ORIGINAL ARTICLE

MARGINAL FIT OF CERAMIC CROWNS FABRICATED WITH CAD-CAM TECHNOLOGY USING A DIRECT AND INDIRECT DIGITAL WORKFLOW.

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ABSTRACT

Statement of problem. Digital dentistry is replacing more and more the conventional ways of working in the dental office and with the aid of CAD/CAM software, the statement of 'single visit prosthodontic treatments' is now possible.
Purpose. The purpose of this study was to investigate the marginal fit of CAD/CAM fabricated crowns compared to the conventional method.
Material and methods. A maxillary right second premolar was prepared for an all ceramic crown. Direct digital impressions were taken with an intra oral scanner and ceramic crowns were milled based on the digital design. The prepared tooth was also recorded with two different impression materials, cast in type IV dental stone and scanned. The resulting STL files were used to design and mill the remaining crowns. A plastic stand was printed to secure the crowns positioned on the abutments. Marginal gap was observed and measured with a stereomicroscope.
Results. The lowest total marginal gap values were measured for the PVS sample group with 54,70μm. The values for the Digital group were in close proximity to this value with a total mean of 57,03μm. The highest marginal gap was found for the PVE sample group with a value of 76,66μm.
Conclusions. Direct digital as well as indirect digital methods are able to produce CAD-CAM crowns with marginal gaps within a clinically acceptable range.
Key words: digital dentistry, CAD/CAM, marginal fit, ceramic crown

INTRODUCTION

One of the key steps of obtaining a precise dental prosthesis is represented by an accurate impression [1]. The errors that may appear during this step can generate a multitude of inaccuracies in the final restoration with serious implications regarding the health of gingival margins, tooth structure or the vitality of the prepared tooth [2,3].

Digital methods of fabricating dental prostheses are slowly but surely replacing the work of the dental technicians by reducing the time and the costs without decreasing the precision and predictability of the restorations [4]. Also shifting from impression materials to optical impression allows for a real time inspection regarding the quality of the impression generating better treatment outcomes and more predictable results [5,6].

A digital impression is created following the same steps of the conventional impression: the capture of the prepared tooth, the antagonist teeth and the occlusion, all these being represented by 3D models. These models are used to digitally design the future restoration with the aid of a CAD/CAM software [7]. Due to the fact that virtual impressions do not change their characteristics over time (such conventional impression materials) the risk of distortions is eliminated as well as the potential cross contamination of the dental technician [8].

The conventional impression requires a stricter working procedure and handling of the impression material along with the tray for the registration and preservation of the details of the preparations [9-12]. Also the external factors such as temperature, humidity, the duration between taking the impression and the casting of the gypsum models, all of these can induce distortions of the impression material [13-15].

Marginal fit is also extremely important for a long lasting restoration. It can range from 25μm to 50μm and in some cases even bigger values were declared as clinically acceptable [16-18]. However, there are not that many studies that compare the differences between the digital and conventional impression methods. The aim of this study was to investigate the marginal fit of CAD/CAM fabricated crowns compared to the conventional method.

MATERIALS AND METHODS

A maxillary right second premolar, set in a maxillary typodont (Frasaco, Greenville, N.C.,USA), was decided to serve as the abutment tooth. Before the preparation a condensation silicone key was made on the model and sectioned in half over the center of the premolar in a bucco-palatal direction to serve as a reference for a correct and uniform amount of reduction during the preparation.

At first the occlusal reduction was performed using a coarse grit diamond rotary instrument (Komet) and the functional cusp was reduced by 2mm and the nonfunctional cusp by 1,5 mm. A 45 degrees bevel was added to the functional cusp to guarantee adequate reduction. In the next step the the contact points with adjacent teeth were removed using a coarse grit separating bur. After this the reduction of axial surfaces was performed with coarse grit heavy chamfer bur providing a circumferential reduction of 1,5 mm and a 6-10° tapered preparation. The resulting finish line was a 1,5mm heavy chamfer which was positioned slightly supragingival over the gingival frasaco mask in order to obtain a good contrast for the later scanning process.

Finally, the global amount of reduction was reevaluated with the silicone key and when found to be correct, all surfaces were blend together using a fine grit diamond bur, followed by a final polishing with abrasive discs.

The prepared maxillary premolar was to serve as the abutment for 12 all ceramic crowns fabricated by different methods described in the following sections.

