INTRODUCTION

Over time, erosion of enamel may lead to loss of occlusal anatomy, in addition to vertical bite height loss. In such a case, a prosthetic treatment using a full crown may be indicated, but, unfortunately, this procedure requires an additional and extensive preparation of the already hampered dentition. For this reason, using a thinly bonded posterior occlusal veneers have been suggested. Advances in dental CAD/CAM technologies and materials in addition to improvements in bond strength and longevity of adhesives, have opened the door to the development of ceramic restorations with superior esthetical and mechanical properties. Lithium disilicate ceramic has shown promising clinical outcomes regarding color stability, integrity, survival rate and wear resistance when used as complete or partial coverage crowns, veneers, inlays and onlays restorations.

Quality of marginal and internal fit plays a very important role in the long-term clinical success of fixed restorations. Open margins on a crown can affect the integrity of the cement seal, causing microleakage and cement dissolution leading to caries, plaque accumulation and finally, periodontal disease. The marginal gap is defined by the vertical distance from the outermost edge of the finish line to the internal surface of the crown’s margin. Moreover, the internal gap is the vertical distances from the axial and occlusal walls of preparation to the internal surfaces of the crown. In addition to that; the absolute marginal discrepancy (AMD), which is the angular combination of the extension error and marginal gap, reflects the total crown misfit in vertical and horizontal directions.

For a long time, sample sectioning followed by microscopic evaluation (light or SEM) was used to measure the marginal and internal fit of restorations, but those methods have several drawbacks as they are achieved on a limited number of tooth sections. Sectioning is a destructive procedure involves the loss of some information, furthermore, the cutting procedures are time-consuming. Nonetheless, the micro-computed tomography is nowadays considered the most updated and non-destructive investigational approach. This study is directed toward evaluating the marginal and internal fit of machinable lithium disilicate occlusal veneer with different cement space settings, by using cone-beam computed tomography scans. The hypothesis is that differences in cement space thickness will not influence the marginal and internal adaptation of IPS e.max CAD lithium disilicate occlusal veneer.

MATERIALS AND METHODS

Three groups of IPS e.max CAD lithium disilicate occlusal veneers with different cement space settings were produced to compare their marginal and internal fit using cone-beam computed tomography scans. A typodont mandibular right first molar (KaVo Dental, Biberach, Germany) was prepared by a single operator for occlusal veneers, with a medium grit tapered diamond bur with a rounded end, using a milling machine (BEGO. PARASKOP, Bremen, Germany). The tooth was prepared as follows: 1.5 mm height extending from the margin to the occlusal plane, 1 mm circumferential rounded chamfer, rounded axio-gingival angle with 1.0-1.5 mm anatomically shaped occlusal reduction. One point five millimeters axial reduction with 6° tapering angle, 1.0-1.5 mm curvature radius. One point five millimeters axial reduction with 6° tapering angle, 1.0-1.5 mm curvature radius (Figs. 1 and 2). Finally, three dimples were made at the level of cemento–enamel junction on mesial, distal and buccal surfaces using round diamond bur.)
were used as guides to standardize the position of the die and its corresponding occlusal veneer within the mold during scanning). Then, 30 resin master dies were made by replicating the prepared tooth using Cerec inLab 3D system (D-64625, Sirona dental system, Bensheim, Germany) and randomly distributed into 3 groups (ten samples for each) according to the cement space parameters (30, 40 and 50 µm) subsequently designed18,26).

The master dies were homogeneously sprayed using fluorinated hydrocarbon pigment suspension (Optispray, Sirona Dental Systems), then digital impressions of all master dies were made using the Cerec scanner (inEos Blue scanner, Sirona Dental Systems). The same occlusal veneer design with identical external contours for all groups was made and simulated cement space of 25 µm strap of 0.5 µm above the finish lines, then, additional cement spaces of 30, 40, and 50 µm were set forming the following three tested groups, A (25–30), B (25–40), and C (25–50), respectively11,12,26).

