

Influence of Digital Techniques on Marginal and Internal Adaptation of all Ceramic Implant Supported Crown

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Abstract

Statement of the Problem: The emergence of different types of scanners and competition in the market raise a question on the influence of these different scanners on the margin accuracy and internal fit of the CAD/CAM generated all-ceramic crowns.

Material and Methods: The prefabricated titanium implant abutments used in this study were selected representing upper first premolar. Three implant abutments were divided into 3 groups as follows: Group 1: consisted of 5 scans with the Cerec Bluecam. Group 2: consisted of 5 scans with the Cerec Omnicam. Group 3: consisted of 5 scans with the Cerec Ineos camera. The vertical marginal gap distance between the crown and the implant abutment was measured using stereomicroscope connected to computer and digital camera. Measurements were made at thirty points for each surface of the crown. A rubber base replica of the space between the crown and the implant abutments was made for each tested specimen to assess its internal fit using the stereomicroscope. The recorded data were collected, tabulated and statistically analyzed.

Result: It was found that the mean and standard deviation values of marginal accuracy data were $130 \pm 3 \mu\text{m}$, $320 \pm 3 \mu\text{m}$ and $100 \pm 2 \mu\text{m}$ with Blue cam, Ineos and Omnicam, respectively. The mean and standard deviation values of internal fit data were $420 \pm 21 \mu\text{m}$, $260 \pm 16 \mu\text{m}$ and $290 \pm 15 \mu\text{m}$ with 3D Blue Cam, Ineos and Omnicam respectively. Result of obtained from Cone beam C.T. revealed that the mean and standard deviation values of internal fit data were $450 \pm 26 \mu\text{m}$, $400 \pm 23 \mu\text{m}$ and $360 \pm 22 \mu\text{m}$ with 3D Blue Cam, Ineos and Omnicam respectively (P-value < 0.05).

Conclusion: Within the limitations of this study, the following conclusions could be drawn: Digitizing techniques (Bluecam, Omnicam and Ineos) had a great influence on the marginal adaptation and internal fit of all-ceramic crowns placed on implant-abutment. Bluecam are the most appropriate digitizing technique in obtaining the best marginal adaptation compared to Ineos. Marginal accuracy and internal fit values recorded in the tested groups lied within the range of clinical "acceptance (100 - 200) μm ". Omnicam scanner is not an appropriate digitizing technique in obtaining the best internal fit compared to bluecam and Ineos.

Keywords: Margin Accuracy; Internal Fit; CAD/CAM; Implant-Abutment; Omnicam; Cone Beam

Introduction

Dental impressions are an important step in restorative dentistry. They transfer the intraoral situation to an extraoral cast, the accuracy of which influences the fit of the restorations, an important factor in the longevity of the final restoration [1]. Traditionally, there are two different implant level impression techniques: pick-up (open tray) and transfer (close tray) techniques [2]. All these techniques

require time and cause tissue inflammation. Otherwise the personal errors (laboratory and clinic) are increased during construction of crown. To increase the accuracy in restoring missing tooth we need to it was necessary neglected all manipulative mistakes.

Hence, in application of the computer-aided design and computer-aided manufacturing (CAD/CAM) techniques, the manufacturing of the restoration is performed either in the dental laboratory using conventional techniques or chair side based on intraoral data acquisition. The idea of intraoral data acquisition is to substitute the conventional impression techniques with an optical impression and to avoid errors caused by the conventional procedure. To avoid reflections influencing intraoral digitizing, refractive powder has to be applied to the abutment to be digitized.

The CAD/CAM systems are formed basically from three main elements: (1) a scanner: data acquisition units that register all the preparation design and the surrounding structures. (2) A software: that creates a virtual restoration and establishes all the milling parameter, and (3) a milling machine: that manufacture the restoration using solid blocks of the chosen restorative material. The precision of these three elements combined will dictate the success of system [3].

A new intraoral acquisition unit (Cerec Omnicam) has been recently launched in the market [6]. This camera captures highly detailed images using a powerful light emitting diode (LED). However, there is no evidence whether these digitizing techniques can influence the margin and internal fit of the crown. A close marginal adaptation is crucial for the long-term prognosis of the restoration [4]. Misfit of all-ceramic restoration reduces longevity and have other adverse effects such as soft tissue irritation, dissolution of cement and discoloration [5]. It was found worth to study the influence of digitizing techniques on marginal and internal adaptation of all ceramic implant supported crown.