1. The direct digital impression

Four digital impressions were made using a chairside intraoral scanner (Planscan, Planmeca) and the digital model was obtained in order to create the digital design (Fig.1).

2.The indirect digital impression

A total of 8 impressions were obtained using two different types of impression materials. The first group consisted of 4 impressions with Identium Medium (Kettenbach), a Polvinylether material(PVE). Correctly sized maxillary perforated plastic impression trays were chosen and covered with a thin layer of the Identium Polivinylether adhesive provided by the manufacturer and let to dry for 30 min.

After complete dryness was ensured the tray was loaded with the Identium Medium impression material with aid of a Sympress automixing unit (Renfert). The obtained impressions were sent to a master technician in the same day and were poured immediately with Class 4 gypsum (Silky- Rock; Whip Mix Corp).

Other 4 impressions were taken using Honigum (DMG) light and heavy body addition silicone(PVS) that were were poured by the same technician as previously described for the Identium impressions. The resulting 8 casts were scanned with PlanScan intraoral scanner and introduced in the digital workflow of the Romexis software as the digital group before. The same designing steps were necessary and the same registered scan of the mandibular antagonist model could be utilized. In total 12 crowns were milled from IPS Empress CAD blocks (Ivoclar) with the PlanMill 40 milling system (Planmeca) resulting in 4 crowns for each of the 3 sample groups.

In order to evaluate the marginal fit of the CAD/ CAM crowns, several preparatory steps were necessary before the actual measurements could take place. A plastic fixation stand was designed and produced with the aid of a 3D printer. In the center of the base of this base a threaded hole was drilled corresponding to the dimensions of the mini screw which holds the individual frasaco teeth in the frasaco model. In the roof of the stand another threaded hole was drilled (Fig.3).

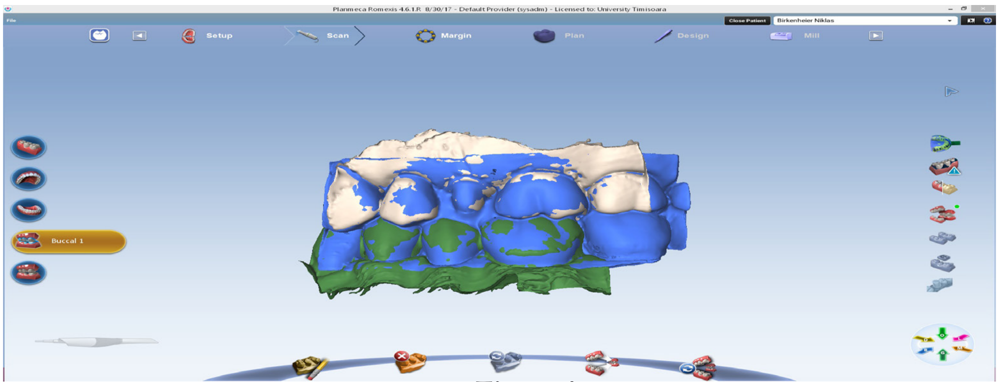


Figure 1.
Digital model in occlusion obtained after scanning with PlanScan Planmeca

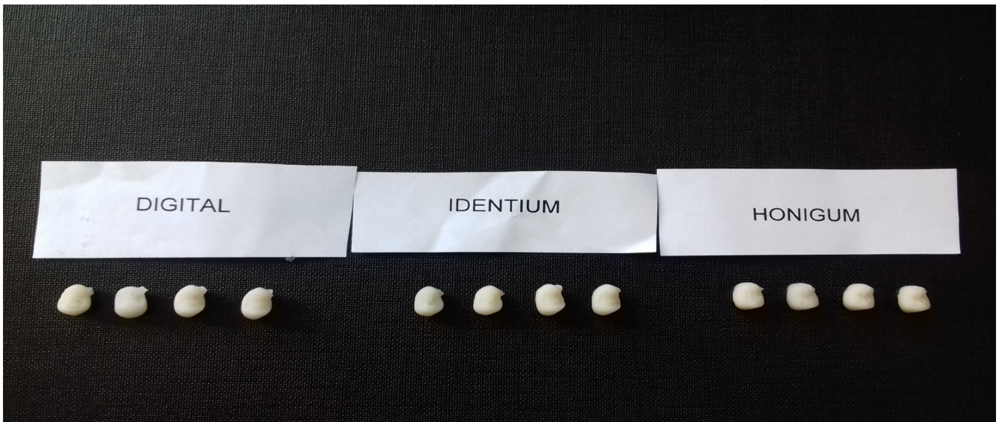


Figure 2.
The three lots of Empress CAD milled crowns obtained with different impression

