in Figure 3. The mean marginal gap of galvanoformed copings for all points prior to porcelain firing ranged from 71 to 143 µm, whereas after firing the mean marginal gap ranged from 178 to 610 µm. According to the paired t-test, the differences in the marginal fit between galvanoformed copings and galvanoceramic inlays were significant at all measurement points ($p<.001$). Figure 3 presents grafical outline of the differences in marginal fit between galvanocoping and galvanoceramic inlay at each measurement point. Galvanoceramic inlays exhibited a significantly larger marginal gap than galvanoformed copings. The maximum changes were observed in points 1 and 9 (mesio-bucco-oclusal and mesio-linguo-oclusal points; at the ocluso-proximal corner part of the restoration), and the minimum changes were determined in points 12, 13 (corner of the mesiolingual cervival point and mesio-cervical point; at cervical terminal part of the inlay) and 6 (at disto-linguo-occlusal point; at occlusal terminal part of the inlay). The highest p value represented the least change in marginal adaptation and was attributed to the 13th point (at the mesio-cervical terminal point) ($p=0.011$).

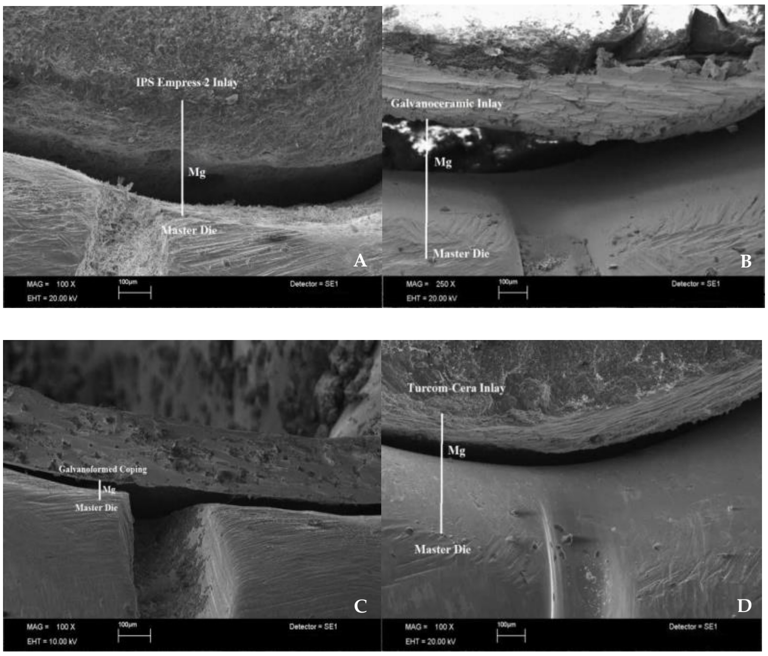

Figure 4. SEM images that were taken from same measurement point (point 5). A. Marginal gap of Lithium disilicate reinforced all-ceramic inlay B. Marginal gap of galvanoceramic inlay; C. Marginal gap of galvanoformed coping D. Marginal gap of Alumina based all ceramic inlay.; Mg: marginal gap.

Scanning electron microscopic images in Figure 4 demonstrates the marginal gaps were taken from same measurement point (point 5) for all inlay type and galvanocoping. As observed, galvanocoping exhibited the closest marginal adaptation, while the galvanoceramic inlay had a significantly greater marginal gap than the other types of inlays. The comparison of marginal gap in measurement points among inlay types are shown in Table 2.

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Two-way ANOVA results indicated a significant difference among inlay types and measurement points. The effect of the inlay material and measurement points and the interaction between these two parameters was found to be significant (F=32.805, p<.001). The mean and standard deviation of the marginal gap was 186±34 µm in alumina inlays, 188±36 µm in lithium disilicate ceramic inlays, and 379±153 µm in galvanoceramic inlays. Except three points (6-distolinguoocclusal point, 12- corner of the mesiolingual cervical point and 13-mesiocervical point), marginal gap of the galvanoceramic inlays higher than 250 µm (Figure 5). When evaluated the marginal gap obtained from the all-measurement points, other two ceramic inlays exhibited similar marginal gap (p=.857).

