Journal of Contemporary Dental Sciences

Original Article

A comparative analysis of marginal accuracy in restorations produced using digital and traditional fabrication techniques

Salsabil Massoud*

Department of Prosthetic Dental Science, College of Dentistry, Qassim University, Qassim, Saudi Arabia

Corresponding Author:
Salsabil Massoud,
E-mail: dr.salsabil.massoud@qudent.org

Access the journal online

Website:
https://jcds.qu.edu.sa/index.php/JCDS

e-ISSN: 1658-8207
p-ISSN: 1658-8193
PUBLISHER: Qassim University

ABSTRACT

Background: Marginal fit of restorations constructed from conventional and digital impressions should be compared, especially with the advent of digital impression procedures, computer-aided design, and computer-aided manufacturing (CAD/CAM) to improve the accuracy of dental restorations.

Materials and Methods: Thirty extracted human molar teeth were divided into three groups – Group I: (10 samples) direct tooth scan using VITA Suprinity, Group II: (10 samples) die scan: using VITA Suprinity, and Group III: (10 samples) control group, used conventional impression that processed to IPS emax Press crowns by the conventional procedures. All tested specimens were examined under a scanning electron microscope. Captures for marginal fit were taken at magnification factor of 150×. Analysis of variance (ANOVA) test was performed to detect a significant interaction between different impression techniques regarding marginal adaptation.

Results: Difference between impression techniques in the same material (VITA Suprinity) regarding marginal fit, when VITA Suprinity crowns were compared with IPS emax press, they recorded 91.3245 μm for direct scan and 99.0060 μm for indirect scan; this result had better marginal fit than conventional technique (using IPS emax press) 123.0265 μm. Although within digital technique itself, the crowns made with direct scan had better marginal fit than the crowns made with indirect scan. However, regarding the ANOVA test, there was no statistically significant difference between tested groups I, II, and III F(p) = 2.481 (0.103).

Conclusion: The combination of the conventional impression and the indirect digitalization/CAD/CAM produced better marginal fit than conventional impression and pressed crowns and the combination of the direct digitalization and VITA Suprinity produced the most accurate marginal fit.

Keywords: Computer-aided design and computer-aided manufacturing, Conventional technique, Direct digitalization, Marginal adaptation, VITA Suprinity

Introduction

The fabrication of a high-quality fixed dental prosthesis requires the expertise of the dentist all along the clinical pathway.[1,2] In addition, the choice of the impression technique seems to influence the accuracy of dental impressions, hence the fitting of the resulting restorations.[3] Digital impressioning procedures may be an approach to improve the accuracy of dental restorations as by their nature these processes eliminate the error-prone conventional impression and gypsum model casting and warrant a high degree of standardization and the information gathered by digital impressioning devices can be entered directly into the digital computer-aided design and computer-aided manufacturing (CAD/CAM) production chain.[4,5] In CAD/CAM, the transformation of the clinical situation into a three-dimensional dataset in the production process of dental restorations can be achieved by direct or indirect digitalization.[6] Indirect, extraoral digitalization starts with a conventional impression that is processed to a gypsum cast and then digitalized in the dental laboratory. In recent years, many new systems for direct, intraoral digitalization have been introduced to dentistry with the aim of digitalizing the workflow.[7] This digital workflow does not require the use of an impression material and trays, leading to improved patient comfort and reduced technique sensitivity.

