Accuracy of the marginal fit of all-ceramic crowns fabricated by direct and indirect digital scanning methods

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Abstract. Marginal fit is important in treatment using fixed dental prostheses. Poor marginal adaptation can result in dental caries and periodontal disease. The objective of this study was to analyze and to compare the marginal fit of all-ceramic crowns fabricated from impressions acquired by direct digital scans intraorally and by indirect digital scans extraorally from working models. Twenty-three posterior teeth were prepared to receive all-ceramic crowns and, then, were digitally scanned intraorally (direct). Impressions were made for working model fabrication and then digitally scanned extraorally (indirect). A total of 46 all-ceramic crowns (Feldspathic ceramic, VITA Mark II; VITA Zahnfabrik) were fabricated by using a CEREC 3D computer-aided design/computer-aided machining system (Sirona). The marginal fit was evaluated by measuring a silicone replica of the gap between the intaglio of the full-veneer crown and the margin of the prepared tooth. The 46 specimens were examined by using an MM-40 Measuring Microscope (Nikon, Japan) at a magnification of 50×. Statistical differences in the marginal fit of the all-ceramic crowns were found between crowns fabricated from direct digitally scanned (70.1 µm ± 13.3) and indirect digitally scanned (82.3 µm ± 12.2) impressions (P < 0.05). The all-ceramic crowns fabricated from the direct digitally scanned impressions were significantly more accurate than those from the indirect digitally scanned impressions.

1. Introduction

Fixed dentures prostheses (FDP) are used to replace damaged or abnormal teeth or teeth that have been lost. They are attached to prepared teeth by using cement material so that they cannot be removed. The types of FDP include artificial crowns (full veneer crown/partial veneer crown/veneers) and bridges that can be made of various dental materials [1].

In the 1960s, metal ceramic became available and considered as the gold standard of crown and bridge because of its satisfactory mechanical and aesthetic properties as well as its internal and marginal adaptations which is clinically acceptable. A disadvantage of a fully veneered metal-ceramic crown is the variations in quality, which is influenced greatly by the fabrication procedures that includes many stages. All-ceramic crowns can give more satisfactory aesthetic results resembling natural teeth in terms of color, surface texture, and transparency, but in terms of strength, this material has some limitations. However, with developments in dental science and technology as well as the increasing awareness of patients of the importance of the aesthetic appearance of dentition in the last decade, all-ceramic crowns become increasingly popular for FDP.
The precision of the marginal fit is an important aspect of FDP. The cervical marginal misfit can lead to exposure of cement by oral fluid, which can result in the dissolution of the cement material. The space formed by the dissolution of the cement material can be a site of plaque accumulation that causes caries as well as changes in the microflora, which can lead to periodontal disease [1,4,5].

Along with the advancements in science and technology, the technique of producing all-ceramic FDP using dilithium silicate and zirconia, which have higher strength and more accurate result in a shorter time, was developed by using the CAD/CAM technology, which was first introduced into dentistry around 1980. Since then, the technology has been applied in two ways: to clinical applications involving making a full-veneer crown in one visit and to conventional manufacture in a dental laboratory. The use of this technique, compared to the conventional techniques, for all-ceramic FDP fabrication is easier and faster [2,3,6,7].

One CAD/CAM available system is the CEREC system. The scanning procedure in the CEREC system uses an optical digital scanner that applies the principle of light triangulation; i.e., the intersection of three linear light lines to determine the location of a particular point in three-dimensional space (3D). The new CEREC system uses blue light instead of infrared to improve the accuracy, resolution, and detail of the information acquired by using a digital scanner, either by scanning directly or indirectly [6,8].

The procedure for direct digital scanning can be used for teeth that have been prepared in a patient’s mouth. Scanning with this technique is more difficult, especially since the exposure time should be short enough to prevent a blurred scan. The results of scanning the surface of a tooth in the mouth are not as good as the results of scanning the surface of a working model (dental stone). The results of the tooth preparation are rounded and sharp on the margins, and there is a transparent tooth surface. This condition can reflect light irregularly so that it can adversely affect the results of scanning using the principle of light triangulation. Therefore, the surface of the prepared teeth should first be coated with opaque powders containing titanium dioxide (Optispray, Sirona) to reflect light evenly and to improve the accuracy of the scan. The size of the camera for scanning in the mouth is also an important factor because the intraoral optical scanning device should be able to enter the patient’s mouth further up to the posterior area so that it can cover all the teeth, including the second and third molars. If technical problems related to direct scanning can be overcome, then this method will have several advantages versus indirect scanning, such as 3D data, as it can be acquired in the clinic so that it can be useful in the diagnostic process, and the time would be shorter for full veneer crown fabricated by chairside [7,9].