Figure 3

Occlusal fixation of a sample crown on the abutment tooth

In order to evaluate the marginal fit of the CAD/CAM crowns, several preparatory steps were necessary before the actual measurements could take place. A plastic fixation stand was designed and produced with the aid of a 3D printer. In the center of the base of this base a threaded hole was drilled corresponding to the dimensions of the mini screw which holds the individual frasaco teeth in the frasaco model. In the roof of the stand another threaded hole was drilled (Fig.3).

The prepared abutment tooth was unscrewed from the model stabilized in the stand through its base. Since both the frasaco abutment and the ceramic crowns were of similar color a mean of contrast had to be provided between the marginal gap and the adjacent crown therefore the crown margin was painted with a circumferential 1mm thick line. The same step was repeated on the abutment tooth where the axial wall adjacent to the heavy chamfer was marked black using magnification in order to not to surpass the line angle and avoid coloring the chamfer itself. The specimens were observed and photographed at 40X magnification with a digital camera (D3300, Nikkon) mounted on a stereomicroscope (Edmund E-Zoom) with two additional Telur LED panels providing an improved lateral light distribution. A calibration scale was recorded using the same focus as for the specimens' photographs.

The marginal gap of the specimen was measured using the software Image J (U.S. National Institutes of Health) by defining the known distance on the measuring scale picture in micrometers in Pixel units and the thereby obtained pixel/ micrometer relationship could be globally applied for all pictures. With the aid of the previously described 4 red dots, 4 measurements were obtained for each specimen.

RESULTS

A total of 48 images were obtained, 4 for each crown representing the buccal, mesial, palatal and distal phases of the crown. Using the Image J software one marginal gap measurement at a predefined position for each image was obtained resulting in a total of 48 measurements.

The best total marginal gap values were measured for the PVS sample group with 54,70µm The values for the digital group were in close proximity to this value with a total mean of 57,03µm. The worst total mean was found for the PVE sample group with a value of 76,66µm (Fig 4).

The PVE sample group values were significantly higher than the corresponding PVS group and digital group values for each individual crown and individual surface. Moreover, they also exhibited greater variations.

With a global surface mean of 44,74µm the crown with the best marginal adaptation was sample crown 4 of the digital group while the crown sample with the worst global marginal adaptation was crown sample 9 of the PVE group with a mean value of 89,11µm (Figure 5).