Using these scanners, an accurate representation of the soft and hard tissues is possible, and a virtual, three-dimensional model is directly produced. This three-dimensional stereolithography file can then be transferred to an automated production device.[8]

Some researchers suggest that the marginal openings ≤120 μm are clinically acceptable.[9,10] When the marginal discrepancies are great, the cement material is exposed to the oral environment, and this leads to a higher rate of cement dissolution, which is caused by oral fluids and chemo-mechanical forces. Moreover, researchers also demonstrated a correlation between increased cement thickness and failure of ceramic restorations.[11,12]

The CEREC system (Sirona Dental Systems, Bensheim, Germany)[13] can be used with a chair-side milling machine, enabling direct, chair-side production of CAD/CAM restorations from industrially manufactured ceramic blocks.[14] The working principle is based on the triangulation of light, with the need for an opaque titanium dioxide powder placed on the tooth surface.[14] In 2000, the CEREC 3 was introduced and the three-dimensional capability was added in 2003. In 2005, the new software enabled the automatic virtual occlusal adjustment.[15] VITA Zahnfabrik offers VITA Suprinity, a new generation of glass ceramic material products. With the aid of an innovative manufacturing process, the glass ceramic is enriched with zirconia (approximately 10% by weight). The results are the world's first zirconia-reinforced lithium silicate ceramic.[16] This study evaluated the marginal fit of CAD/CAM generated all ceramic single crowns made by VITA Suprinity fabricated with digital and conventional methods after direct and indirect digitalization (*in vitro*).

Materials and Methods

The thirty extracted human molar teeth with no caries or anatomical defects were obtained from Oral Surgery Clinic. Teeth were stored at 40°C in 0.9% normal saline until they used for the study, teeth were cleaned, and their roots were embedded in an autopolymerizing resin block.[17] Then, the long axis of the teeth was set perpendicular to the surface of the block. A poly (vinyl siloxane) matrix was made for every tooth prior to any preparation and was sectioned in half in the buccolingual direction. The matrix was served as a guide to verify the amount of tooth reduction for each preparation. All preparations were performed by one investigator, and new diamond burs were used for each preparation.[17] Teeth were prepared for all ceramic crown fabrication, teeth preparation were following accepted guide lines set using a high-speed handpiece, occlusal reduction of 1.5–2 mm and axial reduction of approximately 1–1.5 mm were done, and about a 1 mm deep chamfer margin with 6–10 tapered.[18-20]

Teeth were divided into three groups, Group I: (10 samples) direct tooth scan using VITA Suprinity. Direct scanning was made for the prepared tooth in block using the Cerec in lab scan (sirona), first design modes and restoration type was selected. Moreover, teeth on the visual cast were determined, unnecessary parts of the model were removed by selecting model tools then cut and discard parts. The preparation margins as well as the occlusal limits were identified, contoured, and marked with the software, and insertion axis was detected.[17,21,22]

The internal gap was set to 30 μm, internal gap setting between the prepared tooth and the internal surface of the crown to accommodate the thickness of the luting agent, while the marginal gap was adjusted to 0 μm.[18,19] Once the design of each crown was completed, block size and sprue position were selected, at non-functional cusp. The VITA Suprinity ceramic block (Williams, Ivoclar, Buffalo, NY, U.S.A.) was placed in position in milling unit, and the information was sent to the milling unit through a wireless connection to start milling. All crowns were sintered at 850°C in a ceramic oven, and the completed crowns will be tried on the respective prepared teeth.[17,21,22] Group II: (10 samples) die scan: using VITA Suprinity. Ten custom-made trays were fabricated using acrylic resin.[17] Final impressions were taken with polyvinyl siloxane using custom trays. The master stone dies were fabricated by pouring the final impression; then, the master stone dies were scanned with (CAD/CAM) cerec in lab laser scanning. After that it was evaluated for clarity, data were stored through the computer software. The same computer software was used for designing each crown as same as group I. Group III: (10 samples) control group, used conventional impression that processed to IPS emax Press crowns by the conventional procedures. Outer surface of each crown in all groups was coated by a layer of glaze material and exposed to 1000°C temperature. The other surface was airborne particle abraded to obtain a fitting rough surface ready for bonding to dentin, then etched for 30 s with 5% hydrofluoric acid-etching, washed, and rinsed. Silane copling agent was then applied for 60 s.[23,24]

Cementation procedure

A Rely X Unicem capsule was inserted into the activator and the handle was pressed completely and held for 2–4 s, before insertion into the mixing device (amalgamator), for 15 s at the highest speed.[23] All crowns were cemented to their corresponding molars following specific manufacturer's recommendations under a constant load of 5 kg, which was maintained for 10 min.[22,25] Then, teeth were split mesiodistally into two halves using a slow-speed saw under constant water cooling. All tested specimens were examined under a scanning electron microscope.[26,27] Captures for marginal fit were taken at magnification factor (×150) Figure 1.