Table 2. The comparison of marginal gap in measurement points among inlay types used in the study (the unit of measurement is micron, i.e. µm)

Measured Points	n	Number of measurement	Alumina Based inlay Mean(SD)	Lithium Disilicate Based Inlay Mean(SD)	Galvanoceramic inlay Mean(SD)	p
1	15	30	178(27)^{ab,A}	208(34)^{de,B}	610 (191)^{af,C}	.000
2	15	30	184(32)^{ab,A}	211(28)^{e,A}	475(108)^{adg,B}	.000
3	15	30	207(27)^{b,A}	189(26)^{cde,A}	512(84)^{af,B}	.000
4	15	30	203(34)^{b,A}	201(27)^{cde,A}	423(44)^{ab,B}	.000
5	15	30	209(20)^{b,A}	203(21)^{cde,A}	322(67)^{bh,B}	.000
6	15	30	177(23)^{ab,A}	168(28)^{bc,A}	211(16)^{c,B}	.000
7	15	30	174(37)^{ab,A}	186(44)^{bcde,A}	315(74) ^{bh,B}	.000
8	15	30	183(32)^{ab,A}	219(22)^{e,B}	380(75)^{bde,C}	.000
9	15	30	198(30)^{b,A}	127(18)^{a,B}	598(78)^{f,C}	.000
10	15	30	195(30)^{ab,A}	190(27)^{cde,A}	423(58)^{ae,B}	.000
11	15	30	176(36)^{ab,A}	173(32)^{bcd,A}	363(95)^{beg,B}	.000
12	15	30	200(25)^{b,A}	198(31)^{cde,A}	178(28)^{c,A}	.099*
13	15	30	206(28)^{b,A}	210(28)^{e,A}	193(31)^{c,A}	.249*
14	15	30	173(38)^{a,A}	152(28)^{ab,A}	273(48)^{bh,B}	.000
15	15	30	156(29)^{a,A}	195(25)^{cde,B}	311(53)^{bh,C}	.000
16	15	30	150(19)^{a,A}	183(31)^{bcde,A}	473(111)^{aef,B}	.000
TOTAL	45	1440	186(34)^{b,A}	188(36)^{cde,A}	379 (153)^{beg,B}	.000

Different small letter superscripts in a column show the significant difference among measurement points at p<.05. Different capital letter superscripts in a row shows the significant differences among inlay types at p<.05. Sd: Standart deviation. *p >.05

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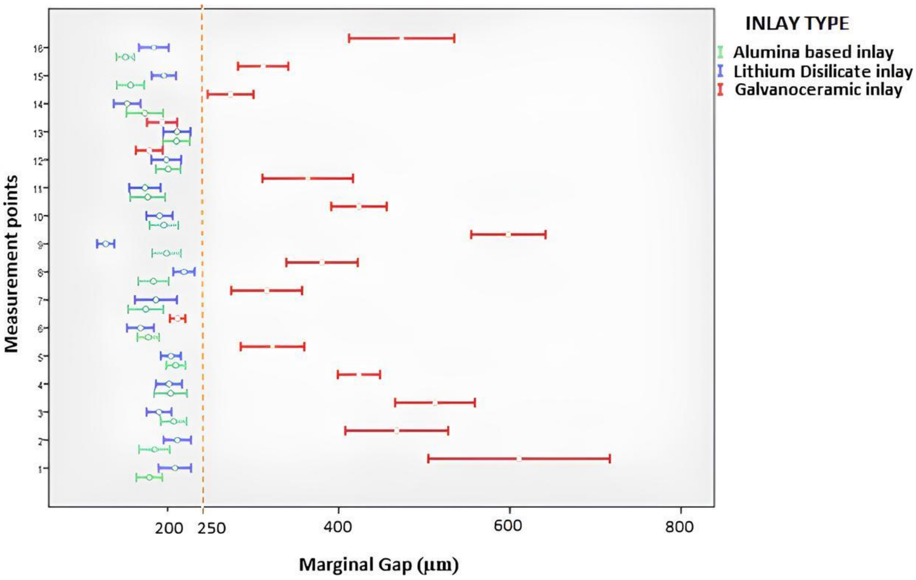

Figure 3. Error bars graphic showing the clustering differences about marginal gaps of the inlays. Marginal gaps of the alumina and lithium disilicate inlay groups are generally under 250 microns. In galvanoceramic inlays, only the measurement points of 6,12 and 13 are under 250 microns. Error bars indicated 95% confidence interval.