In the indirect digital scanning method, the scanning of prepared teeth is performed on a working model. In this technique, a model made from a special material (Cerec stone BC; Sirona) can be used for optical scanning; therefore, the tooth surface of the working model does not need to be coated with opaque powder. This technique requires an impression process, casting of a work model, delivery of the working model to the dental laboratory, and the fabrication of the crown in the lab, so there is a possibility of errors at each of these stages and the processing time is longer [7,9].

Research using optical digital scanners and the active wave-front sampling principle has been conducted by using the Lava Chairside Oral Scanner (Lava COS; 3M Lexington, USA), which showed a more precise marginal fit was achieved by using a full-veneer crown made by direct scanning in the mouth than by scanning a working model extraorally.

The aim of this clinical study was to analyze and compare the marginal fit accuracy of all-ceramic crowns fabricated from impression acquired by digitally scanned intraorally and by indirect digital scans extraorally using blue light and the CEREC system [10].

2. Materials and Methods
The study population was 23 patients (aged between 30 and 50 years) who came to private dental clinics with general circumstances both requiring and having indications for treatment with fully veneered all-ceramic crowns. The research was conducted from September 2012 to December 2013 at
a private dental clinic and laboratory facility of the Metallurgical Engineering Department at the Universitas Indonesia.

In this study, twenty-three posterior teeth were prepared to receive all-ceramic crowns and, then, were digitally scanned intraorally (direct). Impression were made for working model fabrication and then digitally scanned extraorally (indirect). A total of forty-six all ceramic crowns (Feldspathic ceramic, VITA Mark II; VITA Zahnfabrik) were fabricated by using a CEREC 3D computer-aided design/computer-aided machining system (Sirona). The marginal fit was evaluated by measuring a silicone replica of the gap between the intaglio of the full-veneer crown and the margin of the prepared tooth. The forty-six specimens were examined by using an MM-40 Measuring Microscope (Nikon, Japan) at a magnification of 50x.

2.1. Tooth preparation
In each of the 23 subjects, only one tooth was prepared so that 23 teeth were obtained. The tooth preparation was performed by using a diamond bur. Proximal preparation was performed by using a pointed tapered bur (850.314.012; Comet, Brasseler GmbH & Co, Germany). The preparation of the buccal, lingual, and occlusal fields was performed by using a round-end tapered bur (6856.314.016; Comet, Brasseler GmbH & Co., Germany). Deep-chamfer cervical preparation was performed by using a round-end tapered bur (6856.314.016; Comet, Brasseler GmbH & Co, Germany) to achieve a subgingival depth of 0.5 mm in the lingual section with the aid of the retractable cord. The circumferential dimension of each tooth was reduced by 1.2–1.5 mm, the occlusal dimension was reduced by approximately 1.5 mm, and all the internal angles were rounded (Figure 1). The finishing on the cervical margin was performed by using an end cutting bur (10839.314.014; Comet, Brasseler GmbH & Co., Germany). The divergence corner of the preparation was approximately 6° [11,12].

![Figure 1. Example of lower first molar full crown preparation](image)

2.2. Impression making of a prepared tooth
After the preparation was completed, two procedures were applied to each tooth: the tooth was digitally scanned directly, intraorally; then, conventional impression using polyvinyl siloxane (PVS) were made to obtain a working model, which was then digitally scanned extraorally. Subsequently, a temporary denture crown was made from bis-acryl material and cemented with temporary cement.