Results

Analysis of variance (ANOVA) test was performed to detect a significant interaction between different impression techniques regarding marginal fit.

Comparison VITA Suprinity groups and conventional regarding marginal fit

Means and standard deviations of the marginal gaps of the studied groups using VITA Suprinity comparing digital impression (direct and indirect scanning) with conventional impression using IPS-emax Press as a control group are present in [Table 1].

Results of this study revealed that there was a difference between impression techniques in the same material (VITA Suprinity) regarding marginal fit, when VITA Suprinity crowns were compared with IPS e max press, they recorded 91.3245 μm for direct scan and 99.0060 μm for indirect scan; this result had better marginal fit than conventional technique (using IPS e max press) 123.0265 μm. Although within digital technique itself, the crowns made with direct scan had better marginal fit than the crowns made with indirect scan. However, regarding the ANOVA test, there was no statistically significant difference between tested groups I, II, and III F(p) = 2.481 (0.103), and all the results were within the clinically acceptable results.

Discussion

One major parameter for clinical success is the marginal fit of a restoration. The larger the marginal and internal discrepancy, the more rapid is the rate of cement dissolution and the higher is the risk of bacterial insult, causing pulpal inflammation and necrosis.[28,29] The null hypothesis has to be accepted, results from this study indicated that the direct scan with VITA Suprinity material produced the most accurate and acceptable results, for the marginal fit with direct scan (91.3245 μm) more than the indirect scan for the marginal fit (99.0060 μm). When compared with marginal fit of crowns fabricated by conventional method using IPS e max press as a control group and result was 123.0265 μm for marginal fit, these results show no difference and all the gap sizes for compared groups I, II, and III were found to be within clinically acceptable limits. These results agree with those found in a study by Seelbach *et al.*,[30] where a simplified tooth model was used to compare the internal and marginal fit of crowns fabricated by conventional and digital impression methods using CEREC scanning system. They also found that crowns fabricated by conventional and digital impression techniques have similar marginal and internal fit.

Another study done by Abdel-Azim *et al.*,[31] compared marginal and internal fit of lithium disilicate crowns

Table 1: Comparison VITA Suprinity groups and conventional regarding marginal Fit

Method	Mean(μm)	St. Deviation	F(p)
Direct scan	91.3245	27.47107	2.481(0.103)
Indirect scan	99.0060	41.94638	
Conventional	123.0265	28.16544	

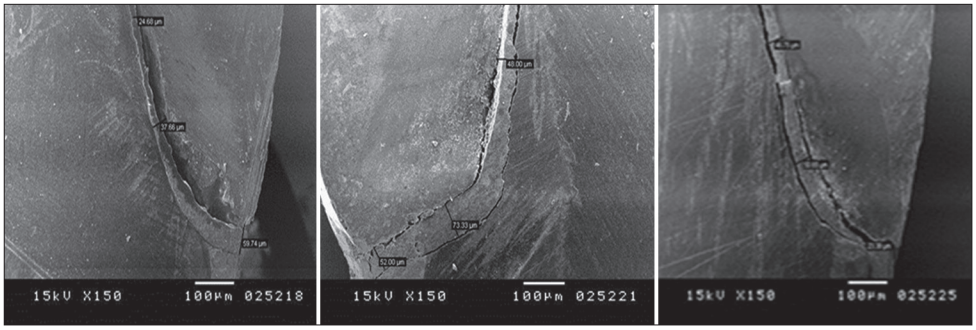

Figure 1: Captures for marginal fit were taken at magnification factor (×150)