Material and Methods

Material used in this study

1. Three Titanium Implants screw.
2. Three Titanium Implant abutments.
3. Vita Mark II Blocks (15 blocks).
4. One Cerec Optisprays (50 ml).
5. Light body Vinyl Polysiloxane impression material (One box).
6. Putty vinyl Polysiloxane impression material (One box).

Methods

Master model fabrications

The prefabricated titanium implant abutments used in this study were selected representing upper first premolar. A specially designed copper squared shape sample holder (2.5 × 2.5 × 2.5 cm) was constructed in order to put the implant screws in epoxy resin* blocks. A special device (centralizer) was fabricated to allow accurate vertical centralization of the implant screw in the sample holder during construction of the epoxy resin block. The device consisted of a lower aluminum base having equally spaced wedges to hold the sample holder and a steel vertical rod fixed to the aluminum base. A horizontal arm was connected to the vertical rod can move up and down in an exact vertical direction by means of screw.

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A vertical cylinder with a central opening is connected to the horizontal arm to which the implant screw is mounted at 90° angle and securely fixed using a screw. The inner surfaces of the walls of the sample holder were painted with separating medium**. The recommended proportions of the powder (polymer) and the liquid (monomer) of the epoxy resin was mixed according to manufacturer's instructions and poured immediately into the sample holder.

The horizontal arm was moved downwards allowing the implant screw to be introduced along its long axis into the center of the resin filled sample holder until the whole screw was embedded, and kept stable till complete polymerization of the resin. Implant abutments were screwed over the implant screws using a special tapered hex tool. The abutment hole was filled with wax (Figure 1).



Figure 1: Epoxy resin block with titanium abutment.

Samples Distribution

The samples were divided into 3 groups each group was divided into according to digitizing techniques:

- Group 1: Implant abutment was scanned 5 times with the Cerec Bluecam* for the production of 5 crowns.
- Group 2: Implant abutment was scanned 5 times with the Cerec Omnicam* for the production of 5 crowns.
- Group 3: Implant abutment was scanned 5 times with the Cerec Ineos Blue* for the production of 5 crowns.
 - The new Cerec SW 4.2 software was used for scans procedures for all groups.

Group 1 (bluecam scanning)

In order to obtain a sharp image without blurring, the abutment was sprayed with an even thin layer of opti spray. The spray applied at the rest of the abutment was sprayed at an angle of 45 degree to ensure that the abutment was coated with a thin even layer, as leaving parts of the abutment unsprayed may influence the scanning while a thick spray layer may influence the internal fit of the final crown.

On the computer screen of acquisition unit, a new file was created in the administration phase under the name of bluecam. The icon of "single restoration" was then selected the type of restoration "crown" was clicked to the upper left first premolar. The design modes "Biogeneric individual" then "next" button was clicked and the abutment was ready for scanning. Before scanning the shake sensitivity of the camera was set to "strict". This option determines how much camera shake is permitted in the automatic mode. The camera was then manually placed over the abutment, and the image was automatically captured when the camera was steady to obtain a clear, sharp and blur free image. From this optical impression, the software generated a 3D virtual abutment. This image was finally stored on the computer, and the procedure was repeated 5 times to obtain five different scans of the abutment (Figure 3).

**Ainsworth Separating Medium, U.S.A

Group 2 (Cerec Omnicam)

There was a complication during scanning on Cerec Omnicam which was the complication in the form of improper response during scanning the implant abutment which necessitated the placement of it in an acrylic cast to simulate the anatomical arch (Figure 2). The implant-abutment was scanned without coating with cerec optispray.



Figure 2: Implant-abutment in acrylic cast.

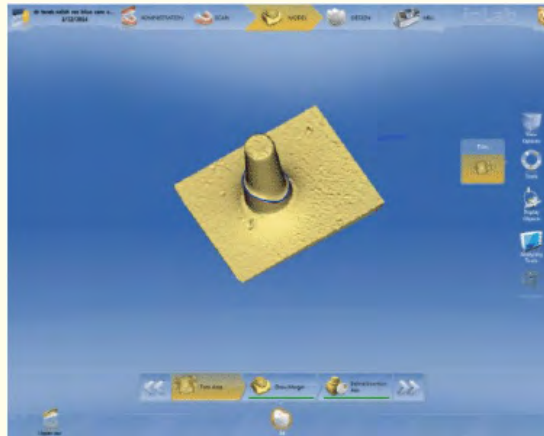


Figure 3: The scanned Abutment.