DISCUSSION

This in vitro study was designed to assess the marginal adaptation of galvano-ceramic inlays with gold margins versus conventionally produced ceramic inlays made by different materials and techniques, and to determine whether had clinically acceptable marginal adaptation. To our knowledge, our study is the first to demonstrate that galvanoceramic inlays do not provide good marginal adaptation and even have clinically unacceptable marginal fit.

Numerous studies have designed in literature to determine the marginal adaptation in restorative materials (1–4). Researchers have preferred on in vitro simulations due to the advantages of the controlled conditions, standardization and reasonable time(13–15). In the present study, one single metal die was used for fabrication of the inlays. The advantage of this was the standardised preparation, which assured that the fabrication of all specimens was based on the same original source and that minimal wear of the die margins occurred during measurements. Moreover, the master die was mounted on a custom-made specimen positioning apparatus that swivelled around its axis, allowing the observation of measurement points without removing the master die during microscopic investigation.

The film thicknesses of cements after cementation can vary depending on the type and properties of the cement and the cementation pressure applied by the dentist. The marginal adaptation of the restoration can be affected by cementation process (16,17). For this reason, the cementation procedure was not accomplished in this study in order to determine the effect of the material used and the fabrication technique regardless of the cements and cementation processes.

Although numerous studies have been reported regarding the marginal fit of galvanoceramic crowns(9,12,18), information about marginal integrity of galvanoceramic inlays is unclear. Galvanoformed crown copings and galvanoceramic crowns have exhibited superior marginal adaptation when compared the crowns made of all ceramic or non-noble alloy materials (12,18). Buso et al. (8) reported that the mean marginal gap of the galvanoformed crown copping was 30±19 µm. Shiratsuchi et al. (9) reported that the marginal gap of the galvanoformed crown copping was between 18–50 µm. In our study, we observed that the mean marginal gap of the galvanoformed copings to be 107±25 µm, higher than that reported by these studies(8,9) The reason of this would be galvanoformed crown copings have a circular margin, while galvanoformed inlay copings have linear occlusal and approximal margins, intersecting at right angles to each other.

The results of this study revealed that there was a significant increase at marginal gap of galvanoceramic inlay after porcelain firing. Studies about crown restorations in literature has been reported that there was a change in marginal fit after porcelain firing. A previous study(9) reported that the marginal gap of the galvanoformed crown copping was 18–50 µm, while that of the galvanoceramic crown was 24–89 µm. Petteno et al.(18) reported that the marginal gap of the galvanoceramic crown was approximately two times greater than that of the galvanoformed crown copings. In our study, the marginal gaps of galvanoceramic inlays were increased after porcelain firing, in agreement with the results of these studies (9,18). However, we differently found that the marginal discrepancy of galvanoceramic inlays was approximately three times greater than that of the galvanoformed copings. These differences may be the result of variability in the restoration type used and/or the measurement method. Some studies in literature (19,20) indicated that firing of the porcelain may cause marginal distortion. Komine et al.(20) stated that galvanoformed crowns undergo marginal distortion due to shrinkage of porcelain mass, and this factor caused marginal discrepancy nearly 34µm when used shoulder finish line. Since inlay margins extend linearly, unlike crown margins, the shrinkage in the porcelain would be pulled the galvanocoping margins towards the centre of the inlay and away from the inlay cavity walls. This may explain why the marginal discrepancy after porcelain firing was much higher in inlays compared to crowns.