(emax CAD) fabricated by CAD/CAM technology and using conventional impression and he concluded that the digital groups did not have a statistically significant difference in marginal and internal gap size compared with the conventional group. The conventional and digital groups had larger variance in average gap size by location. Another study for Jonathan and Ruse[32] who use emax CAD to evaluate marginal and internal fit of crowns fabricated by digital and conventional methods and he found that no difference would be found in the fit of ceramic crowns fabricated with a digital and with a conventional method, but it was smaller than that measured in crowns fabricated with the conventional method. However, the marginal and internal gap of both groups fell within clinically acceptable limits of marginal opening.

The increased marginal gap size of the conventional group could be the result of a number of factors influencing the accuracy of the impression and cast in the conventional impression workflow. The type of tray used can affect the quality of the resulting impression. Plastic or metal stock trays have been shown to increase dimensional inaccuracies when compared with custom trays. A custom tray offers an advantage by providing a uniform thickness of impression material, which improves the accuracy of the resulting cast.[33,34] In this study, custom trays were used to reduce the effect of bulk material on the impression accuracy. Additional factors that can influence the dimensional accuracy of an impression are that the impression is susceptible to dimensional changes over time because of possible instabilities in the tray itself and the impression material.[34] These effects could have influenced the accuracy of the impression and cast in the conventional group.

The use of the conventional method of crown fabrication needs careful selection of materials and meticulous fabrication procedures which are necessary to compensate for expansions and contractions of the different materials involved to create an accurately fitting crown. However, the impossibility of controlling all the variables, combined with a propensity for human error, can result in poor marginal and internal fit and even misfit.[32]

According to the present study, the crowns made from indirect scanning (group II) and crowns made from conventional impression (groups III) have a larger marginal gap than the crowns made from the direct scan (groups I) that means that the combined techniques (conventional impression and indirect scan to the stone cast) were not as accurate as the direct digital impression. However, no significant difference was found between the CAD/CAM crowns made from the direct and indirect scanning and the crowns made by conventional method, indicating that both techniques had a similar accuracy.

On the other hand, Anadioti *et al*.[35] found that the crowns made from the digital impression had statistically significant larger marginal and internal gap than the crowns made from the conventional impression; he explains that the direct comparison between the pressed and the CAD/CAM fabrication techniques should be done with caution since the production methods are so different; in other words, since for the CAD/CAM crowns the dies were scanned, there was the possibility that any irregularities on the dies were "smoothed out" by the software to facilitate the crown fabrication. The reason why the marginal gap of the crowns fabricated by CAD/CAM was statistically larger than that of the crowns fabricated by conventional technique might be attributed to the overall fit of the crown, which may have been affected by the internal adaptation. However, according to the present study, the fabrication of either VITA Suprinity or emax press will result to almost similar marginal fit. Furthermore, results show that CAD/CAM crown margins and internal fit can be accurately produced when either a stone or tooth itself is scanned using CEREC3 scanner.

A suggestion for this occurrence was thought to be possible irregularities on the stone model surface as a result of the fabrication procedure that would not allow a uniform marginal and internal adaptation of the crowns. For the CAD/CAM crowns, the stone models were scanned, which could change the model surface either because of the resolution of the scanner or because of processing of the software that would eliminate any defects interfering with the CAD/CAM procedure.[35]

Another study done by Ahrberg and Lauer[29] which aimed was to evaluate the marginal and internal fit of CAD/CAM fabricated zirconia crowns resulting from direct versus indirect digitalization; he found that the mean of the marginal gap was 61.08 μm (±24.77 μm) for computer-aided impression which was statistically significant difference, the relevance of this difference is debatable because the mean, confidence interval, and maximum value is below the described threshold of 120 μm, indicating acceptable clinical fit. This can also

be explained by the fact that no internal adjustments were necessary for any of the evaluated frameworks produced by digital or conventional impressions at the try-in session. The maximum of the gap values was nearly similar for digital and conventional impressions, with values of 104.65 and 115.76 μm, respectively.