The Omnicam was manually placed over the abutment, and the image was automatically captured when the camera was steady to obtain a clear, sharp and blur free image.

From this optical impression, the software generated a 3D virtual abutment. This image was finally stored on the computer, and the procedure was repeated 5 times to obtain five different scans of the abutment.

Group 3 (Cerec Ineos blue scanning)

In this group, the abutment scanning was done by the rotational scan technique of the Cerec Ineos blue.

Preparing the model

The abutment was secured in the center of the rotation mouse after being covered with optispary. A model holder was used to tilt the implant abutment at an angle of 15°.

Scanning of the implant abutment

The rotational scan icon was clicked and then the rotation mouse was moved on the shifting plate until the entire abutment was displayed in the image field.

The rotation mouse was rotated to ensure the implant abutment remained in the image field in every position, and then the focus of the image was adjusted by the aid of the rotary knobs until a sharp, clear blur free image was obtained. The start button on the Ineos blue was clicked where 8 single scans were taken in rapid succession.

The computer software combines these 8 scans until a single clear image is displayed on screen. The image was stored. The process was repeated 5 times to produce 5 crowns.

Designing the ceramic crown

Margin identification

The position of the finish line was defined using the automatic margin detector, where the Cerec software automatically detects the preparation margin when the cursor is moved along the preparation border.

The procedure started by double clicking the left mouse button at a clearly visible position on the preparation margin, where a red dot appeared indicating this starting point.

The cursor was then moved along the preparation margin where a green line appeared indicating that the automatic margin detector is active. After tracing the margin the line was fixed with a single click. The line color became blue and will not change its position.

Trimming undesired areas: Trimming serves to hide the adjacent teeth and undesired areas, comparable to create a saw cut model. To start the process the icon "Trim Area" on the step menu was clicked. Trimming was performed using the so-called trim line, which dissects the model and remove the undesired areas.

Defining the insertion axis

The insertion axis determines the alignment of the 3D model in the virtual design. This is very important for the generation of the initial proposal and milling the restoration. The undercuts or areas, which may interfere with the insertion of the restoration, are highlighted with yellow color. The model was rotated until no undercuts marked with the yellow color were visible. The "OK" icon was then clicked to confirm the insertion axis. The model phase was completed and the "next" icon was clicked to proceed to the design phase.

Adjusting the spacer: This parameter determines the space between the crown and the implant abutment and hence the degree of friction. Ceramic crowns should display a passive fit. The die spacer was set to 25 µm as Aditya Priyam., *et al* [20].

Framework design: The design of the crown was performed using the biogeneric feature of the Cerec software and it was not modified (Figure 4).



Figure 4: Crown Design.

Milling the crown: To start the milling process the type and size of the used ceramic block were selected. The selected block Vita Mark II size 12 was plugged into the spindle in the milling chamber and secured in place by the setscrew. The door of the milling chamber was then closed. The start button was clicked to begin the milling of the crown by two diamond burs under copious irrigation. The left instrument used was the “step bur 15” while the right one was the “cylinder pointed bur 15.” This process was performed 15 times to produce the 15 crowns. Obtained from the 15 different scans of the 3 groups.

Adjusting the crown: After milling the door of the milling chamber was opened. The ceramic block was loosened from the spindle with the setscrew. The crown was then removed and the sprue was cut using a diamond wheel.

Glazing Firing: Glaze firing was conducted using paste glaze* mixed ceram glazing liquid and an even layer was applied on the entire surface of the crown using brush. Then, the glazing firing was carried out according to manufacturer’s firing parameters. Finally, the ceramic crowns were ultrasonically cleaned and were then checked using magnifying lens to detect any defects, irregularities or cracks before being checked for proper seating on their corresponding implant abutment. Each ceramic crown was then placed on the corresponding implant abutment to check its seating accuracy before microscopic measurements guided by finish line configuration of the implant abutment being more cervical on the buccal surface, Eight guiding vertical lines were made on both the crowns and the epoxy resin blocks using an indelible pen (mid-buccal, mid-lingual, mid-mesial, mid-distal, mesio-buccal, disto-buccal, mesio-lingual and disto-lingual line angles) to provide fixed points for vertical marginal gap distance measurements (Figure 5).