After each occlusal veneer was designed, the data was sent to the Cerec in Lab milling unit (D-64625, Sirona dental system) for ceramic occlusal veneers milling from IPS e.max CAD lithium disilicate blocks (Ivoclar Vivadent, Schaan, Liechtenstein). After milling process, occlusal veneers for the three tested groups were crystallized in programat P310 furnace (Programat P310, Ivoclar Vivadent). No adjustments were made to the ceramic veneers before marginal and internal fit measurements23).

To ensure the standardization of the computed tomography images for all slices, one master die with its corresponding occlusal veneer placed in a mold with dimensions of 4×3×3 cm filled with light body polyvinyl siloxane (3M ESPE, Express, Dental Products, St. Paul, MN, USA) from its buccal side until mesial and distal dimples are covered followed by embedding a stainless steel wire (0.1 mm) as a fixed starting reference point parallel to the longitudinal axis of the mesial side. This mold standardizes the position of all samples during scanning. A circle with 20 different diameters (each step 9° increase) was placed at the center of the same image position of every scanned specimen27,28) to measure four different locations as follow:

1. Occlusal value (OCG): which is the mean of the three occlusal values (O1, O2, and O3): After dividing the length of the occlusal surface into four equal parts, one measurement in the middle
and two in the middle of each half was taken.

2. Axial value (AXG): The mean of two right and left axial values (A1 and A2): at the middles of axial walls.

3. Marginal value (MAG): The mean of two right and left marginal values (M1 and M2) at the middle of the finish line.

4. Absolute marginal discrepancy value (AMD): The mean of two right and left distances between the margin of occlusal veneer and die margin (AMD1 and AMD2). The occlusal veneers were seated onto their corresponding dies without any luting medium.

Each tooth was scanned using micro CT (SkyScan 1072, Bruker, Kontich, Belgium) with the following setting parameters: 10 W, 100 kV, 98 mA, a 1 mm thick aluminum plate, 15× magnification, 4.9 s exposure time. The digital data were developed using a reconstruction software (NRecon 1.6.6.0, Bruker). Cross-sections of samples were made with a distance of 9 degrees. Images were acquired from 20 slices were used to measure four sites per slice (occlusal, axial, marginal and absolute marginal discrepancy) with a total of 80 measuring values for each tooth as illustrated in Figs. 3 and 4.

RESULTS

The results of all measurement sites (OCG, AXG, MAG, and AMD) were evaluated. Computed statistical analyses were performed for each group separately using statistical-package of social science (SPSS Statistics v22.0; IBM, New York, USA) statistic software. Using Shapiro-Wilks test, normality of the data distribution was evaluated (The test rejects the hypothesis of normality when the $p \leq 0.05$) followed by one-way ANOVA to conclude the significance of differences. Non-parametric Kruskal-Wallis test was used ($p \leq 0.05$ considered to indicate statistical significance). Mann-Whitney $U$ test was used for post hoc analysis to compare each two different groups. A total of 600 images were obtained for the three groups, including ten occlusal veneer/group and four measuring value/slice with 2,400 measuring values. A summary of mean gap values, standard deviations, minimum and maximum gap values) in micrometer ($\mu$m) at the four tested sites (Occlusal, Axial, Marginal and Absolute marginal discrepancy) for the three tested groups, are shown in Table 1 where the values of all tested sites ranged from 52.11 $\mu$m to 97.34 $\mu$m (below 100 $\mu$m).

A summary of mean rank statistical values in Kruskal-Wallis test and values of Mann-Whitney $U$ test at the four tested sites (Occlusal, Axial, Marginal, and Absolute marginal discrepancy) for all tested groups, is listed in Table 2.

