The Influence of Different Fabrication and Impression Techniques on the Marginal Adaptation of Lithium Disilicate Crowns (A comparative *in vitro* study)

Shatha Saadallah, B.D.S [(1)]
Abdul Kareem J. Al-Azzawi, B.D.S., M.Sc. [(2)]

ABSTRACT

Background: The marginal adaptation has a key role in the success and longevity of the fixed dental restoration, which is affected by the impression and the fabrication techniques .The objective of this *in vitro* study was to evaluate and compare the marginal fitness of lithium disilicate crowns using two different digital impression techniques (direct and indirect techniques) and two different fabrication techniques (CAD/CAM and Press techniques).

Materials and Methods: Thirty two sound upper first premolar teeth of comparable size extracted for orthodontic reason were selected in this study .Standardized preparation of all teeth samples were carried out with modified dental surveyor to receive all ceramic crown restoration with 1 mm deep chamfer finishing line, 4 mm axial length and 6 degree convergence angle. Half of the teeth were duplicated and poured in type IV dental stone to have sixteen dies and then these dies and the remaining teeth divided in to two groups according to the type of digital impression techniques (n=16) as follow: Group A: Indirect digital impression technique scanned by inEos X5 camera; **Group B**: Direct digital impression technique scanned by CEREC AC Omnicam camera. Each group was subdivided according to the technique of fabrication into two subgroups (n=8): Press technique using IPS e-max press (A_1, B_1); CAD/CAM technique using IPS e-max CAD (A_2, B_2).Marginal gaps were evaluated on the prepared teeth at four defined points on each aspect using digital microscope at a magnification of (280X). One way ANOVA and LSD tests were used to identify and localize the source of difference among the groups.

Results: The results showed that indirect digital impression with IPS e-max CAD/CAM group A_2 revealed the poorest marginal integrity with (55.93 μm ± 3.300). Group B_2 and group A_1 were next in line with(44.49 μm ± 6.840 and 37.74 μm± 5.433) respectively, while in the first group of restorations, the result of 29.9 μm ± 5.534 obtained with direct digital impression with pressable ceramic was clearly better.

Conclusions: All the tested digital impression techniques showed clinically acceptable accuracy and intraoral scanning with pressable ceramic significantly enhanced the marginal fit

Key words: Marginal fitness, CAD/CAM system, Digital impression, Press technique. **(J Bagh Coll Dentistry 2017; 29(4):20-26)**

INTRODUCTION

Marginal fit is an important predictor of the clinical success and longevity of dental prosthesis [(1)]. Marginal discrepancy can be defined as the vertical distance from the finish line of the preparation to the cervical margin of the restoration [(2)]. Poor marginal adaptation increases plaque accumulation, recurrent caries and causing periodontal diseases [(3)].

Increasing patients demand for esthetic dental restoration have made metal-free, all-ceramic system more widely distributed due to their enamel-like color, light transmission and improved reproduction of the translucency of natural teeth [(4,5)]. Several ceramic systems which may differ in composition or fabrication technique are available; lithium disilicate is one of them.

Lithium disilicate is a glassy ceramic that has 70% crystalline phase and claim to have optimum esthetics, natural light refraction and high flexural strength in the range of 360-400 MPa [(6)].

(1) Master Student, Department of conservative, college of dentistry, University of Baghdad.
(2) Professor, Department of conservative, college of dentistry, University of Baghdad.

It can be made using either lost-wax hot pressing techniques (IPS E.max Press) or (CAD/CAM) milling procedures (IPS E.max CAD) [(7)].

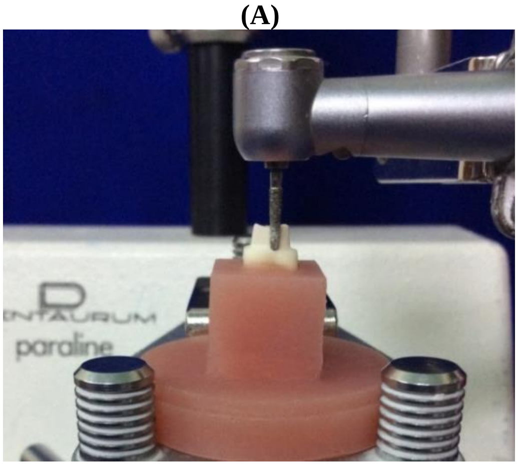
Impressions made with elastomers materials, also known as conventional impressions, represent a commonly used procedure in general dental practice. Low reproduction of the preparation margins, tearing of the impression material and an undistinguishable margin on the stone dies are frequently encountered problems [(8)].

