AJDS LAZHAR
Al-Azhar Journal of Dental Science
Vol. 21- No. 3- 245:251- July 2018
Record 1110-2624 | the ISSN Portal
portal.issn.org

THE INFLUENCE OF FINISH-LINE CURVATURE AND SCANNING METHODS ON THE MARGINAL FIT OF CAD/CAM CERAMIC CROWNS: AN IN-VITRO STUDY

Atef A. Ismail*, Hussein R. Mohammed** *and* Hesham I. Othman***

ABSTRACT

Aim of the study: the purpose of this study was to evaluate the influence of finish line curvature and scanning methods on the marginal gap of CAD/CAM Ceramic crowns. **Methodology:** Forty-two crowns were fabricated from Vita mark II blocks using Cerec in Lab system, and divided into two main groups (21 each) according to the scanning method (direct and indirect scanning). Each group was divided into three subgroups (7 each) according to finish line curvature (1mm, 3mm, and 5mm). Optical impressions for direct group were taken for the dies directly using the Cerec scanner, but for indirect group; physical impression was taken for the dies then poured in stone which scanned by using the Cerec scanner. The completed crowns were cemented to the corresponding dies and the marginal gap was evaluated. The collected data was statistically analyzed using two-way ANOVA test and Post Hoc test and the significance level was set at $p \leq 0.05$. There was no statistically significant difference ($p \leq 0.05$) between subgroups of (1mm) and (3mm) curvature **but** there was statistically significant difference ($p \leq 0.05$) between both subgroups of (1mm and 3mm) curvature and subgroup of (5mm) curvature. **Conclusion:** Finish line curvature more than 3mm has an effect on the marginal gap of Vita Mark II crowns.

INTRODUCTION

The natural appearance of ceramic restorations has made them the treatment of choice for anterior teeth. However, this advantage must be considered against the possible lack of good marginal adaptation, which is essential for the clinical success and quality of a ceramic restoration [1]. Insufficient adaptation of restorations may result in an increase in plaque accumulation, ultimately leading to periodontal disease and secondary caries, which can result in pulpal inflammation [2,3]. Furthermore, exposure of the dental luting agent at the marginal gap to the oral environment also leads to a rapid increase in cement dissolution, a situation which is widely recognized as a major cause of restoration failure[4,5].

The natural gingival architecture and tooth anatomy of the anterior region leads to the greater likelihood of an abutment preparation with a higher degree of finish line curvature in that region than in the posterior region. Furthermore, the labial finish lines of both incisor and canine teeth are often found to be located more apically, a phenomenon attributable to gingival recession. These factors contribute to the need for greater degrees of curvature for abutment teeth in the anterior region [6].

Several authors have demonstrated that the marginal discrepancy of ceramic crowns is influenced by several factors. While some investigations have assessed clinical variables such as tooth preparation geometry or type of cement, in others, factors related to dental laboratory fabrication techniques have been evaluated [7,8]. Most investigators contin-

* Demonstrator, Crown and Bridge Department, Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University.
** Lecturer, Crown and Bridge Department, Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University.
*** Professor, Crown and Bridge Department, Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University.

ued to use the criteria established by McLean and von Fraunhofer (1971) [9] who, after examining more than 1000 crowns, concluded that 120µm was the maximum tolerable marginal opening. Marginal gaps of 1-161µm have been reported in the literature for conventionally fabricated ceramic crowns[10,11]. In contrast, marginal gaps of 17-118 µm have been reported for CAD/CAM-fabricated ceramic crowns [12,13]. Various investigators have also examined the marginal adaptation of CAD/CAM ceramic FDPs[14,15]. It is well known that these systems produce higher quality restorations by using industrially prepared ceramic materials and a standardized manufacturing process which reduces production time [16,17].

Fabricating precisely fitting fixed restoration is a crucial issue for any dentist and for the longevity of the restorations for patients' satisfaction. An accurate impression of the prepared teeth is a must for construction of a definitive cast which will allow for fabricating a precise fixed prosthesis. Addition silicon vinyl polysiloxane impression materials solved the issue of dimensional accuracy, poor taste and odor. They also had high modulus of elasticity, excellent tear strength, superior flowability and lack of distortion. The main drawback of the polysiloxane impression materials is that they are hydrophobic. This can lead to the inability to capture fine details if problems with hemostasis and/or moisture control occur during impression making [18].