Regarding OCG, the Kruskal-Wallis test revealed no statistical differences between group 1 (25–30 $\mu$m) and group 2 (30–35 $\mu$m), and group 3 (35–40 $\mu$m).
Table 3  Kruskal-Wallis statistical results of occlusal gap evaluation (µm) for the three tested groups

| Group | n  | Mean | St.d | Min. | Max. | X²  | df |
|-------|----|------|------|------|------|-----|----|
| 25–30 µm | 10 | 84.88 | 7.25 | 74.99 | 93.99 |     |    |
| 25–40 µm | 10 | 87.53 | 7.09 | 75.99 | 94.17 | 1.435 | 2  |
| 25–50 µm | 10 | 89.08 | 5.66 | 79.95 | 97.43 |     |    |

Similar letters, groups did not exhibit a statistically significant difference. St.d: standard deviation, Min.: minimum value, Max.: maximum value, X²: Chi-square, df: degree of freedom

Table 4  Kruskal-Wallis statistical results of axial gap evaluation (µm) for the three tested groups

| Group | n  | Mean | St.d | Min. | Max. | X²  | df |
|-------|----|------|------|------|------|-----|----|
| 25–30 µm | 10 | 82.42 | 6.12 | 72.77 | 89.17 |     |    |
| 25–40 µm | 10 | 86.97 | 5.13 | 75.77 | 92.11 | 4.648 | 2  |
| 25–50 µm | 10 | 87.16 | 6.07 | 79.99 | 95.88 |     |    |

Similar letters, groups did not exhibit a statistically significant difference. St.d: standard deviation, Min.: minimum value, Max.: maximum value, X²: Chi-square, df: degree of freedom

Table 5  Kruskal-Wallis statistical results of marginal gap evaluation (µm) for the three tested groups

| Group | n  | Mean | St.d | Min. | Max. | X²  | df |
|-------|----|------|------|------|------|-----|----|
| 25–30 µm | 10 | 77.06 | 6.31 | 68.91 | 87.49 |     |    |
| 25–40 µm | 10 | 67.16 | 4.95 | 60.44 | 75.18 |     |    |
| 25–50 µm | 10 | 57.34 | 4.02 | 52.11 | 65.80 |     |    |

Similar letters, groups did not exhibit a statistically significant difference. St.d: standard deviation, Min.: minimum value, Max.: maximum value, X²: Chi-square, df: degree of freedom

Table 6  Kruskal-Wallis statistical results of absolute marginal discrepancy (µm) for the three tested groups

| Group | n  | Mean | St.d | Min. | Max. | X²  | df |
|-------|----|------|------|------|------|-----|----|
| 25–30 µm | 10 | 82.58 | 8.54 | 70.94 | 92.46 |     |    |
| 25–40 µm | 10 | 84.66 | 6.58 | 77.84 | 92.88 | 1.263 | 2  |
| 25–50 µm | 10 | 85.42 | 7.17 | 74.44 | 92.44 |     |    |

Similar letters, groups did not exhibit a statistically significant difference. St.d: standard deviation, Min.: minimum value, Max.: maximum value, X²: Chi-square, df: degree of freedom

Regarding AXG, the Kruskal-Wallis test revealed no statistical differences between group 1 (25–30 µm) (82.42±6.12 µm) and other two groups (group 2 (25–40 µm) (86.97±5.13 µm) (p=0.063), and group 3 (25–50 µm) (87.16±6.07 µm) (p=0.075), also, there was no statistical differences between group 2 and group 3 (p=0.100) (Tables 2 and 4).

Regarding MAG, the Kruskal-Wallis test revealed statistical differences between group 1 (25–30 µm) (77.06±6.31 µm) and other two groups (group 2 (25–40 µm) (67.16±4.95 µm) (p<0.001), and group 3 (25–50 µm) (57.34±4.02 µm) (p<0.001), also, there was a statistical difference between group 2 and group 3 (p<0.001) (Tables 2 and 5).