There are several reasons for these problems, including the knowledge and skill level of the practitioner [(9)]. However, there are potential sources of error are not practitioner-related include the disinfection procedures, total or partial separation of the impression material from the tray and transportation to the dental laboratory under different climatic conditions [(10,11)]. To eliminate the need for the traditional impression-taking, model-pouring and laboratory-shipping steps of fabricating crowns, CAD/CAM systems introduced in the dental field [(12)]. Digital Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) is a 3-dimensional scanning technology being utilized in dentistry to increase productivity, patient satisfaction and optimize the quality of the restoration as well as the efficiency of the workflow [13].

MATERIALS AND METHODS

Teeth preparation: Thirty two sound recently extracted maxillary 1st premolar were collected for this study, the root of each tooth was embedded in an individual block of acrylic to about (2mm) below the CEJ by the aid of surveyor. Each specimen was prepared to receive all ceramic crown using high speed turbine hand piece with water coolant that was adapted to the vertical arm of the modified dental surveyor in such a way that the long axis of the clinical crown kept parallel to that of the bur all the way during tooth preparation procedure to ensure the same convergence angle for all specimens (Fig.1). Each specimen was prepared with the following preparation features; a planar (anatomical) occlusal reduction, 1.0 mm depth deep chamfer finishing line, 6 degree convergence angle and 4 mm height (Fig.2).

(A)



(B)

Figure 1: Tooth preparation with modified dental surveyor.

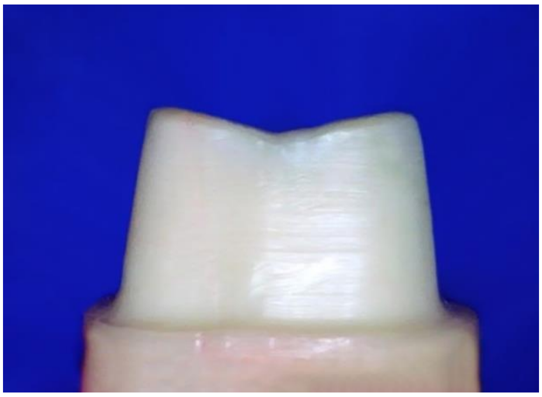


Figure 2: Finished prepared tooth.

Impression procedures

Impression was taken for sixteen teeth by one step impression technique using addition silicone heavy and light body viscosity. The heavy impression material (Express™ XT Penta™ H) was automatically mixed by Pentamix Lite automatic mixing machine (3M ESPE, Germany), while the light body material (Express™ XT) was mixed and dispensed using a garant dispenser (3M ESPE, Germany). The heavy body was injected into the special tray and the light body material was carefully injected on the prepared tooth until the tooth was completely covered then the special tray loaded with heavy body was seated on the specimen by a dental surveyor under a 500 g load until the three guided pines completely engaged the holes in the acrylic base of the specimen (Fig. 3).This procedure was continued sixteen times to get sixteen impression. Impressions were then poured by type IV dental die stone; all the procedure was done according to the manufacturer's instructions.

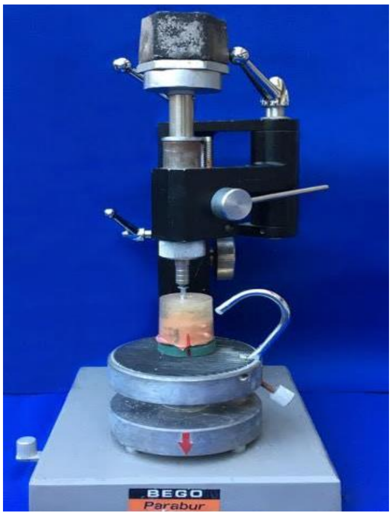


Figure 3: Impression taking with dental surveyor.