Figure 5: 8 points of measurements in magnification 40x

*Ivoclar Vivadent, Schaan, Liechtenstein.

The vertical marginal gap distance of the ceramic crowns were checked microscopically at the eight predetermined points to ensure that it was within the acceptable range (less than 150 μm) [26].

Microscopic measurement of the internal fit

A polyvinyl siloxane replica of the space between the Implant abutment and the ceramic crown was made for each tested specimen. A light body silicon impression material was injected in the fitting surface of the crown. The crown was then seated under constant pressure using the holding device (jig) to make sure that the crown reached the margin of the implant abutment. After setting of the light body impression material, the crown was removed from the implant abutment, resulting in a thin film of light body representing the space between the crown and the implant abutment (Figure 6). For the purpose of stabilization of the light body film inside the crown, a heavy poly vinyl siloxane rubber base impression material was injected into the crown with the light body film.



Figure 6: The film thickness was measured.

After setting, an H-endodontic file was embedded into the heavy body to facilitate the separation of ceramic crown from two layer of the siloxane rubber base impression. The silicone block obtained from each crown was sectioned with a razor blade bucco-lingually with extremely care was exercised to equalize each portion.

The film of light body thickness was measured at six points for each specimen using a stereomicroscope with precision of + 0.5 with magnification x40.

The image was recorded with a digital camera fit on the microscope. The images were exported to a computer and analyzed with an image-processing program. Then data were collected, tabulated and statistically analyzed.

Cone Beam measurement of the internal adaptation

Since, the cone beam measure only radiopaque materials (Gutta percha). Gutta percha replica of the space between the Implant abutment and the ceramic crown was made for each tested specimen.

A thermo-plastic Gutta percha (Obtura II system)* was injected in the fitting surface of the crown. The crown was then seated onto the implant abutment constant pressure using the holding device to make sure that the crown reached the margin of the Implant abutment.

After setting of the Gutta percha, the crown was removed from the Implant abutment, resulting in a thin film of Gutta percha adherent to inner surface of the crown representing the space between the crown and the Implant abutment. Gutta percha stick to the inner surface of the crown due to the surface of abutment is very smooth and the inner surface of the crown is rough.

*Obtura Spartan, Earth City, MO.

For the purpose of stabilization of the Gutta percha film inside the crown, a pink wax was slightly softens then packed into the crown lined with the Gutta percha film to facilitate cone beam measurement.

Planmeca ProMax® 3D Max is a dedicated 3D imaging device that produces all required volume sizes for diagnosing the maxillofacial region – from the smallest special cases to images of the entire head. CBCT X-ray unit is designed to obtain complete information on your patient’s anatomy in the minutest detail. After the exposure, the software of Planmeca was used to detect and measure the film thickness of Gutta percha at six points for each specimen.

The image was recorded. The images were exported to a computer and analyzed with an image-processing program (Figure 7 and 8). Then data were collected, tabulated and statistically analyzed.

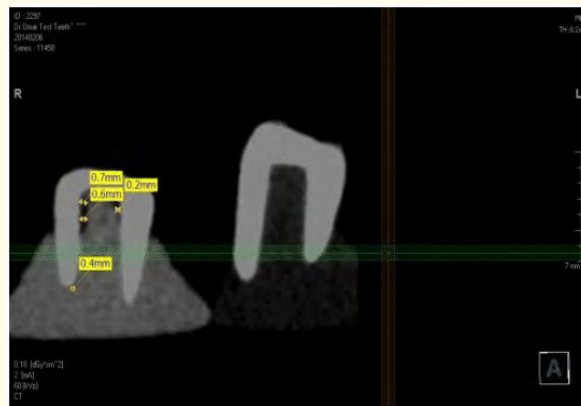


Figure 7: Longitudinal section of the samples.