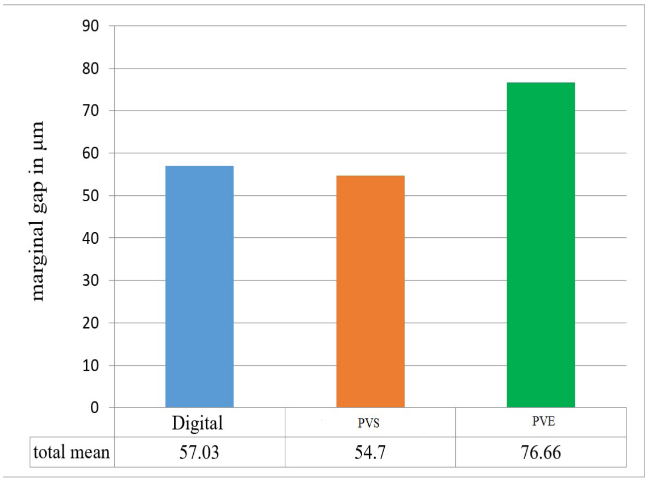


Figure 4

Total mean values of the digital, PVS and PVE groups

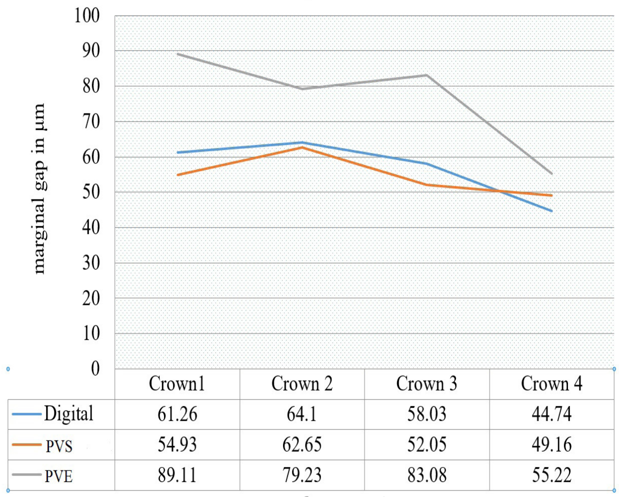
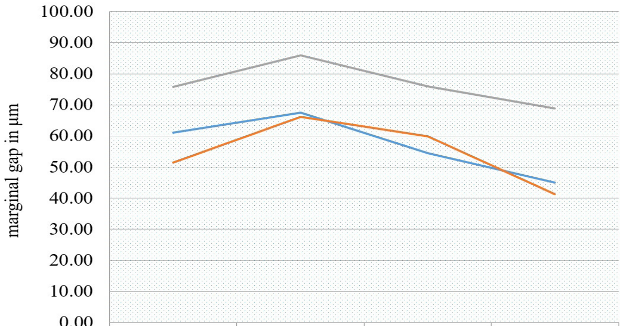


Figure 5

Line diagram showing the marginal gap mean value in µm of all surfaces together of each sample crown

In case of all 3 sample groups the surface with the largest marginal gap was the mesial surface and the smallest marginal gap values were measured at the distal surface.

The largest marginal gap was recorded at the mesial surface of sample crown 11 of the digital group and the smallest marginal gap at the distal surface of sample crown 8 of the PVS sample group (Figure 6).



	buccal mean	mesial mean	palatal mean	distal mean
Digital	61.07	67.49	54.56	45.00
PVS	51.42	66.11	59.91	41.34
PVE	75.85	85.96	75.92	68.91

Figure 6.

Line diagram comparing the mean marginal gap values of the 3 sample groups in the buccal, mesial, palatal and distal surfaces

Chipping defects of varying size and extent could be observed on crown margins belonging to all sampled groups as illustrated in Figure 7.

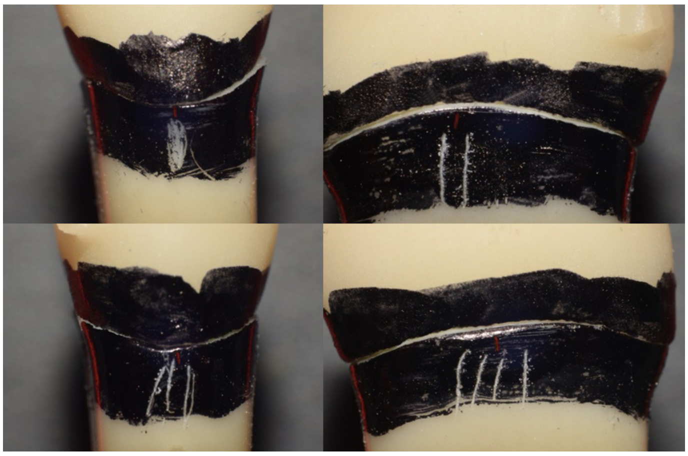


Figure 7.

Crown sample 4 (Digital) from buccal, mesial, palatal and distal view

DISCUSSIONS

The size of the marginal gap is an essential parameter for the quality of a restoration since it influences its survival and thus the success of the prosthetic restoration. A larger marginal gap presents an increased risk for breakdown of the luting cement that fills the area of misfit which ultimately favors the occurrence of a wide set of pathologies ranging from simple carious lesions to periodontal and pulpal pathology [16,17].

This in vitro study compared the marginal adaptation of CAD-CAM crowns fabricated by a direct digital method and an indirect digital method using a Polivinylether and a Polivinylsiloxane impression material.

All the obtained results were found to be below the clinically acceptable marginal misfit value of 120 µm defined by Mc Lean and Frauenhofer, however the ideal marginal gap value of 25-40 µm set by the ADA could not be reached

It was initially expected that the direct digital group would obtain the best results. This was found to be partially true since the best crown sample belonged to this group and the PVS group obtained similar results as the direct digital group. The PVE group was the group with the highest marginal gap values. Its mean marginal gap was found to be ca. 20 µm larger than the gap means of the other 2 groups.