Samples grouping

The prepared teeth specimens and the working dies are divided into two groups according to the technique of digital impression:

Group A: Indirect digital impression technique. **Group B:** Direct digital impression technique. Each group was then subdivided into two subgroups according to the fabrication techniques as follow: **A_1:** Indirect digital impression was taken for eight dies using CEREC inEos X5 scanner for the fabrication of eight IPS e-max Press crowns. **A_2:** Indirect digital impression was taken for eight dies using CEREC inEos X5 scanner for the fabrication of eight IPS e-max CAD/CAM crowns. **B_1:** Direct digital impression was taken for eight prepared teeth using intraoral CEREC AC Omnicam camera for the fabrication of eight IPS e-max Press crowns. **B_2:** Direct digital impression was taken for eight prepared teeth using intraoral CEREC AC Omnicam camera for the fabrication of eight IPS e-max CAD/CAM crowns.

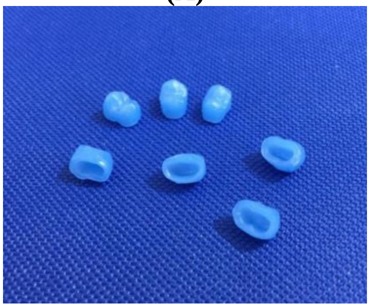
Crowns fabrication

inLab MC X5 (Sirona Dental Systems, Bensheim, Germany) was used to fabricate the full ceramic crowns and the wax patterns using CEREC in-Lab (version 15.2) software.

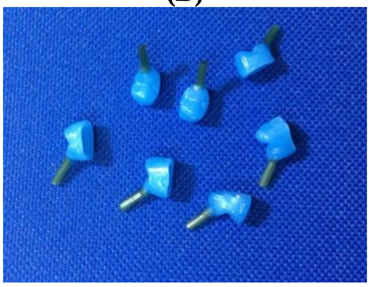
CAD/CAM Crowns fabrication (A_2, B_2): IPS e-max CAD (LT A2, Ivoclar Vivadent, Schaan, Liechtenstein) block was used to construct ceramic crowns for these groups. The crowns were designed using the biogeneric software according to the recommended parameters (80 µm cement spacer and 100 µm marginal thickness) then crystallized in a short 25 minutes firing cycle in a ceramic firing furnace (Programat P310, Ivoclar Vivadent/technical, Schaan, Liechtenstein) at 840ºC according to the manufacturer's instructions.

Pressing fabrication technique (A_1, B_1): The same procedure used for the fabrication of IPS e-max cad crowns was followed here in order to fabricate a digital wax patterns using blue CAD/CAM wax blank (BiLKiM, Izmir, Turkey). The sixteen wax patterns were sprued and invested into the investment ring. The investment ring was then preheated in a burn out furnace at (850ºC) for 45 min. After that, the ring was removed from the preheated furnace and a cold IPS e.max press (LT A2, Ivoclar Vivadent, Schaan, Liechtenstein) ingots were placed inside the investment ring followed by placement of cold IPS Alox Plunger and then transferred into the center of the preheated pressing furnace (programat EP3000; Ivoclar Vivadent Schaan, Liechtenstein) at 920ºC (Fig. 4).

(A)



(B)



(C)

(D)

(E)

Figure 4: Steps of press crown fabrication.

Measurement of the marginal gap

The marginal fit of the crown was calculated by measuring the vertical gap between the margin of the tooth and that of the ceramic crown.

A specially designed holding device was used to apply a static load of (50 N) on the tested crowns to ensure the accuracy of their seating and to hold them in place during the examination [14]. With a Dino-lite digital microscope at a magnification of 280X the measurements were performed on four points on each tooth surface (two on both sides of the indentation): first point was determined on the edge of the indentation whereas the second one was (1mm) from the first point, a total of 16 marginal adaptation evaluation sites for each tooth [15] (Fig. 5). The digital images were captured by (Dino capture software) and then analyzed with image analysis software (Image J, 1.50i, U.S. National Institutes of Health, Bethesda, MA, USA) which was used to measure the vertical marginal gap by drawing a line between the margin of the tooth and that of the crown. Calibration for magnification was made by taking an image of a millimeter ruler at the same magnification (280 X) and input into (Image J) and converted the readings from pixels to (µm) (Fig.6).