2.2.1. The procedure for fabrication of all-ceramic crowns by direct digital scanning intraorally.
- Placement of the retraction cord (Ultrapak, Ultradent). The surface of the prepared tooth was dried and ensured to be dry with the aid of a saliva ejector and suction during scanning, then sprayed with titanium oxide powder (CEREC Optisray, Sirona) (Figure 2).
- Recording of prepared tooth, dental antagonists, and dental recording in a state of occlusion, from the buccal direction with a digital scanner CEREC Bluecam (Sirona) (Figure 3).
2.2.2. The procedure for making all-ceramic crown by indirect digital scanning extraorally.

- Placement of retraction cord (Ultrapack, Ultradent). The prepared tooth surfaces were dried and ensured to be dry with the help of a saliva ejector and suction until shortly before impression. Preformed impression with PVS type putty, low viscosity (LV), extra low viscosity (XLV) (Aquasil Ultra; Dentsply) single impression method was used and working times were in accordance with the manufacturer’s instructions. An impression tray was removed from the mouth after 5 min 30 s. Impression of antagonist teeth with alginate material and bite registration was made by using virtual bite registration (Virtual Bite, Ivoclar Vivadent). The disinfection of the impression was performed by using 3% NaOCl. Then the impression was sent to the laboratory.

- The working model was made by using cast stone (CEREC Stone BC) according to the manufacturer’s instructions [13-16].

- Indirect digital scanning (CEREC in Eos Blue) of a working model (Figure 3).

- The all-ceramic crown was fabricated by using an InLab MC XL (Sirona) milling machine from an all-ceramic block (VITABLOCS Mark II; VITA Zahnfabrik) (Figure 5).

**Figure 2.** (A) Titanium oxide powder (CEREC Optisray, Sirona); (B) Direct intraoral digital scanning using a CEREC Bluecam (Sirona) scanner.

**Figure 3.** Indirect extraoral digital scanning (CEREC in Eos Blue) of a working model.
**Figure 4.** Computer-aided design (CAD) was performed by using the CAD software (CEREC 3D version 3.0) (A) Related dental scanning results; (B) Digital scanning result of bite marking (antagonizing teeth); (C) The designs of crowns as well as a picture of the magnitude of contact occlusion (blue) with the antagonist teeth.

**Figure 5.** Computer-aided machine (InLab MC XL, Sirona). A. An all-ceramic block is placed inside the milling machine, B. The all-ceramic block milling process for making a crown in accordance with the design.

2.3. **Measurement of marginal gap**

- On visits for insertion of the all-ceramic crown, the temporary crowns were removed and the prepared tooth was cleaned with pumice and a brush.
- Impression between the inner surface of the all-ceramic crown and the surface of the prepared tooth was performed. Prior to this impression, no adjustments were made to the prepared teeth or to the all-ceramic crowns.
- For each prepared tooth, all-ceramic crowns made by scanning directly and indirectly, were completely filled with a very low viscosity silicone XLV (Dentsply) and inserted to the prepared tooth. After it was setting, the all-ceramic crown was removed from the prepared tooth with an excavator by hand. When removing the all-ceramic crown, the silicone must remain attached to the crown; if the silicone did not adhere to the crown, it should be redo. This silicone layer is the replica of the marginal gap. Then, a low viscosity (LV) silicone material was added to the crown to stabilize the silicone layer so that it could merge with the XLV silicone layer without causing distortion (Figure 6). The result from using the XLV and LV material was referred to as the specimen.

**Figure 6.** XLV (yellow) silicone material was applied to the all-ceramic crown intaglio. A gap was present between the prepared tooth and full artificial crown in the mouth, so the intaglio gap molding was filled with LV (green) silicone material.

- After setting, the specimen was removed from the all-ceramic crown and then cut into four parts in a buccolingual and mesiodistal direction using a sharp cutter (Figure 7). All the specimens were prepared and measured by the same operator. The thickness of the XLV
coating represent the cervical margin fit was measured by using an MM-40 (Nikon, Japan) microscope at 50× magnification in the cross-sectional direction of the buccal, lingual, mesial, and distal cervical margin.

![Figure 7](image)

**Figure 7.** (A) After the silicone material setting, the artificial crown can be removed, (B) Specimens made of XLV and LV silicone materials along with the direction of cutting.

![Figure 8](image)

**Figure 8.** Sections of specimens that have been cut in the cross-sectional direction. Green: represented prepared tooth. Yellow: gap between the artificial crown and the prepared teeth. The distance between points A and B is the measured cervical margin gap; (A) the intaglio of the all-ceramic crown margin; (B) the base of the cervical preparation of the tooth.