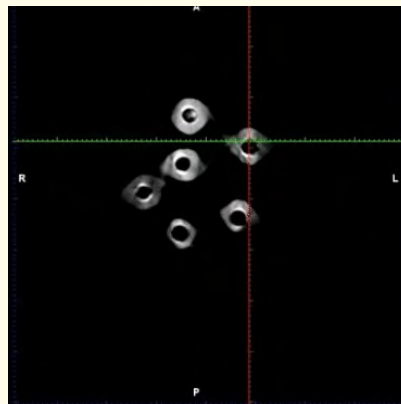


Figure 8: Cross section of the samples By CBCT.

Results

Data were presented as mean and standard deviation (SD) values. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. All measurements showed non-parametric distribution, so Kruskal-Wallis test was used to compare between the three groups. Mann-Whitney U test was used for pair-wise comparisons when Kruskal-Wallis test is significant.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Overall marginal adaptation (mean of the four surfaces)

There was a statistically significant difference between marginal adaptation of the three groups (P -value = 0.024). Pair-wise comparisons between the groups revealed that Ineos showed the statistically significantly highest mean marginal adaptation. There was no statistically significant difference between Blue and Omni; both showed the statistically significantly lowest mean marginal adaptation (Table 1 and Figure 9).

Blue		Ineos		Omni		P-value
Mean	SD	Mean	SD	Mean	SD	
130 ^b	3	320 ^a	3	100 ^b	2	0.024*

Table 1: The mean, standard deviation values and results of Kruskal-Wallis and Mann-Whitney U tests for comparison between marginal adaptations of the three groups

*: Significant at $P \leq 0.05$, Different superscripts are statistically significantly different

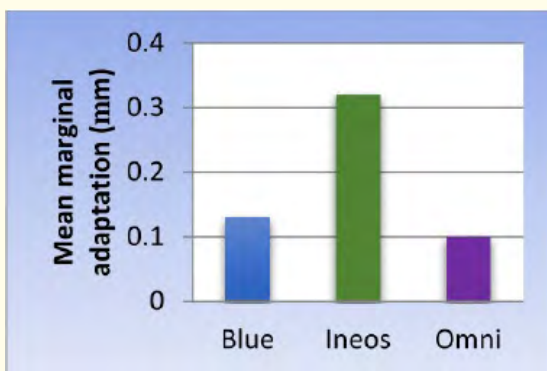


Figure 9: Bar chart representing comparison between mean marginal adaptations of the three groups.

Internal adaptation

Internal adaptation for different groups using Conventional replica technique

Means and standard deviations (SD) of internal adaptation for different groups using Conventional replica technique were presented in table 2 and figure 10. Omni ($380 \pm 16 \mu\text{m}$) showed the highest mean Internal adaptation followed by Blue ($190 \pm 12 \mu\text{m}$) followed by Ineos ($170 \pm 9 \mu\text{m}$) with an insignificant difference between Blue and Ineos at $p = 0.09$.

®IBM Corporation, NY, USA.

®SPSS, Inc., an IBM Company.

Conventional						p-value
Blue		Ineos		Omni		
Mean	SD	Mean	SD	Mean	SD	
190	12	170	9	380	16	0.09*

Table 2: Mean and standard deviation (SD) and results of Kruskal-Wallis test for internal adaptation for different groups in Conventional technique.

Same letter within each row are not significantly different at $p=0.05$.

NS= Non-Significant

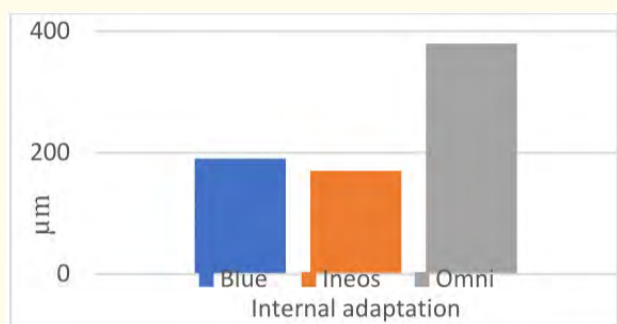


Figure 10: Histogram showing the mean internal adaptation for different groups in Conventional technique.

Internal adaptation for different groups using Cone beam CT

Mean and standard deviation (SD) of internal adaptation for different groups in CBCT were presented in table 3 and figure 11.