This might be due to that in indirect digitalization where we need to produce a model made out of stone using conventional impression and in contrast, direct intraoral digitalization merges these steps into a digital workflow, this digital workflow eliminates the need for model to fabricate crowns, and this higher inaccuracies in the conventional workflow can be explained by the potential sources of error and the long process chain.[21] Contrary to these findings, the study of Seelbach *et al*.[30] did not find a statistically significant difference between the marginal gap of crowns produced on the basis of digital (CEREC blue cam) and conventional method.

Conclusion

There was a difference in accuracy between the two impression techniques, conventional and digital, considering the marginal fit of the crowns fabricated by those methods. There was no difference in accuracy between the direct and indirect digitalization, considering the marginal fit of the crowns fabricated by those methods. There was an interaction between the impression technique (direct, indirect digitalization, and conventional) and crown fabrication method (press and CAD/CAM), considering the marginal fit of the crowns fabricated by any combination of those methods. The combination of the conventional impression and pressed crowns produced the least accurate marginal fit. The combination of the conventional impression and the indirect digitalization/CAD/CAM produced better marginal fit than conventional impression and pressed crowns. The combination of the direct digitalization and VITA Suprinity, marginal fit in vitro produced the most accurate results.

Funding

This research received no external funding

Data Availability Statement

All data generated or analyzed as part of this study are included in this published article.

Conflicts of Interest

The author has no potential conflict of interest related to the publication of this paper. The authors state that there are no financial and personal relationships with other people or organizations that could inappropriately influence their work.

References

1. Henkel G. A comparison of fixed prostheses generated from conventional vs digitally scanned dental impressions. Compendium 2007;28:422-31.
2. Hwang YC, Park Y, Kim H. The evaluation of working casts prepared from digital impressions. Oper Dent 2013;38:655-62.
3. Frederik JF, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. Clin Oral Investig 2012;17:1201-8.
4. Mehl A, Ender A, Mormann W, Attin T. Accuracy testing of a new intraoral 3D camera. Int J Comput Dent 2009;12:11-28.
5. Syrek A, Reich G, Ranftl D, Klein C, Cerny B, Brodesser J. Clinical evaluation of all-ceramic crowns fabricated from intraoral digital impressions based on the principle of active wave front sampling. J Dent 2010;38:553-9.
6. Christensen GJ. Will digital impressions eliminate the current problems with conventional impressions? J Am Dent Assoc 2008;139:761-3.
7. Beuer F, Schweiger J, Edelhoff D. An overview of recent developments for CAD/CAM generated restorations. Br Dent J 2008;204:505-11.
8. Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques: Evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health 2014;14:10.
9. Belser U, MacEntee M, Richter W. Fit of three porcelain-fused-to-metal marginal designs *in vivo*: A scanning electron microscope study. J Prosthet Dent 1985;53:24-9.
10. Sailer I, Feher A, Filser F, Gauckler LJ, Lüthy H, Hämmerle CH. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int J Prosthodont 2007;20:383-8.
11. Wettstein F, Sailer I, Roos M, Hämmerle CH. Clinical study of the internal gaps of zirconia and metal frameworks for fixed partial dentures. Eur J Oral Sci 2008;116:272-9.
12. Thompson VP, Rekow DE. Dental ceramics and the molar crown testing ground. J Appl Oral Sci 2004;12:26-36.
13. Rekow ED. Dental CAD/CAM systems: A 20-year success story. J Am Dent Assoc 2006;137 Suppl:5S-6.
14. Ahrberg D, Christoph H, Ahrberg M. Evaluation of fit and efficiency of CAD/CAM fabricated all-ceramic restorations based on direct and indirect digitalization: A double-blinded, randomized clinical trial. Clin Oral Invest 2016;20:291-300.
15. Mormann WH. The evolution of the CEREC system. J Am Dent Assoc 2006;137 Suppl:7S-13.
16. Brochure for products of a German company in the dental industry and systems for dental practices and dental Laboratories.
17. Akbar JH, Petrie CS, Walker MP, Williams K, Eick JD. Marginal adaptation of CEREC 3 CAD/CAM composite crowns using two different finish line preparation designs. J Prosthodont 2006;15:155-63.
18. Sailer I, Gottnerb J, Kanelb S, Hammerle CH. Randomized controlled clinical trial of zirconia-ceramic and metal-ceramic posterior fixed dental prostheses: A3-year follow up. Int J Prosthodont 2009;22:553-60.
19. Sorrentino R, De Simone G, Tetè S, Russo S, Zarone F. Five-year