According to the literature, the acceptable marginal gap for dental restorations, including both crown and inlay/onlay, is controversial. Some studies accepted that the ideal marginal gap should be below 120 µm to prevent dissolution of the luting cement, while the most authors have stated that a marginal gap should be below 200 µm that is the clinically acceptable threshold (3,13,17,21–23). There are many factors that can influence this value; among them are production methods, materials used for restorations, and measurement techniques. Holmes et al. (12)defined the absolute marginal discrepancy as the hypotenuse of a right triangle, the sides of which are the vertical and horizontal marginal discrepancies. The perpendicular measurement from the surface of the abutment to the margin of the retainer is called the "marginal gap". Absolute marginal discrepancy values are higher than marginal gap values and it can be up to 250 µm (24) According to a systematic review study investigated marginal and internal fit of inlay/onlay restorations stated that the measured mean marginal gap of inlay/onlay restorations ranged between 36 µm and 222.5 µm (13). Another study that used the absolute marginal discrepancy measurement technique to evaluate the marginal fit of inlays reported a mean marginal gap of 177 ± 69 µm (25). These different results indicate that marginal gap measurements can vary depending on restoration types and measurement methods, but are generally under 250 micrometers. According to our results, mean marginal discrepancy of alumina based and lithium disilicate based inlays were within clinically acceptable limitations, whereas the mean data from galvanoceramic inlays had clinically unacceptable marginal discrepancy (over 250 µm), in contrary to manufacturer's declarations and commonly predicted. Only the 3 points at the occlusal and gingival terminal ends of the inlay restoration were within acceptable limits. Considering the linear structure of the inlay restoration, it can be seen that these three points are on the short edges. This confirmed that the porcelain shrinks substantially towards the center of the inlay, so that the marginal discrepancy at the long edges is much greater.

Galvanoformed copings for inlays exhibited much better marginal adaptation than both galvano-ceramic inlay and the other ceramic inlays at all measurement points in our study. This shows that if thin galvanoformed coping structure can be protected from the negative effects of porcelain firing, it can have a much better marginal fit than ceramic inlays produced by other methods. In order to obtain the advantage of the superior properties of gold margins, future studies should focus on methods to apply porcelain into the inlay without allowing shrinkage of the galvanoformed copings.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions may be drawn; First, the galvano-copings exhibited that nearly perfect marginal fit, but porcelain application dramatically disrupted this adaptation, so galvanoceramic inlays had the largest marginal gaps. Second, the marginal fit of the lithium disilicate and the alumina-based inlay restorations were generally similar to each other. Additionally, mean marginal fit of these inlays was within clinically acceptable limits, but galvanoceramic inlays had marginal discrepancy over 200-250 µm that is upper limit of marginal discrepancy for clinical acceptance of dental restorations.

Conclusively, the inlays produced with current galvanoforming technology is inconvenient due to high marginal discrepancy. However, if the new methods that reduce or eliminate the shrinkage effect of the porcelain can be developed in further studies, much more adapted and highly biocompatible inlays with gold margins can be used in dental practice.

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Authorship contributions

Concept: OC, ZE, AG; Design: OC, ZE, AG; Data Collection or Processing: OC, ZE, Analysis or Interpretation: OC, AG; Literature Search: OC, ZE; Writing: OC, AG.

Declaration of competing interest

No conflict of interest was declared by the authors.

Ethics

This article does not contain any studies with human participants or animals performed by any of the authors.