Regarding AMD, the Kruskal-Wallis test revealed no statistical differences between group 1 (25–30 µm) (84.88±7.25 µm) and other two groups (group 2 (25–40 µm) (87.53±7.09 µm) (p=0.481), and group 3 (25–50 µm) (89.08±5.66 µm) (p=0.247). Furthermore, there was no statistical differences between group 2 and group 3 (p=0.796) (Tables 2 and 3).
DISCUSSION

In this study, the first part of the hypothesis was rejected, because the thickness of the cement space is directly affected the marginal adaptation, but, the second part of the hypothesis was accepted because the thickness of the cement space did not influence the internal adaptation. This study was performed in vitro, which offered standardized and optimized conditions in the experimental performance, which may not be possible to achieve in vivo. The master dies were copied from one previously prepared acrylic tooth to avoid any variability in preparation dimensions.

Until the time of this study, no published studies have focusing on the marginal and internal fit of a ceramic occlusal veneer. Therefore, the total comparison of the outcomes was not possible. However, the results of the present study can be compared with those focusing on marginal and internal gap evaluation in different types of materials and preparation designs, especially those fabricated using different cement spaces with CAD-CAM technologies.

The tooth was prepared as follows: 1.5 mm height extending from the margin to the occlusal plane, 1 mm circumferential rounded chamfer, rounded axio-gingival angle with 1.0 mm curvature radius. One point five millimeters axial reduction with 6° tapering angle, 1.0–1.5 mm anatomically shaped occlusal reduction.

The mean internal gap values of all tested groups did not imitate the designed cement spaces in the design software, this result is in accordance with that of the other studies. This may be attributed to the preparation design, especially the length of the axial walls, which might affect the accuracy of fit. Previous study recommended cement space setting to be set to be at 50 µm or more, where 30 µm for clearance of cement thickness, and the remaining 20 µm for potential distortion in the restoration caused by the production. Despite any premature contacts within the fitting surface may change the proper seating of the occlusal veneer and consequently increase the internal and marginal discrepancies, adjustments on occlusal veneer were not performed in the present study, to avoid biasing of the internal and marginal gap values.

Micro-computed tomography is nowadays considered the most updated and non-destructive investigational approach for the assessment of marginal and internal gaps. It is more accurate than the other measuring methods for marginal and internal gaps evaluation.

In addition, using micro-CT for accuracy fit evaluation provides qualitative and quantitative relationship between the restoration, and the die. Many investigators have researched on the marginal adaptation of ceramic crown, with some performed measurements on 4 to 8 points and others on 16 to 24 points per specimen. In this study, 20 measurements were obtained for each site to evaluate the marginal and internal adaptation of each occlusal veneer. The results of the study indicated that the increase of the cement space improved the marginal fit of IPS e.max CAD occlusal veneer as proposed by other authors. In contrast with other studies which postulated that, an increase of the cement space does not improve the marginal fit.

Some studies have reported that the ideal value for marginal adaptation should be 100 to 200 µm to be clinically acceptable. Other studies have considered that it should be less than 100 µm. Therefore, the results of marginal and internal gaps for all the three tested groups presented in this study can be considered clinically acceptable. The marginal gap values for this study were lower than those reported by other studies. These differences may be attributed to the differences in the scanning accuracy, used materials, preparation designs.

In comparison with previous studies, who measured a mean AMD for crowns, the AMD values of all groups in the present study are lower. A possible explanation for these results might be that, occlusal veneers have been used instead of full-coverage crowns, in addition to that, the crowns were not cemented but only stabilized on their respective dies with silicone material.

There were several limitations to the present study. All the restorations were evaluated without cementation because of the radiopacity of the luting agent might alter the accuracy of measurements (this is a limitation of using micro-CT scan for adaptation assessment), moreover, the method is exemplified for only one type of ceramic material, therefore, extension of the research for other types of ceramic materials, as well as for other designs is required.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that, an increase in the digital cement space significantly improved the marginal fit of IPS e.max CAD occlusal veneer. There was no significant effect of increasing digital cement space value on both internal fit and absolute marginal discrepancy of IPS e.max CAD occlusal veneer.