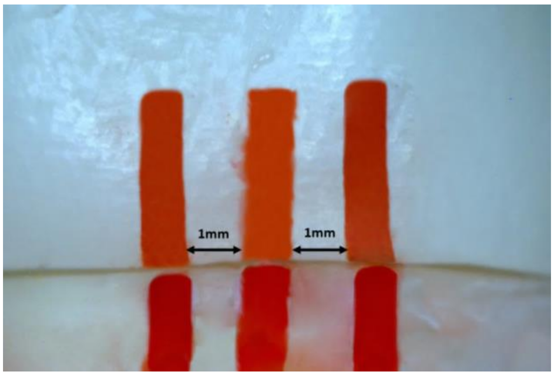


Figure 5: Points of measurement.

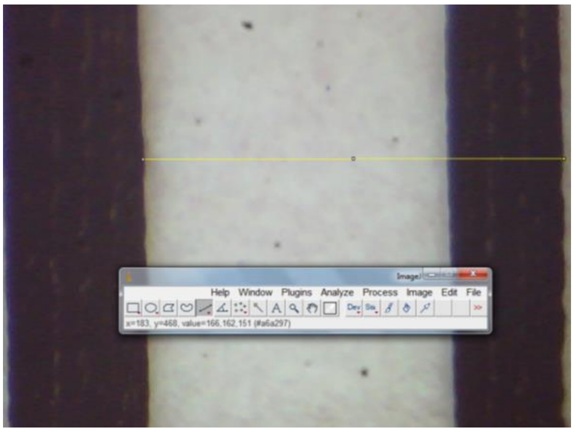


Figure 6: Image of one millimeter at 280X magnification.

Statistical analyses

Data were collected and analyzed using SPSS (statistical package of social science) software version 18.

The following statistics were used:

A- Descriptive statistic: including mean, standard deviation, statistical tables and graphical presentation by bar charts.

B- Inferential statistics

I. One way analysis of variance test (ANOVA) was used to see if there were any significant differences among the means of subgroups.

II. LSD (least significant difference) test was carried out to examine the source of differences among the four subgroups.

RESULTS

Total of (512) measurements of vertical marginal gap from four subgroups were recorded, with 16 measurements for each crown.

Table (1) showed that the highest mean of vertical marginal gap was recorded in group A_2 (55.93 µm ± 3.300).While the lowest mean marginal gap was recorded in group B_1 (29.91 µm ±5.534) and this clearly explained in (Fig.7) while Table (2) and Table (3) showed that there is a highly significant difference in vertical marginal gap among the four subgroups.

Table 1: Descriptive statistics of vertical marginal gap for all groups in (µm) .

Digital technique	Groups		Descriptive Statistics			
			N	**Min**	**Max**	**Mean**
Indirect digital technique	**A**	**A_1**	8	22.029	47.788	37.74±5.433
		A_2	8	43.072	62.169	55.93±3.300
Direct digital technique	**B**	**B_1**	8	17.468	42.276	29.91±5.534
		B_2	8	27.431	59.661	44.49±6.840

Table 2: ANOVA test among the groups.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	27963.264	3	9321.088	160.833	0.000 (HS)
Within Groups	1622.747	28	57.955		
Total	29586.012	31			
HS: P≤0.01					

Table 3: LSD test for comparison of significance between subgroups.