Saadallah used a similar method as in the present study to examine the marginal adaptation of lithium disilicate crowns fabricated by CAD-CAM and heat press methods and also compared the results of direct and indirect digitalization of the aforementioned groups. The impression technique used for the indirect digital approach was a one-step technique using a light body-(Express™ XT) and heavy body addition silicone (Express™ XT Penta™ H). As in the present study all results were found to be within the clinically acceptable range, the indirect digital mean being 55.93 and the direct digital meaning being 44.49 µm [19].

Ahrberg et al used a silicone replica technique to compare CAD-CAM ceramic crowns obtained by in vivo intraoral scanning and scanning of the cast model obtained from a conventional polyether monophase impression with Impregum Penta Soft (3M ESPE, Seefeld, Germany). The mean result of the direct scan was 61 µm and the result of the indirect scan 70 µm. Ahrberg et al concluded the fit of the direct digital group to be significantly better. He also emphasized the advantage in terms of time efficience of this method [20].

Another study by Rai et al examined the marginal gap of metal ceramic crowns by stereomicroscopy and found direct scanning to lead to the smallest marginal gap values, the mean value of the direct digital group being ~40 µm better than the indirect digital group. As in the present study the results were found to be within the clinically acceptable range, however the large difference stands in contrast between the direct digital and indirect digital results stands in contrast to the results of this study [21].

Feruzzi Lima et al conducted a study on the marginal adaptation of CAD-CAM onlays and likewise received results within clinically acceptable range. In this case however the indirect digital method obtained better results than the direct digital group, the mean difference between the two groups being just ~18 µm [22].

Other studies did not scan the cast model obtained by the conventional impression but rather used scannable impression materials.

For instance, Lee et al evaluated the fit of zirconia copings fabricated by direct and indirect digital impression procedures. Apart from the axial and occlusal fit, the marginal adaptation was examined for a sample group fabricated by direct scanning, a second sample group obtained from impression scanning and a third obtained from a lost-wax casting technique. The study did not find significant differences between the three methods and better results were obtained than in the present study with the direct scan group having a marginal adaptation of 18,1 µm and the other groups 23.2 and 32.3µm respectively [23].

During the present study the direct digital approach certainly proved to be less time consuming requiring less steps than the indirect digital method, which necessitated for the impressions to be poured before scanning.

Less steps should also give rise to less inaccuracies so that it was at first rather surprising to find very similar results for the PVS group and the direct scan group. The PVS group was able to record the marginal detail excellently which can be attributed to the high fluidity of the light body correcting the lower ability for detail reproduction of the previously obtained heavy body impression.

This feature was not given for the PVE impression making use of a monophase technique which also corresponds with the results obtained by the aforementioned studies that likewise examined monophase impression materials of a medium viscosity. The simplification of the impression process by just using a medium viscosity in monophase technique seems to come at the cost of not being able to capture such fine detail.

The study was able to fulfill its goal of comparing the direct digital and indirect methods of crown fabrication and provided a reproducible and standardized method of measuring the marginal adaptation without having to sacrifice the integrity of the crown.

In addition to that it could be demonstrated that the type of impression material has an effect on the ultimate size of the marginal gap due to the different behavior and characteristics of impression materials.

It has to be said that a greater number of samples should be included in future studies to further investigate if an indirect digital technique using Honigum addition silicone is consistently able to perform on a similar level as the direct digital method.

Moreover, the number of measuring points should be increased so that the global appearance of the marginal discrepancy is appreciated, rather than just one measuring point for each surface. Chipping defects that were found to be randomly present on all samples could have appeared by chance at the point of measurement on a crown with an otherwise good fit.

Alternatively, a way could be found to calculate the surface of the whole marginal gap in square micrometers rather than to rely on individual measuring points. This should be the ultimate goal since it provides for the possibility of a true anatomical comparison.

Another source of potential inaccuracies was the degradation of the milling bur which was not taken into consideration during the present study. Each milling process will lead to micro changes on the surface of a bur which ultimately influences the precision of a new bur compared to a bur after several milling processes. Therefore, it should be replaced for each sample group or ideally each crown to be milled.

Lastly the placement of the black contrast line was difficult to perform even under magnification and could have potentially given rise to some degree of human error.