REFERENCES

1) Loomans B, Opdam N, Attin T, Bartlett D, Edelhoff D, Frankenberger R, et al. Severe tooth wear: European consensus statement on management guidelines. J Adhes Dent 2017; 19: 111-119.
2) Schlueter N, Luka B. Erosive tooth wear —a review on global prevalence and on its prevalence in risk groups. Br Dent J 2018; 224: 364–370.
3) Varma S, Preiskel A, Bartlett D. The management of tooth wear with crowns and indirect restorations. Br Dent J 2018; 224: 343-347.
4) Krummel A, Garling A, Sasse M, Kern M. Influence of bonding surface and bonding methods on the fracture resistance and survival rate of full-coverage occlusal veneers made from lithium disilicate ceramic after cyclic loading. Dent Mater 2019; 35: 1351-1359.
5) Uzgur R, Ercan E, Uzgur Z, Colak H, Yalcin M, Ozcan M.
Cement thickness of inlay restorations made of lithium disilicate, polymer-infiltrated ceramic and nano-ceramic CAD/CAM materials evaluated using 3D X-ray micro-computed tomography. J Prosthodont 2018; 27: 456-460.

6) Xia H, Picart P, Montresor S, Guo R, Li JC, Yusuf Solemen O, et al. Mechanical behavior of CAD/CAM occlusal ceramic reconstruction assessed by digital color holography. Dent Mater 2018; 34: 1222-1234.

7) Moslehiard F, Nikzad S, Geraminpanah F, Mabhou F. Full-mouth rehabilitation of a patient with severely worn dentition and uneven occlusal plane: a clinical report. J Prosthodont 2012; 21: 56-64.

8) Homsey FR, Ozcan M, Khoury M, Majzoub ZAK. Comparison of fit accuracy of pressed lithium disilicate inlays fabricated from wax or resin patterns with conventional and CAD-CAM technologies. J Prosthodont 2018; 120: 530-536.

9) Euán R, Figueras-Álvarez O, Cabratos-Terme J, Oliver-Parra R. Marginal adaptation of zirconium dioxide copings: influence of the CAD/CAM system and the finish line design. J Prosthodont 2014; 112: 155-162.

10) Al-Akhali M, Kern M, Elsayed A, Samran A, Chaar MS. Influence of thermomechanical fatigue on the fracture strength of CAD-CAM-fabricated occlusal veneers. J Prosthodont 2019; 121: 644-650.

11) Ozcelik TB, Yilmaz B, Seker E, Shah K. Marginal adaptation of provisional CAD/CAM restorations fabricated using various simulated digital cement space settings. Int J Oral Maxillofac Implants 2018; 33: 1064-1069.

12) Seker E, Ozcelik TB, Rath N, Yilmaz B. Evaluation of marginal fit of CAD/CAM restorations fabricated through cone beam computerized tomography and laboratory scanner data. J Prosthodont 2016; 115: 47-51.

13) Baig MR, Gonzalez MA, Abu Kasim NH, Abu Kassim NL, Farook MS. Effect of operators’ experience and cement space on the marginal fit of an in-office digitally produced monolithic ceramic crown system. Quintessence Int 2016; 47: 181-191.

14) Rakhshan V. Marginal integrity of provisional resin restoration materials: A review of the literature. Saudi J Dent Res 2015; 6: 33-40.

15) Contrepois M, Soenen A, Bartala M, Laviola O. Marginal adaptation of ceramic crowns: a systematic review. J Prosthodont 2013; 110: 447-454.e10.

16) Martinez-Rus F, Suarez MJ, Rivera B, Pradies G. Influence of CAD/CAM systems and cement selection on marginal discrepancy of zirconia-based ceramic crowns. Am J Dent 2012; 25: 67-72.