- The thickness of the replica of the specimen at the marginal fit is measured by drawing a perpendicular line from the internal surface of the all-ceramic crown cervical margin (point A) to the bottom of the cervical preparation of the tooth (point B) (Figure 8). This value illustrates the magnitude of the cervical marginal fit between the all-ceramic crowns both made with directly and indirectly scanned and the prepared tooth.

2.4 Data Analysis
The statistical data processing was performed by using IBM application version 20. The univariate analysis was performed to determine the averages, standard deviations, and data distribution. The bivariate analysis using paired t-tests was performed to assess the differences in marginal fit accuracy between the all-ceramic crowns prepared by the direct digital scanning and by the indirect digital scanning. The Wilcoxon test was used to assess differences in the marginal fit accuracy between all-ceramic crowns prepared by the direct digital scanning and by the indirect digital scanning on tooth surface. The Kruskal–Wallis test and one-way ANOVA tests were used to determine the significance
of differences in the marginal fit accuracy at points located on four tooth surfaces [17,18]. The level of statistical significance was set to $P < 0.05$.

3. Results
The marginal fit between the prepared cervical margin of the tooth and the cervical margin of the all-ceramic crown measured for all the 23 posterior teeth. There were 23 posterior tooth specimens made by direct impressions and 23 made by indirect impressions. The marginal fit measurements were performed at four points for each specimen: buccal (B), lingual (L), mesial (M), and distal (D). These points were measured on both specimens to obtain 368 dots. For a tooth surface obtained from the mean values between the points from both parts of the specimen 184 points were obtained (Table 1), which were then used in the statistical analysis (Table 2).

**Table 1.** Average measurements of the cervical marginal fit between the crown and the prepared teeth on four tooth surfaces.

| Tooth Surface | Buccal | Lingual | Mesial | Distal | Average |
|---------------|--------|---------|--------|--------|---------|
| Direct        | 67.1   | 67.1    | 69.9   | 76.2   | 70.1    |
| Indirect      | 82.7   | 80.8    | 82.5   | 82.9   | 82.3    |

**Table 2.** Univariate test results of cervical marginal fit measurement between artificial crowns prepared from direct impressions and indirect impressions.

|                | Min    | Max    | Median | SD     | Average |
|----------------|--------|--------|--------|--------|---------|
| Direct         | 46.6   | 92.3   | 73.8   | 13.3   | 70.1    |
| Indirect       | 61.0   | 102.3  | 83.5   | 12.2   | 82.3    |

3.1. Cervical marginal fit accuracy of the all-ceramic crowns fabricated by direct and indirect digital scanning at four points on the tooth surface
The marginal fit measurements between all-ceramic crowns fabricated by direct digital scanning were performed at four points (buccal, lingual, mesial, and distal) (Table 3). There were no significant differences in the magnitudes of the marginal fit at the points on the four surfaces ($P = 0.264$). The mean value of the marginal fit at the buccal and lingual points was equal to 67.1 μm, and the mean marginal fit at the mesial point was slightly larger at 69.9 μm, whereas the mean marginal fit at the distal point was much greater at 76.2 μm.

**Table 3.** Cervical marginal fit accuracy of the all-ceramic crown fabricated by direct digital scanning at four points on the tooth surface.

|                | $N$   | Average ($\mu m$) | SD     | $P$-value |
|----------------|-------|-------------------|--------|-----------|
| Kruskal–Wallis Test | 0.264 |                   |        |           |
| Buccal Point    | 23    | 67.07             | 15.06  |           |
| Lingual Point   | 23    | 67.12             | 15.25  |           |
| Mesial Point    | 23    | 69.87             | 20.94  |           |
| Distal Point    | 23    | 76.15             | 18.20  |           |

$P < 0.05$ (significant)
The marginal fit between the all-ceramic crowns from indirect digital scanning was measured on four surfaces (buccal, lingual, mesial, and distal). The results of the Kolmogorov–Smirnov normality test showed the distribution of the marginal fit measurement data was normal. The indirect group had also the same data variance. Therefore, a one-way ANOVA parametric statistical test was used. The test results showed there were no significant differences in the magnitudes of the cervical marginal fit at the points on the four surfaces (P = 0.970) (Table 4). The mean values of the gaps at the buccal, mesial, and distal points were similar (approximately 82 µm), whereas the mean cervical marginal fit at the lingual point was slightly smaller at 80.9 µm.