CONCLUSIONS

With the limitations of this study, the following conclusions were drawn:

1. Direct digital as well as indirect digital methods are able to produce CAD-CAM crowns with marginal gaps within a clinically acceptable range;
2. The individual characteristics of the impression material utilized in the indirect digital method seem to affect the degree of marginal adaptation;
3. The direct digital method proves to be less time consuming and also requires less technical steps that the indirect digital method;
4. The marginal adaptation of a crown is an essential parameter with respect of the survival of a restoration but it is by far not the sole criteria to be taken into consideration;

Future studies should aim on regarding the area of the marginal gap as a surface area in square micrometers rather than calculating a mean value comprised of representative measuring points to obtain a true image of the dimensions of the marginal gap.

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REFERENCES

[1]. Burton JF, Hood JA, Plunkett DJ, Johnson S. The effects of disposable and custom-made impression trays on the accuracy of impressions. J Dent 1989;17:121-3.

[2]. Janenko C, Smales RJ. Anterior crowns and gingival health. Aust Dent J 1979;24:225-30.

[3]. Bader JD, Rozier RG, McFall WT Jr, Ramsey DL. Effect of crown margins on periodontal conditions in regularly attending patients. J Prosthet Dent 1991;65:75-9.

[4]. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. BrDent J 2008;204:505-11.

[5]. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from20 years of experience. Dent Mater J 2009;28:44-56.

[6]. Mormann WH. The evolution of the CEREC system. J Am Dent Assoc 2006;137:7S-13S.

[7]. Kachalia PR, Geissberger MJ. Dentistry a lacarte: in-office CAD/CAM technology. J Calif Dent Assoc 2010;38:323-30.

[8]. 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.

[9]. Dixon DL, Breeding LC, Brown JS. The effect of custom tray material type and adhesive drying time on the tensile bond strength of an impression material/adhesive system. Int J Prosthodont 1994;7:129-33.

[10]. Mandikos MN. Polyvinyl siloxane impression materials: an update on clinical use. AustDent J 1998;43:428-34.

[11]. Herrera SP, Merchant VA. Dimensional stability of dental impressions after immersion disinfection. J Am Dent Assoc 1986;113:419-22.

[12]. Johansen RE, Stackhouse JA Jr. Dimensional changes of elastomers during cold sterilization. J Prosthet Dent 1987;57:233-6.

[13]. Corso M, Abanomy A, Di Canzio J,Zurakowski D, Morgano SM. The effect of temperature changes on the dimensional stability of polyvinyl siloxane and polyether impression materials. J Prosthet Dent1998;79:626-31.

[14]. Rodriguez JM, Bartlett DW. The dimensional stability of impression materials and its effecton in vitro tooth wear studies. Dent Mater 2011;27:253-8.

[15]. Thongthammachat S, Moore BK, Barco MT, Hovijitra S, Brown DT, Andres CJ. Dimensional accuracy of dental casts: influence of tray material, impression material, and time. J Prosthodont 2002;11:98-108.

[16]. Jacobs MS, Windeler AS. An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent1991;65:436-42.

[17]. May KB, Russell MM, Razzoog ME, Lang BR. Precision of fit: the Procera AllCeram crown. J Prosthet Dent 1998;80:394-404.

[18]. Mclean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131:107-11.

[19]. Shatha Saadallah, B.D.S, Abdul Kareem J. Al-Azzawi, B.D.S., M.Sc. The Influence of Different Fabrication and Impression Techniques on the Marginal Adaptation of Lithium Disilicate Crowns (A comparative in vitro study). Bagh Coll Dentistry 2017; 29(4):20-26

[20]. Danush Ahrberg, Hans Christoph Lauer, Martin Ahrberg, Paul Weigl. 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) 20:291–300DOI 10.1007/s00784-015-1504-6

[21]. Rai R, Kumar S A, Prabhu R, Govindan RT, Tanveer FM. Evaluation of marginal and internal gaps of metal ceramic crowns obtained from conventional impressions and casting techniques with those obtained from digital techniques. Indian J Dent Res 2017;28:291-7

[22]. Fernanda Ferruzzi Lima, Constantino Fernandes Neto, José H. Rubo, et al. Marginal adaptation of CAD-CAM onlays: Influence of preparation design and impression technique. J Prosthet Dent 2017

[23]. Bora Lee, Kyung Chul Oh, Daewon Haam. Evaluation of the fit of zirconia copings fabricated by direct and indirect digital impression procedures. J Prosthet Dent 2017