Advances in computerization, optics, miniaturization, laser technologies, and introduction of CAD/CAM concepts have enabled the capture of dental impressions. Three-dimensional (3D) digitizing scanners have been used in dentistry for more than 20 years and has improved to obtain virtual impression that undergone a paradigm shift. Most commercially available CAD/CAM systems capture data from models in laboratory, using optical digitizers of various types. As well, some systems offer the possibility to scan the impression directly without cast fabrication [19]. They are sensitive to any motion; these high precision digitizers use technologies that prevent them from being used intraoral. In the dentist office, a conventional impression is taken using impression material and sent to a dental lab where it is scanned or poured in stone. In the dental lab, a bench top optical digitizer allows scanning of impressions, full casts, dies, wax-ups, frameworks, or implant abutments automatically. It also offers a solution for storage of casts and orthodontics treatment planning and analysis. Scanning time is highly dependable on the image resolution, number of CCD (camera) used in the device, and the technology used in a specific system. It may take between 1 to 5 minutes, depending on the device, to scan a model of a three unit (FPD) [19]. Therefore, the hypothesis in this study was the finish line curvature as well as the scanning methods will influence the marginal gap of CAD/CAM ceramic crowns.

MATERIALS AND METHODS

In the present study, a total of 42 acrylic right maxillary central incisors (Columbia Dentoform Corp. New Youk) was used. They divided into two main groups (I & II) according to scanning methods. **Group I:** Twenty-one samples were scanned directly from the jaw model after preparation (Direct method). **Group II:** Twenty-one samples were scanned from poured gypsum casts (Indirect method). Each group was dividing into **3 subgroups** according to finish line curvature (1mm, 3mm, and 5mm).

All acrylic teeth were prepared using milling surveyor (BEGO. PARASKOP, Germany) at the level of 1mm above the mid-point of the mesial cervical margin. The vertical arm of the device was moved down 1mm, 3mm, and 5mm according to a built-in graduation ruler to prepare a mark on the finish line of the facial and palatal surfaces. Then preparation was completed by one operator using high speed handpiece (SUPER torque 660B; KaVo

Dental Products, Lake Zurich, Ill). Six-degrees taper diamond rotary cutting instrument (NTI Diamond Instrument Z847KR 016) was used to create 12 total convergence angle1-mm deep chamfer margin, 2-mm incisal reduction, 1.5-mm axial reduction [20], as illustrated in Figure (1). Each prepared tooth was inserted in the same position in the model cast and tightened with a screw before impression taking.

For direct group; the cast models were sprayed by Cerec® Optispray (Sirona Dental System GMBH, Germany) then optical impressions were repeated for the 21 prepared teeth. But for indirect group; 21 impressions were made (Express ™ STD Poly vinyl siloxane, 3M ESPE-Germany) for the samples, manipulation was done according to manufacturer's instruction, then poured with dental stone (Shera premium, Shera co-Germany) and subsequently scanned with Cerec scanner. All crowns were fabricated from Vita Mark II (Vita-Germany) blocks using Cerec in Lab system (Sirona Dental Systems GmbH, D-64625 Bensheim, Germany) according to the manufacture instruction. Automatic margin detection was done for the virtual die, insertion axis was determined, and restoration parameters were set. The milled crowns were then checked on their corresponding dies and given a serial number according to each group. With the aid of a specially designed cementing device (of 4.0Kg weight) [21], the milled crowns were cemented by Automix TOTALCEM (Itena, Paris, France) self-adhesive resin cement to their corresponding prepared acrylic teeth. The cemented crowns were subjected to measure the vertical marginal gap distance which represented by the vertical distance between the edge of the restoration and the finish line of the acrylic tooth. The marginal gap has been measured by stereomicroscope (Leica EZ4 ND Germany) using a fixed magnification of 35X and integrated digital camera with SD card slot. Then the obtained data were collected and tabulated using Microsoft Excel 2010. The mean vertical marginal gap for each specimen was calculated and then subjected to statistical analysis.