Groups		**Mean Differences**	**P- Value**
A_1	A_2	-18.19	0.000(HS)
	B_1	7.83	0.000(HS)
B_2	A_2	-11.44	0.000(HS)
	B_1	14.58	0.000(HS)
HS: P<0.01			

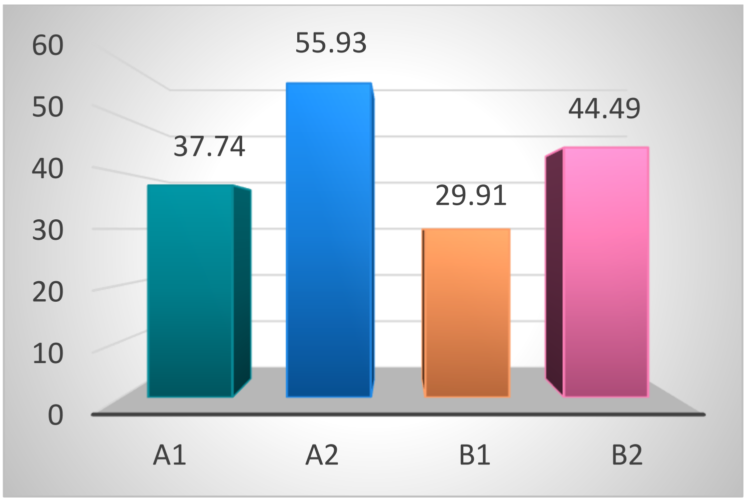


Figure 7: Bar-chart showing the mean values of the marginal gap in (μm) for all subgroups.

DISCUSSION

Results obtained from the current study showed that the marginal gap of the four groups was within the clinically acceptable range because the mean marginal gap with the range of 120 μm have been proposed as being clinically acceptable with regard to the longevity of restorations[16].

Effect of digital impression technique: The results of this study revealed that indirect digital technique groups had significantly higher marginal gap than the direct digital groups.

The higher inaccuracy of the indirect way is always present from the first steps of the process until completion of the definitive restoration due to the fact that conventional impression technique requires numerous steps such as impression materials selection, tray selection, use of adhesives, disinfection, transportation, pouring and since every step in a workflow contributes to the risk of overall failure, the elimination of the conventional impression and its inherent risks, results in higher accuracy [17,18]. On the other hand, direct digital impressions (Omnicam camera) do not require disinfection, land transportation or fabrication of a gypsum cast. Thus, the potential for dimensional inaccuracies could be eliminated, or at least dramatically reduced [17].

The results of this study agree with Jonthan *et al*. (2014) [19] and Khdaier and Ibraheem (2016) [20] who founded that crowns fabricated with direct digital impressions showed more accurate marginal adaptation. However, this finding is in contract with Salem *et al.* (2016) [21] who concluded that the conventional impressions are significantly more accurate. Such disagreement could be due to the difference in the methodology used.

Effect of the fabrication technique: According to the results of this study, crowns fabricated with CAD/CAM technique showed higher marginal gap than crowns fabricated with press technique. This may be due to the shrinkage of the material during crystallization process causing distortion of the margins.

At the time of milling, IPS e-max CAD block is partially crystallized (lithium metasilicate) and the size of particles generally ranges between 0.2 µm and 1.0 µm with a flexural strength of 130 MPa. After crystallization at 840°C for 25 minutes in a furnace, the size of the particles increases under control to 5 µm. Through such modification processes, the flexural strength of the restoration increases to 360 MPa, an increase of 170% [22, 23]. The crystal spacing becomes denser and the proportion of fine lithium disilicate crystals within the glassy matrix increases from 40% to 70% after complete crystallization. Such changes was not fully controllable and causes 0.2% linear shrinkage which affect the overall fit of the dental prosthesis, increasing marginal gaps [24,25,26]. In pressed ceramics, sintering shrinkage during firing may be avoided because it is fabricated by a combination of the lost-wax and heat pressed techniques. In this technique, the complete contour wax pattern is invested and a ceramic ingot is pressed into the resultant investment mold to the full extent of the wax pattern [27].

The result of this study was coinciding with Mously *et al*. (2014) [28] and Neves *et al*. (2014) [29] who found that lithium disilicate restoration fabricated with the press technique had significantly smaller marginal gap than those fabricated with CAD technique.

However, the finding of this study is disagree with study done by Jonthan *et al*. (2014) [19] who found that E-max CAD restoration had significantly smaller marginal gap than E-max press restoration; such disagreement could be due to the difference in the methodology used.