CBCT						p-value
Blue		Ineos		Omni		
Mean	SD	Mean	SD	Mean	SD	
450	26	400	23	360	22	0.591 NS

Table 3: Mean and standard deviation (SD) and results of Kruskal-Wallis test for internal adaptation for different groups in CBCT.

Same letter within each row are not significantly different at $p = 0.05$.

NS: Non-Significant

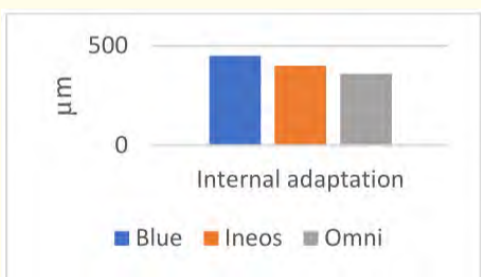


Figure 11: Histogram showing the mean internal adaptation for different groups in CBCT.

Blue ($450 \pm 26 \mu\text{m}$) showed the highest mean Internal adaptation followed by Ineos ($400 \pm 23 \mu\text{m}$) followed by Omni ($360 \pm 22 \mu\text{m}$) with an insignificant difference between each others at $p = 0.591$.

Internal adaptation for different groups

Mean and standard deviation (SD) of internal adaptation for different groups in CBCT were presented in table 4 and figure 12.

Conventional						CBCT						p-value
Blue		Ineos		Omni		Blue		Ineos		Omni		
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
190	12	170	9	380	16	450	26	400	23	360	22	0.02*

Table 4: Mean and standard deviation (SD) and results of Kruskal-Wallis test for internal adaptation for different groups.

Same letter within each row are not significantly different at $p = 0.05$. NS: Non-Significant

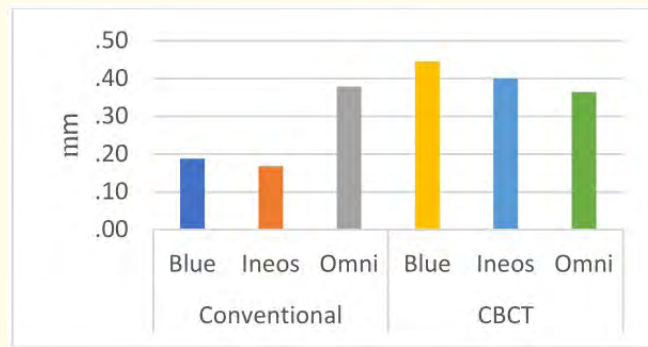


Figure 12: Histogram showing the mean internal adaptation for different groups.

Adaptation Using CBCT, Blue (450 ± 26 μm) showed the highest mean Internal followed by Ineos (400 ± 23 μm) followed by Omni (360 ± 22 μm) for CBCT followed by Omni (380 ± 16 μm) for conventional technique with an insignificant difference between each other. Ineos (170 ± 9 μm) for conventional replica technique showed the lowest internal adaptation followed by Blue (190 ± 12 μm) with an insignificant difference between each other.

Internal adaptation for different techniques regardless of other variable

Mean and standard deviation (SD) of internal adaptation for different technique regardless of other variable were presented in table 5 and figure 13.

X-ray				p-value
Conventional		CBCT		
Mean	SD	Mean	SD	
310	17	400	24	0.127 NS

Table 5: Mean and standard deviation (SD) and results of Mann-Whitney test for internal adaptation for different technique regardless of other variable.

Same letter within each row are not significantly different at $p = 0.05$. NS: Non-Significant.

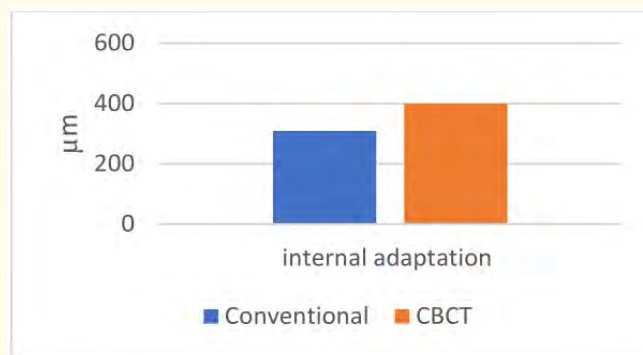


Figure 13: Histogram showing the mean internal adaptation for different technique type regardless of other variable.