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REFERENCES

1. Adel M, Hamdy A, Sabet A, Ebeid K. Effect of cervical margin relocation on marginal adaptation and microleakage of indirect ceramic restorations. Journal of Prosthodontics. 2024;33(4).
2. Haralur SB, AL Ghaseb GA, Alqahtani NA, Alqahtani B. Comparison of microleakage between different restorative materials to restore marginal gap at crown margin. PeerJ. 2021;9.
3. Taha AI, Hafez ME. An in vitro study measuring marginal gaps of inlay restorations fabricated from different CAD-CAM materials after thermocycling. BMC Oral Health. 2023;23(1).
4. Papadiochou S, Pissiotis AL. Marginal adaptation and CAD-CAM technology: A systematic review of restorative material and fabrication techniques. Vol. 119, Journal of Prosthetic Dentistry. 2018.
5. Weishaupt P, Bernimoulin JP, Lange KP, Rothe S, Naumann M, HÄgewald S. Clinical and inflammatory effects of galvano-ceramic and metal-ceramic crowns on periodontal tissues. J Oral Rehabil. 2007;34(12).
6. Oleszek-Listopad J, Sarna-Bos K, Szabelska A, Czelej-Piszcz E, Borowicz J, Szymanska J. The use of gold and gold alloys in prosthetic dentistry - A literature review. Vol. 28, Current Issues in Pharmacy and Medical Sciences. 2015.
7. Gradinaru I, Jipu R, Hurjui L, Balcoș C, Mitrea M, Antohe ME. Galvanoformation in fixed prostheses: procedure always up to date. Vol. 9, Romanian Journal of Medical and Dental Education.
8. Buso L, Neisser MP, Bottino MA. Evaluation of the marginal fit of electroformed copings in function of the cervival preparation. Braz Dent Sci. 2010;7(1).
9. Shiratsuchi H, Komine F, Kakehashi Y, Matsumura H. Influence of finish line design on marginal adaptation of electroformed metal-ceramic crowns. Journal of Prosthetic Dentistry. 2006;95(3).
10. Polansky R, Heschl A, Arnetzl G, Haas M, Wegscheider W. Comparison of the marginal fit of different all-ceramic and metal-ceramic crown systems: an in vitro study. Int J Stomatol Occlusion Med. 2010;3(2).
11. Kaán B, Eichner K, Kaán M, Fejérdy P, Róth L. In vivo and in vitro study of the marginal sealing in ceramic-covered gold inlays. Fogorv Sz. 1998;91(12).

12. Holmes JR, Pilcher ES, Rivers JA, Stewart RMQ. Marginal fit of electroformed ceramometal crowns. Journal of Prosthodontics. 1996;5(2).
13. Goujat A, Abouelleil H, Colon P, Jeannin C, Pradelle N, Seux D, et al. Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies. Vol. 121, Journal of Prosthetic Dentistry. 2019.
14. Raghav PS, Abirami S, Gupta A, Yusufi FNK, Afroz S. Effect of Different Impression Techniques on Marginal Fit of Restoration – An In Vitro Study. Indian Journal of Dental Research. 2023;34(3).
15. Yang S, Li Q, Chen S yuan, Yu H. Effect of multiple firings on the marginal fit of monolithic zirconia crowns: An in vitro study. Journal of Prosthetic Dentistry. 2023;130(6).
16. de Almeida JG dos SP, Guedes CG, Abi-Rached F de O, Trindade FZ, Fonseca RG. Marginal Fit of Metal-Ceramic Copings: Effect of Luting Cements and Tooth Preparation Design. Journal of Prosthodontics. 2019;28(1).
17. Ferrari M, Dagostin A, Fabianelli A. Marginal integrity of ceramic inlays luted with a self-curing resin system. Dental Materials. 2003;19(4).
18. Pettenò D, Schierano G, Bassi F, Bresciano ME, Carossa S. Comparison of marginal fit of 3 different metal-ceramic systems: an in vitro study. Int J Prosthodont. 2000;13(5).
19. Balkaya MC, Cinar A, Pamuk S. Influence of firing cycles on the margin distortion of 3 all-ceramic crown systems. Journal of Prosthetic Dentistry. 2005;93(4).
20. Komine F, Shiratsuchi H, Kakehashi Y, Matsumura H. Influence of porcelain-firing procedures on the marginal distortion of electroformed metal-ceramic restorations. Quintessence Int (Berl). 2007;38(10).
21. Papaspyridakos P, Vazouras K, Chen Y wei, Kotina E, Natto Z, Kang K, et al. Digital vs Conventional Implant Impressions: A Systematic Review and Meta-Analysis. Vol. 29, Journal of Prosthodontics. 2020.
22. Björn AL, Björn H, Grkovic B. Marginal fit of restorations and its relation to periodontal bone level. II. Crowns. Odontol Revy. 1970;21(3).
23. McLean JW, Von F. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131(3).
24. Demir N, Ozturk AN, Malkoc MA. Evaluation of the marginal fit of full ceramic crowns by the microcomputed tomography (micro-CT) technique. Eur J Dent. 2014;8(4).
25. Rippe MP, Monaco C, Volpe L, Bottino MA, Scotti R, Valandro LF. Different methods for inlay production: Effect on internal and marginal adaptation, adjustment time, and contact point. Oper Dent. 2017;42(4).