prospective clinical study of posterior three-unit zirconia-based fixed dental prostheses. Clin Oral Invest 2012;16:977-85.
20. Pak HS, Han JS, Lee JB, Kim SH, Yang JH. Influence of porcelain veneering on the marginal fit of Digident and Lava CAD/CAM zirconia ceramic crowns. J Adv Prosthodont 2010;2:33-8.
21. Lee KB, Park CW, Kim KH, Kwon TY. Marginal and internal fit of all-ceramic crowns fabricated with two different CAD/CAM systems. Dent Mater J 2008;27:422-6.
22. Ghazy M, El-Mowafy O, Roperto R. Microleakage of porcelain and composite machined crowns cemented with self-adhesive or conventional resin cement. J Prosthodont 2010;19:523-30.
23. Bilkhair A. Fatigue behavior and failure modes of monolithic CAD/CAM hybrid-ceramic and all-ceramic posterior crown restorations. 2013;35-45.
24. Pagniano RP, Seghi RR, Rosenstiel SF, Wang R, Katsube N. The effect of a layer of resin luting agent on the biaxial flexure strength of two ceramic systems. J Prosthet Dent 2005;93:459-66.
25. Keshvad A, Hooshmand T, Asefzadeh F, Khalilinejad F, Alihemmati M, van Noort R. Marginal gap, internal fit, and fracture load of leucite-reinforced ceramic inlays fabricated by CEREC in lab and hot-pressed techniques. J Prosthodont 2011;20:535-40.
26. Aboushelib MN. Fatigue and fracture resistance of zirconia crowns prepared with different finish line designs. J Prosthodont 2012;21:22-7.
27. Trifkovic B, Budak I, Todorovic A, Hodolic J, Puskar T. Application of replica technique and SEM in accuracy measurement of ceramic crowns. Measur Sci Rev 2012;12:90-97.
28. 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.
29. Ahrberg D, Lauer HC, Ahrberg M, Weigl P. Evaluation of fit and efficiency of CAD/CAM fabricated all-ceramic restorations based on direct and indirect digitalization: A double-blinded, randomized clinical trial. Clin Oral Investig 2016;20:291-300.
30. Seelbach P, Brueckel C, Wöstmann B. Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig 2013;17:1759-64.
31. Abdel-Azim T, Rogers K, Elathamna E, Zandinejad A, Metz M, Morton D. Comparison of the marginal fit of lithium disilicate crowns fabricated with CAD/CAM technology by using conventional impressions and two intraoral digital scanners. J Prosthet Dent 2015;114:554-9.
32. Ng J, Ruse D, Wyatt C. A comparison of the marginal fit of crowns fabricated with digital and conventional methods. J Prosthet Dent 2014;112:555-60.
33. Burton JF, Hood JA, Plunkett DJ, Johnson SS. The effects of disposable and custom-made impression trays on the accuracy of impressions. J Dent 1989;17:121-3.
34. Eames WB, Sieweke JC. Seven acrylic resins for custom tray and five putty-wash systems compared. Oper Dent 1980;5:162-7.
35. Anadioti S, Aquilino SA, Gratton DG, Holloway JA, Denry I, Thomas GW, *et al*. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impression. J Prosthodont 2014;23:610-7.