CBCT ($400 \pm 24 \mu\text{m}$) showed the highest mean Internal adaptation followed by conventional X-ray ($310 \pm 17 \mu\text{m}$) with an insignificant difference between each other's at $p = 0.127$.

Discussion and Conclusion

Single-tooth implant-supported restorations demand a particularly high standard of esthetic quality since the adjacent natural teeth provide an immediate comparison to the artificial implant-supported crown [7].

The demand for achieving superior esthetic quality in implant dentistry has led to an increase in the development of new materials and new technology [19].

Recently, all ceramic crowns have come into wide use in the posterior region as well as the anterior region because of their natural look and excellent biocompatibility [20].

Apart from strength and esthetics, marginal and internal accuracy of fit are valued as the most important criteria for the clinical quality and success of all ceramic crowns [21-23]. Increased marginal discrepancy of a crown favors the rate of cement dissolution and of microleakage [10,24]. Poor marginal adaptation increases plaque retention and changes the composition of the subgingival microflora indicating the onset of periodontal disease [25].

Acceptable fit discrepancies have been reported to range from 50 to 150 μm [26].

There is no doubt that digital CAD/CAM-based technologies have become established in the laboratory routine. The model surfaces must be digitized to be able to use CAD/CAM methods. This is done in the laboratory with special scanners based on many various technologies. Quite some time before the introduction of scanners and digital techniques in the laboratory, partial sections of the jaw could be digitized intraorally relatively simply with the Cerec system.

An intraoral scanning system must be able to reach every point in the oral cavity. Because it is not possible to immobilize the oral cavity, it should be scanned very quickly to avoid blurred images. Larger areas or entire jaws are displayed by an overlapping combination of single exposures. Optical systems either video- or laser-based - appear to fulfill these requirements best of all [27].

In this study, implants were embedded in epoxy resin blocks as its modulus of elasticity value approximates that of human bone [15].

For the purpose of standardization, an implant-abutment was selected to simulate a prepared maxillary first premolar considering the average dimensions of the tooth according to Wheeler [28]. The selected prefabricated titanium implant abutments used in this study had the same shape and dimensions as supplied by the manufacturer. The abutment's dimensions were: 7 mm axial height, 3 degree axial taper and circular deep chamfer finish line of 0.8 mm according to Elbasty [15].

In order to avoid reflections and to create a matt measurable surface the implant abutment was powdered with optispray (Sirona Dental Systems, Bensheim, Germany) prior to scanning as performed by Reiss B [29], Ender A and Mehl A [8], Luthardt RG., *et al.* [18] and Galhano GAP, *et al* [30].

However, some authors Rudolph H., *et al.* [30] and Quaas A., *et al.* [31] stated that the powder layer results in an additional thickness of 13 - 85 μm and that extraoral digitization with impression taking and model fabrication is more accurate than intraoral digitization.

The luting space setting in this study was set to 25 μm as advocated by Aditya Priyam., *et al.* [20] who mentioned that when the luting space was set to 25 μm , crowns with a good fit could be fabricated on the Cerec 3 system, regardless of the occlusal convergence angle of the abutment.

Although the material is out of scope of this study, yet the selection of Vita Mark II blocks was made according to the clinically relevant physical properties and indications of different ceramics as mentioned by Wiedhahn K [32].

However, the results were not in agreement with Cook KT and Fasbinder DJ [17] who stated that the improved image resolution does not necessarily translate to a better fitting restoration. Other aspects of the CAD/CAM crown fabrication process would seem to be limiting factors to further improvement in fit or adaptation.

The vertical cervical marginal gap measurement is one of the most frequently used methods to record the accuracy of fit of the restoration [10,33]. In spite of the presence of various testing methods and measuring tools, the direct view method using the stereomicroscope is considered more convenient, accurate, easy and rapid for determining the marginal gap distance and the crown is retrievable, unlike cementation, embedment and sectioning method that causes destruction of the crown.

Cone beam CT technique used to replace the old technique by new and easy one and much close to Micro CT but less accurate. Because Cone beam software can measure only 100µm or more.

Measurements were made without cementation in the present study, otherwise cement properties and cementation procedures [16,34,35] may influence the results that would be out of scope of the present study.