RESULTS

Quantitative data were described using range minimum (Min) and maximum (Max), mean, standard deviation (±SD) and median. Significance of the obtained results was judged at the 5% level. Two way (ANOVA) was assessed to showing the effect of each factor and the interaction between the groups. F-testfor normally quantitative variables, to compare between more than two groups. Data were fed to the computer and analyzed using IBM1 SPSS software package version 20.0 for windows.

Effect of finish line curvature and impression technique on the vertical marginal gap:

According to Post Hoc Test (Tukey), regarding the finish line curvature used in direct impression technique, there was statistically significant difference ($p \leq 0.05$) between subgroup (1) curvature of 1mm (20.38 ± 2.32) and subgroup (3) curvature of 5mm (29.35 ± 2.14). Also, there was statistically significant difference ($p \leq 0.05$) between subgroup (2) curvature of 3mm (22.36 ± 2.60) and subgroup (3), meanwhile there is no statistically significant difference ($p \leq 0.05$) between subgroup (1) and subgroup (2).

Regarding the finish line curvature used in indirect impression technique, there was statistically significant difference ($p \leq 0.05$) between subgroup (1) curvature of 1mm (35.85 ± 1.93) and subgroup (3) curvature of 5mm (42.19 ± 5.33). Also, there was statistically significant difference ($p \leq 0.05$) between subgroup (2) curvature of 3mm (37.87 ± 3.03) and subgroup (3), meanwhile there was no statistically significant difference ($p \leq 0.05$) between subgroup (1) and subgroup (2).

According to Post Hoc Test (Tukey), regarding the scanning methods, there was statistically significant difference between three subgroups (1mm/ 3mm/5mm) in direct technique (20.38 ± 2.32) (22.36 ± 2.60) (29.35 ± 2.14) respectively and three subgroups in indirect technique (35.85 ± 1.93) (37.87 ± 3.03) (42.19 ± 5.33) respectively as shown in table (1) and graphically drawn (Figure 2).

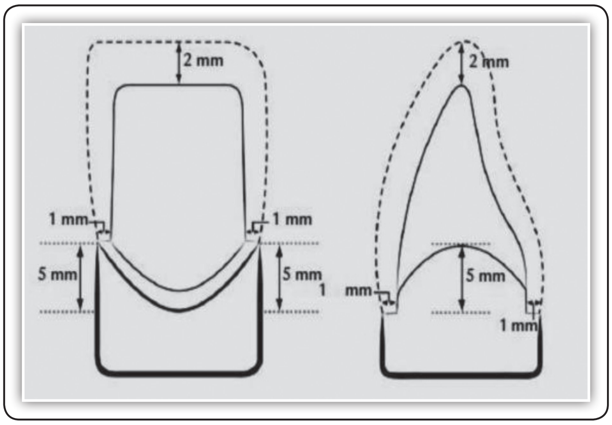

FIG (1) Diagram showing Labial (left) and distal views (right) of 5mm

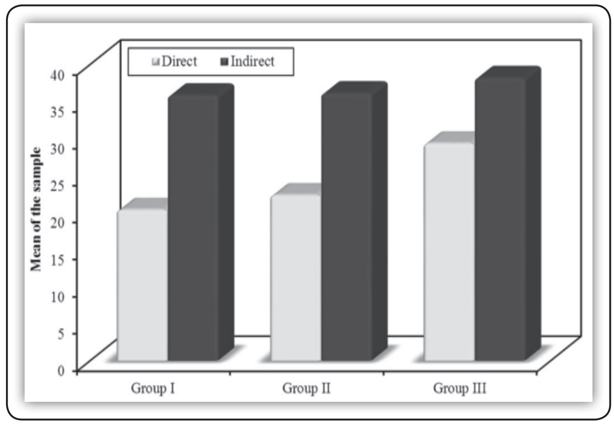

Fig. (2) Diagrammatic chart representing the measurements of the marginal gap in μm of the studied groups according to finish line curvature and scanning methods.

TABLE 1: Comparison between total vertical marginal gap results (Mean±SD) as function of curvature of finish line and scanning methods.