REFERENCES

1. Hamza TA, Ezzat HA, El-Hossary MM, Katamish HA, Shokry TE, Rosenstiel SF. Accuracy of ceramic restorations made with two CAD/CAM systems. J Prosthet Dent 2013; 109(2): 83-87.
2. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthodont Dent 1989; 62(4): 405-408.
3. Maritilo, Gjerdet NR, Tvinnereim HM. The firing procedure influences properties of a zirconia core ceramic. J Dent Mater 2008; 24: 471-475.
4. Christensen GJ. Esthetic dentistry-2008. J Alpha Omega 2008; 101: 69-70.
5. Fasbinder D, Dennison J, Heys D, Neiva G. A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report. J Am Dent Assoc 2010; 141: 105-114.
6. Tysowsky G. The science behind lithium disilicate: today's surprisingly versatile, esthetic and durable metal-free alternative. J Oral Health 2009.
7. Anadioti E, Aquilino S, Gratton D, Holloway J, Denry I, Thomas G, Qian F. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impressions. J Prosthodont 2014; 23: 610-617.
8. Christensen GJ. Laboratories want better impressions. J Am Dent Assoc 2007; 138(4): 527-529
9. Christensen GJ. The state of fixed prosthodontic impressions. Room for improvement. J Am Dent Assoc 2005; 136: 343-346.
10. Al-Bakri IA, Hussey D, Al-Omari WM. The dimensional accuracy of four impression techniques with the use of addition silicone impression materials. J Clin Dent 2007; 18(2): 29-33.
11. Touchstone A, Nieting T, Ulmer N. Digital transition: the collaboration between dentists and laboratory technicians on CAD/CAM restorations. J Am Dent Assoc 2010; 141(2): 15S-19S.
12. Tan PL, Gratton DG, Diaz-Arnold AM, Holmes DC. An in vitro comparison of vertical marginal gaps of CAD/CAM titanium and conventional cast restorations. J Prosthodontics 2008; 17(5): 378-383.
13. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br J Dent 2008; 204(9): 505-511.
14. Beuer F, Aggstaller H, Edelhoff D, Gernet W, Sorensen J. Marginal and internal fits of fixed dental prostheses zirconia retainers. Dent Mater J 2009; 25: 94-102.
15. Lombardas P, Carbunaru A, Mcalarney ME, Toothaker RW. Dimensional accuracy of castings produced with ringless and metal ring investment systems. J Prosthet Dent 2000; 84(1): 27-31.
16. Mclean JW, Vonfraunhofer JA. The estimation of cement film thickness by an in vivo techique. Br Dent J 1971; 131(3): 107-111.
17. Syrek A, Reich G, Ranftl D, Klein C, Cerny B, Brodesser J. Clinical evaluation of all-ceramic crowns fabricated from digital impressions based on the principle of active wavefront sampling. J Dent 2010; 38(7): 553-559.
18. Burgess JO, Lawson NC, Robles A. Comparing Digital and Conventional Impressions and Assessing the accuracy, efficiency, and value of today's systems. J inside Dentistry 2013; 9(11).
19. Jonathan NG, Ruse D, Wyatt C. A comparison of the marginal fit of crowns fabricated with digital and conventional methods. J Prosthet Dent 2014; 112(3): 555-560.
20. Khdaier RM, Ibraheem AF. Marginal fitness of CAD/CAM all ceramic crowns constructed by direct and indirect digital impression techniques: An in vitro study. J Bagh coll Dentistry 2016; 28(2): 30-33.
21. Salem NM, Abdel Kader SH, Al Abbassy F, Azer AS. Evaluation of fit accuracy of compute raided design/computer-aided manufacturing crowns fabricated by three different digital impression techniques using cone-beam computerized tomography. Eur J Prosthodont 2016; 4(2): 32-36.
22. Giordano R. Materials for chairside CAD/CAM-produced restorations. J Am Dent Assoc 2006; 137: 14S-21S.
23. Helvey GA. Retro-fitting an existing crown adjacent to a removable partial denture in a single visit. J Inside Dentistry 2009; 5(3): 34-41.
24. Shen J, Kosmac T. Advanced Ceramics for Dentistry. J El Savier 2014; 227-248
25. Azarbal A. Marginal fit comparison of CAD/CAD crowns milled from two different materials. Master thesis, Pittsuburgh University, College of Dentistry, 2015.