17) Farrell CV, Johnson GH, Oswald MT, Tucker RD. Effect of cement selection and finishing technique on marginal opening of cast gold inlays. J Prosthodont Dent 2008; 99: 287-292.

18) Dauti R, Lilaj B, Himel P, Moritz A, Schedle A, Cvikl B. Influence of two different cement space settings and three different cement types on the fit of polymer-infiltrated ceramic network material crowns manufactured using a complete digital workflow. Clin Oral Investig 2020; 24: 1929-1938.

19) Renne W, McGill ST, Forshue KV, DeFee MR, Meninno AS. Predicting marginal fit of CAD/CAM crowns based on the presence or absence of common preparation errors. J Prosthodont Dent 2012; 108: 310-315.

20) Ricciutiello F, Amato M, Leone R, Spagnuolo G, Sorrentino R. In vitro evaluation of the marginal fit and internal adaptation of zirconia and lithium disilicate single crowns: Micro-CT comparison between different manufacturing procedures. Open Dent J 2018; 12: 160-172.

21) Nawafleh NA, Mack F, Evans J, Mackay J, Hatamleh MM. Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: a literature review. J Prosthodont 2013; 22: 419-428.

22) Kim JH, Jeong JH, Lee JH, Cho HW. Fit of lithium disilicate crowns fabricated from conventional and digital impressions assessed with micro-CT. J Prosthodont Dent 2016; 116: 551-557.

23) Neves FD, Prado CJ, Prudente MS, Carneiro TA, Zancope K, Davi LR, et al. Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique. J Prosthodont 2014; 112: 1134-1140.

24) Maeder M, Pasie F, Ender A, Ozcan M, Benic GI, Ioannidis A. Load-bearing capacities of ultra-thin occlusal veneers bonded to dentin. J Mech Behav Biomed Mater 2019; 95: 165-171.

25) Edelhoff D, Guth JF, Erdelt K, Brix O, Liebermann A. Clinical performance of occlusal onlays made of lithium disilicate ceramic in patients with severe tooth wear up to 11 years. Dent Mater 2019; 35: 1319-1330.

26) Kale E, Seker E, Yilmaz B, Ozcelik TB. Effect of cement space on the marginal fit of CAD/CAM-fabricated monolithic zirconia crowns. J Prosthodont 2016; 116: 890-895.

27) Pelekanos S, Koumanou M, Koutayas SO, Zinelis S, Eliades G. Micro-CT evaluation of the marginal fit of different In-Ceram alumina copings. Eur J Esthet Dent 2009; 4: 278-292.

28) Krasanaki ME, Pelekanos S, Andreiotelli M, Koutayas SO, Eliades G. X-ray microtomographic evaluation of the influence of two preparation types on marginal fit of CAD/CAM alumina copings: a pilot study. Int J Prosthodont 2012; 25: 170-172.

29) Renne W, Wolf B, Kessler R, McPherson K, Meninno AS. Evaluation of the marginal fit of CAD/CAM crowns fabricated using two different chairside CAD/CAM systems on preparations of varying quality. J Esthet Restor Dent 2015; 27: 194-202.

30) Yıldırım G, Uzun IH, Keles A. Evaluation of marginal and internal adaptation of hybrid and nanoceramic systems with microcomputed tomography: An in vitro study. J Prosthodont 2017; 118: 200-207.

31) Prudente MS, Davi LR, Nabbout KO, Prado CJ, Pereira LM, Zancope K, et al. Influence of scanner, powder application, and adjustments on CAD/CAM crown misfit. J Prosthodont Dent 2018; 119: 377-383.

32) Boening KW, Wolf BH, Schmidt AE, Kastner K, Walter MH. Clinical fit of Procera AllCeram crowns. J Prosthodont Dent 2000; 84: 419-424.

33) Lee H, Kim HS, Noh K, Paek J, Pae A. A simplified method for evaluating the 3-dimensional cement space of dental prostheses by using a digital scanner. J Prosthodont 2017; 118: 584-586.