Mean of the sample	Min. – Max.	Mean ± SD.
Group I	17.68 – 23.91	20.38[d] ± 2.32
Group II	17.94 – 25.89	22.36[d] ± 2.60
Group III	26.59 – 32.10	29.35[c] ± 2.14
Group I	33.70 – 38.56	35.85[b] ± 1.93
Group II	30.85 – 41.76	37.87[b] ± 3.03
Group III	34.21 – 49.15	42.19[a] ± 5.33
F	49.700*	
P	<0.001*	

F,p: F and p values for ANOVA test, Significant between groups was done using Post Hoc Test (Tukey)
**: Statistically significant at p ≤ 0.05*

DISCUSSION

The natural appearance of ceramic restorations has made them the treatment of choice for anterior teeth. However, the possible lack of good marginal adaptation is considered to be one of the major shortages of such an esthetic restoration. This Insufficient adaptation may result in not only an increase in plaque accumulation, ultimately leading to periodontal disease, but also secondary caries, which may lead to pulpal inflammation [(2,3)]. Furthermore, exposure of the dental luting agent at the marginal gap to the oral environment also leads to a rapid increase in cement dissolution, a situation which is widely recognized as a major cause of failure for such restorations [(4,5).]

The natural gingival architecture and tooth profile of the anterior region often require some precautions and specifications such as execution of finish line preparation in abutment teeth with a higher degree curvature in that region more than we do in the posterior region [(6)].

Interestingly, the advances made in computer science and technology, CAD/CAM systems have been used widely for construction of ceramic restorations. CAD/CAM systems are available in 3 different production approaches depending on their location: direct (scan intraorally rather than take impression), indirect (impression, cast and scan) and centralized milling center (data scan, sent and restoration milled) [(19)].

The present study evaluated the influence of finish line curvature and impression techniques on the vertical marginal gap width of the ceramic restorations.

In the present study 42 acrylic teeth (totally upper right central incisors) were assembled according to power test. Acrylic teeth were selected in this study for better standardization and because of the variability in the natural teeth. All teeth were prepared by the aid of milling surveyor using diamond stone with taper angle of 6 and tip diameter of 1mm in order to make a 12 total convergence angles of each opposing two surfaces. Then a manual finishing for preparation was done by one operator to adjust the curvature of the finish line. Deep chamfer finish line was employed in all teeth because it is thought to be more compatible biologically and mechanically with the ceramic materials that was subsequently used to cover prepared teeth [22,23].

Selecting of both direct and indirect scanning methods because of many dentists all over the world are still using both methods until now. Using addition silicon impression material because of its high accuracy, elastic recovery, and stability rather than other types of impression materials [18]. The vertical marginal gaps between teeth finish line and restorations in all samples were measured using stereomicroscope. This device was used due to simplicity, availability, not sacrificing the samples and it has used in so many other studies and has proved credibility (10,24).

Four potential measuring sites were selected along the marginal finish line on each axial surface [25]. A total of sixteen readings for each individual crown were obtained. The mean reading of the whole sample has been calculated. Vita block Mark II was used because the restorations were all anterior crowns that is one of the indications of uses of such brand. The choice of inEos Blue scanner was in order to decrease the variables in scanning models and because of the technology of inEos innovation was built on Sirona's intraoral Bluecam technology [26].

The hypothesis of this study was the vertical marginal gap between the teeth and restorations will be affected by degree of finish line curvature and impression technique was accepted by the results of this study. The results of this study showed that (subgroup 1, direct method) showed the least vertical marginal gap (20.38±2.32μm), followed by (subgroup 2: direct method) (22.36±2.6μm), then (subgroup 3, direct method) (29.36±2.14μm), then (subgroup, 1 indirect method) (35.85±1.93μm), (subgroup 2: indirect method) (37.87±3.03μm) and widest vertical marginal gap was seen in (subgroup 3: indirect method) (42.19±5.33μm).

The quantitative evaluation of the marginal adaptation is not yet standardized and can be misleading [27]. According to Guess et al [28]. 100μm is the clinically acceptable marginal gap for ceramics. Another previous study reported that 100 - 200μm is the clinically acceptable range for long-term preserved dental prostheses [29]. All results were within the clinically acceptable range of marginal gap which is set to 120μm by McLean and von Fraunhofer [9].