26. Kim J, Seunghan OH, Soo-Hyuk. Effect of the Crystallization Process on the Marginal and Internal Gaps of Lithium Disilicate CAD/CAM Crowns. Hindawi Publishing Corporation 2016.
27. Subasi G, Ozturk N, Inan O, Bozogullari N. Evaluation of marginal fit of two all-ceramic copings with two finish lines. Eur J Dent 2012; 6(2): 163-168.
28. Mously HA, Finkelman M, Zandparsa R, Hirayama H. Marginal and internal adaptation of ceramic crown restorations fabricated with CAD/CAM technology and the heat-press technique. J Prosthet Dent 2014; 112(2): 249-256.
29. Neves FD, Prado CJ, Prudente MS, Carneiro TA, Zancopé K, Davi LR, Mendonça G, Cooper LF, Soares CJ. Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique. J Prosthet Dent 2014; 112: 1134-1140.

الخلاصة

التطابق الهامشي له دور رئيسي في نجاح تركيبات الاسنان الثابتة على المدى الطويل والذي بالتأكيد يتأثر بتقنيات التصنيع والطبعات .

الهدف من هذه الدراسة المختبرية هو لتقييم ومقارنة التطابق الهامشي للتيجان المصنعة من مادة الخزف الزجاجي باستخدام اثنين من تقنيات الطبعات (تقنية الطبعة الرقمية المباشرة وغير المباشرة) واثنين من تقنيات التصنيع المختلفة (مساعدة الحاسوب/المنحوت بواسطة الحاسوب وتقنية الضغط) بواسطة المجهر الرقمي.

تم اختيار (32) من الاسنان الضواحك الاولى العليا ذات الاحجام المتقاربة والمقلوعة لغرض العلاج التقويمي . تحضير موحد ومثالي لجمع عينات الاسنان تم بواسطة جهاز مساح الاسنان المعدل للحصول على 1 ملم حافات لثوية نوع الشدف العميق ،4 ملم طول محوري و6 ملم زاوية تقارب ثم اخذ طبعة لنصف نماذج الاسنان للحصول على نماذج جبسية ثم تقسيم النماذج الجبسية والاسنان المتبقية الى مجموعتين لكل مجموعة (16) عينة .

مجموعة أ:تم تصويرها بتقنية الطبعات الرقمية غير المباشرة باستخدام كاميرا (inEos X5).

مجوعة ب : تم تصويرها بتقنية الطبعات الرقمية المباشرة باستخدام كاميرا(omnicam) .

ثم تم تقسيم كل مجموعة الى مجموعتين لكل منها (8 عينة)

مجموعة أ 1 ومجموعة ب1: تم ترميم الاسنان باستخدام مادة IPS e-mx press.

مجموعة أ 2 ومجوعة ب 2: تم ترميم الاسنان باستخدام مادة IPS e-max CAD.

لقد تم قياس الانضباط الحافي من مستوى عمودي لأربع علامات مؤشرة على وسط كل سطح من اسطح السن (الانسي، الوحشي، الخدي واللهوي) . تم اجراء القياس بواسطة المجهر وبتكبير X280 وبرنامج معالج الصور (image J).

اظهرت نتائج هذه الدراسة ان اقل معدل للفجوة الهامشية كان (29.91 مايكرون) للمجموعة ب 1 واعلى معدل للفجوة الهامشية كان (55.93 مايكرون) للمجموعة أ 2 .

نتائج ال ANOVA احادي الاتجاه وال LSD اظهرت اختلافا احصائيا عاليا بين المجاميع

من هنا نستنتج ان تقنية الطبعات الرقمية المباشرة اظهرت نتائج افضل من تقنية الطبعات غير المباشرة واظهر(IPS e-max Press) افضل نسب تطابق هامشي. مزيج الطبعات الرقمية المباشرة باستخدام كاميرا (Omnicam) مع (IPS e-max) ينتج الهوامش الاكثر دقة.