All measurements were done on the implant-abutment that provided a stable reference that couldn't be easily damaged rather than the stone dies [16,23,36]. Furthermore, manufacturing the crowns on their implant-abutment was performed to test the effect of the scanning technique only without potential addition of variables during laboratory steps of duplication of a stone die including: impression technique, time between impression making and pouring the die stone, and slight variations in water/powder ratio of the stone.

Seating the crowns properly on their corresponding implant-abutment for the purpose of vertical marginal gap measurements was performed using the specially designed holding jig having a spring to hold the restoration on the abutment with a standardized force [16,48]. The measurements were performed at the four surfaces taking the readings at eight equidistant points on each surface for achieving optimum accuracy [11,12,16].

Many authors detected that range of clinical acceptability of vertical marginal gap openings were between 50 and 150 µm [11,26,37]. Thus, results of the present study for all groups were in the midrange from 13 µm to 120 µm which was considered to be clinically acceptable, except Ineos blue.

Regarding the marginal fit the Cerec Omnicam showed the lowest values 100 ± 20 µm, followed by the Cerec Bluecam 130 ± 30 µm and finally the Cerec Ineos camera which showed the highest marginal discrepancy 320 ± 30 µm. There was a statistically significant difference between the three modalities (P-value < 0.001), however, all the results were within the clinically acceptable range.

These results were consistent with the information provided by Mehl A., et al. [8], Steinbrenner, et al. [38], and Pieper., et al. [9] who reported that the accuracy was higher with the Cerec Bluecam than the previous models, reaching up to 19 µm in single tooth images. This was attributed to the significant modifications that include: 1) the use of blue light (470 nm) instead of infrared light (820 nm) which improved the accuracy by around 60%, accordingly the resolution of the small details which increased by the same order of magnitude, 2) the use of a new lens configuration that increased the focus depth range, as a result surfaces are better depicted from both close and distant ranges, meaning that the camera position is no longer as critical for accuracy as it was used to be, 3) The automatic capture mode, where the picture is taken automatically as soon as the camera detects a focused and blur free image.

The internal fit was reported to be of paramount importance in the success of the dental restorations. It should also be highlighted that with all- ceramic restorations, poor internal adaptation could result in reduced resistance to fracture [39]. Although no conclusive evidence is available concerning the optimal internal space, 50 - 100 µm is considered acceptable in due respect of the physical and clinical properties of resin-based luting agents [40-42]. In vitro studies of machine milled, all ceramic crowns revealed that the mean internal gaps ranged from 30 to 204 µm [11,43,44].

Different techniques had been proposed for internal fit measurement; however, the internal replica technique was used in this study where low- viscosity impression material was injected in the fitting surface of the restoration. This step is followed by seating the restoration on the preparation. The thin layer of the low-viscosity material was stabilized by higher viscosity impression material to facilitate handling. The internal replica can then be sectioned and magnified. This technique was considered more convenient, accurate, easy and rapid for determining the internal gap distance and the crown is retrievable, unlike cementation, embedment and sectioning method that causes destruction of the crown [14,45,46].

The light body thickness was measured at six points for each section of each specimen using a stereomicroscope with precision of + 0.5µm. The results obtained in this study showed that the Cerec Ineos scanner presented the lowest internal gap values $260 \pm 16 \mu\text{m}$ followed by Cerec Omnicam $290 \pm 15 \mu\text{m}$, finally Cerec bluecam $420 \pm 21 \mu\text{m}$. There was no statistically significant difference between the four modalities (P-value < 0.05) and the results were within the range of clinical acceptance (100 - 300) µm.

The results were concurrent with the findings of Mehl A., et al. [8], Steinbrenner., et al. [38], Pieper., et al. [47] and Nakamura Takashi., et al. [20] who reported better fit of the crowns fabricated after scanning with the Bluecam, based on the shorter wavelength of the blue light (470 nm) that provides significantly higher scanning precision. However, the results were not in agreement with Luthardt RG., et al. [30] who stated that the Cerec scan (Inlab) showed improved internal fit compared with the Cerec camera. However, the differences between the data- acquisition techniques were small compared to their absolute values.

Moreover, the results were not in agreement with Cook KT and Fasbinder DJ [17] who stated that the improved image resolution does not necessarily translate to a better fitting restoration. Other aspects of the CAD/CAM crown fabrication process would seem to be limiting factors to further improvement in fit or adaptation.

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