Regarding the scanning method, the results of the present study showed that direct technique showed less marginal gap than indirect technique. This may be due the smaller number of clinical and laboratory steps in direct technique, and the elimination of human factors. The use of a smaller number of materials may also lead to less marginal gap because this limit the shrinkage of the impression materials and the expansion of the dental stone, in addition to other variables in the indirect methods such as mixing ratios, mixing time, temperature, and storage of the materials. This was in agreement with Syrek et al[30], Boeddinghaus et al. [31] and Lee and Gallucci[32] and disagreement with Yang et al.[33] and Basaki et al.[34]

Regarding the finish line curvature, the results showed no significant difference between subgroups 1 and subgroup 2 in both groups. While there were significant differences between both (subgroup 1 and 2) and subgroup 3. A number of factors which could give rise to the discrepancies in the greater degree of abutment finish line curvature subgroup (3). This could be attributed to the greater the degree of the finish line curvature, the greater the length of the finish line, the greater the precision needed to trace that finish line in impression and restoration fabrication.

Furthermore, the different margin levels relating to the greater degree crown finish line curvature required much greater accuracy of the longer line of the crown margin than the equal margin level of crown margin. Also, the greater the length of the margin may prevent the complete escaping of the excess cement which could affect the seating and the marginal fit of restoration. This was in agreement with a finding of Chu and Cha [6] and Bindl and Mormann [29].

CONCLUSION

Within the limitation of this study, the following conclusions can be drawn:

1- Direct scanning reveals less vertical marginal gap than indirect one.

2- 5 mm finish line curvature recorded the highest vertical marginal gap.

3- The misfit of all restorations was within the clinically accepted range.

CLINICAL RECOMMENDATION

According to the current study, both direct and indirect scanning methods could be used safely regardless of the finish line curvature.

REFERENCES

1. Kelly J. Ceramics in restorative and prosthetic dentistry. Annu. Rev. Mater. Sci. 1997; 27:443–68.
2. Jacobs MS, Windeler AS. An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent 1991; 65:436–42.
3. Goldman M, Laosonthorn P, White RR. Microleakage: full crowns and the dental pulp. J Endod 1992; 18:473–5.
4. Beuer F, Aggstaller H, Edelhoff D, Gernet W, Sorensen J. Marginal and internal fits of fixed dental prostheses zirconia retainers. Dent Mater 2009; 25:94–102.
5. Holden J, Goldestein G, Hittelman E, Clark E. comparison of the marginal fit of pressable ceramic to metal ceramic restorations. J Prosthodont 2009; 18:645–8.
6. Chu A, Cha L. The influence of finish line curvature on the marginal gap width of ceramic copings. J Prosthet Dent. 2013; 109:227–33
7. Quintas A, Oliveira F, Bottino M. Vertical marginal discrepancy of ceramic copings with different ceramic materials, finish lines, and luting agents: an in vitro evaluation. J Prosthet Dent 2004; 92:250-7.
8. Shearer B, Gough M, Setchell D. Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. Biomaterials 1996; 17:1891-5.
9. McLean J, von Fraunhofer J. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971; 131:107-11.
10. Pera P, Gilodi S, Bassi F, Carossa S. In vitro marginal adaptation of alumina porcelain ceramic crowns. J Prosthet Dent 1994; 72:585-90.
11. Sulaiman F, Chai J, Jameson LM, Wozniak WT. A comparison of the marginal fit of InCeram, IPS Empress, and Procera Crowns. Int J Prosthodont 1997; 10:478-84.
12. Bindl A, Mormann W. Marginal and internal fit of all-ceramic CAD/CAM crown copings on chamfer preparations. J Oral Rehabil 2005; 32:441-7.
13. Coli P, Karlsson S. Precision of a CAD/CAM technique for the production of zirconium dioxide copings. Int J Prosthodont 2004; 17:577-80.
14. Castillo de Oyague R, Sanchez-Jorge MI, Sanchez Turrion A, Monticelli F, Toledano M, Osorio R. Influence of CAM vs. CAD/CAM scanning methods and finish line of tooth preparation in the vertical misfit of zirconia bridge structures. Am J Dent 2009; 22:79-83.
15. Kohorst P, Brinkmann H, Li J, Borchers L, Stiesch M. Marginal accuracy of four-unit zirconia fixed dental prostheses fabricated using different computer-aided design/computeraided manufacturing systems. Eur J Oral Sci 2009; 117:319-25.
16. Persson A, Andersson M, Oden A, Sandborgh-Englund G. A three-dimensional evaluation of a laser scanner and a touch-probe scanner. J Prosthet Dent 2006; 95:194-200.
17. Luthardt R, Sandkuhl O, Herold V, Walter M. Accuracy of mechanical digitizing with a CAD/CAM system for fixed restorations. Int J Prosthodont. 2001; 14:146-51.

18. Gonçalves F.S. et al. Dimensional Stability of Elastomeric Impression Materials: A Critical Review of the Literature. Eur. J. Prosthodont. Rest. Dent. 2011; 19:1-4.

19. Quaas S, Rudolph H, Luthardt RG.Direct mechanical data acquisition of dental impressions for the manufacturing of CAD/CAM restorations.J Dent. 2007; 35:903-8.

20. Colpani JT, Borba M, Bona AD. Evaluation of marginal and internal fit of ceramic crown copings. Dent Mater 2013; 29:174–80

21. Beyabanaki E, Siadat H, Fathi B, Alikhasi M and Ghodsi S. Accuracy of implant transfer using closed tray technique with different viscosities of polyvinyl siloxane. 2015; 1:42-47.

22. Rahshenas N . Effect of Shoulder and Deep Chamfer Finish Lines on Marginal Fitness of Electroformed P.F.M. Restorations. J Interdiscipl Med Dent Sci 2014; 2:145.

23. Al-Zubaidi ZAK, Al-Shamma A. The Effect of Different Finishing Lines on the Marginal Fitness of Full Contour Zirconia and Glass Ceramic CAD/CAM Crowns (An in vitro study). J Dent Mater Tech 2015; 4:127-36.

24. Vaswani P, Sanyal K,Gosavi S,Kore A. An In-vitro Comparative Stereomicroscopic Analysis and Evaluation of Marginal Accuracy in Porcelain Fused to Metal Copings Fabricated in Two Different Finish Lines Using Variant Die Materials. J Clin Diagn Res. 2017;11(1).

25. Holmes J, Bayne S, Holland G, Sulik W. Considerations in measurements of marginal fit. J Prosthet Dent 1989; 62:405–8.

26. www.Kuohwa.com.tw/Sirona inEos Blue.

27. Katsoulis J, Mericske-Stern R, Rotkina L, Zbären C, Enkling N, Blatz M. Precision of fit of implant-supported screw-retained 10-unit computer-aided-designed and computer-aidedmanufactured frameworks made from zirconium dioxide and titanium: an in vitro study. Clin Oral Implants Res. 2014; 25:165–74.

28. Guess P, Vagkopoulou T, Zhang Y, Wolkewitz M, Strub J. Marginal and internal fit of heat pressed versus CAD/CAM fabricated all-ceramic onlays after exposure to thermomechanical fatigue. J Dent.2014; 42:199–209.

29. Bindl A, Mormann W. Marginal and internal fit of all-ceramic CAD/CAM crown copings on chamfer preparations. J Oral Rehabil 2005; 32:441-7.

30. Syrek A, Reich G, Ranftl D, Klein C, Cerny B, Brodesser J. Clinical evaluation of allceramic crowns fabricated from intraoral digital impressions based on the principle of active wavefront sampling. J Dent. 2010; 38:553–9.

31. Boeddinghaus M, Breloer ES, Rehmann P, Wostmann B. Accuracy of single-tooth restorations based on intraoral digital and conventional impressions in patients. Clin Oral Investig. 2015; 19:2027–34.

32. Lee S, and Gallucci G. Digital vs. conventional implant impressions: efficiency outcomes. Clin. Oral Impl. Res. 2013; 24:111–15.

33. Yang X et al. Accuracy of Digital Impressions and Fitness of Single Crowns Based on Digital Impressions. Materials 2015; 8:3945-57.

34. Basaki K, De Souza H, Finer Y. Accuracy of Digital vs Conventional Implant Impression Approach: A Three-Dimensional Comparative In Vitro Analysis. Int J Oral Maxillofac Implants 2017; 32:792–99.