**Table 4.** Results for the marginal fit of the all-ceramic crowns prepared from indirect digital scans at four points on the tooth surface.

| N   | Average (µm) | SD  | P-value |
|-----|--------------|-----|---------|
| Buccal Point | 23 | 82.67 | 14.64 | 0.970 |
| Lingual Point | 23 | 80.85 | 16.68 |
| Mesial Point | 23 | 82.54 | 15.95 |
| Distal Point | 23 | 82.94 | 16.80 |

P < 0.05 (significant)

3.2. Differences in the accuracies of the cervical marginal fit between the measuring points on each tooth surface for the all-ceramic crown fabricated by direct and indirect scans

The Wilcoxon test was used to determine the significance of the differences in the marginal fit accuracy between all-ceramic crowns fabricated by direct digital scanning and by indirect digital scanning on every tooth surface. There were significant differences in the marginal fit accuracies at the buccal, lingual, mesial, and distal points between the crowns made from the direct digital scans and the indirect digital scans (P < 0.05) (Table 5).

**Table 5.** Differences in the accuracies of the cervical marginal fit between all-ceramic crowns fabricated from direct and indirect digital scans between measuring points on each tooth surface.

| N   | Average | SD  | P-value |
|-----|---------|-----|---------|
| Buccal Point direct–indirect | 46 | 74.87 | 16.67 | 0.000 |
| Lingual Point direct–indirect | 46 | 73.98 | 16.98 | 0.000 |
| Mesial Point direct–indirect | 46 | 76.21 | 19.49 | 0.000 |
| Distal Point direct–indirect | 46 | 79.54 | 17.66 | 0.030 |

P < 0.05 (significant); Wilcoxon Test

3.3. Differences in cervical marginal fit accuracy between all-ceramic crowns fabricated by direct and indirect digital scans

Based on the previous test, there were no significant differences in the accuracies of the cervical marginal fit of the all-ceramic crowns from the direct and indirect scans at the four measuring points on the tooth surfaces. The cervical marginal fit accuracy for one specimen was calculated from the average measurement value of the four surface points. Therefore, it was obtained 23 values for the direct digital scan cervical marginal fit measurements and 23 values for the indirect digital scan cervical marginal fit measurements (Table 6).

The Shapiro–Wilk test was used to test the data normality, and the data were found to be normally distributed. Therefore, subsequent measurements were assessed by using the parametric paired t-test.
Table 6. Differences in the cervical marginal fit accuracies of the all-ceramic crowns fabricated from direct digital scans and indirect digital scans

|                | N  | Average | SD  | P-value |
|----------------|----|---------|-----|---------|
| Direct scan    | 23 | 70.1    | 13.3| 0.000   |
| Indirect scan  | 23 | 82.3    | 12.2|         |

P < 0.05 (significant); T-test

A paired t-test was used to determine the differences in cervical marginal fit accuracies between the direct scan and indirect scan groups. There was a significant difference in marginal fit accuracies between the groups (P < 0.05). The all-ceramic mock crowns prepared by direct digital scanning had greater marginal fit accuracy (70.1 μm ± 13.3) than that of the crowns fabricated by indirect digital scanning (82.3 μm ± 12.2).

4. Discussion

Previous research on in vitro marginal fit measurements has been conducted, but in this study, marginal fit measurements were performed in vivo (as in a clinical setting). The marginal fit was measured using the replica of the marginal gap made by taking impression with XLV material and all-ceramic crowns to the prepared teeth in the mouth. The measurement was done outside the mouth by microscopy (Nikon MM-40, Japan), to obtain measurement results similar to those that would be obtained clinically [19].

In this research, the average value of the marginal fit of all-ceramic crowns fabricated with direct scan was 70 μm and 82 μm for all-ceramic crowns fabricated from from indirect digital scans. Both of these gaps were still within acceptable limits for a full veneer crown. These results were in accordance with the results of other studies, including the Witkowski et al. study in which it was found the magnitude of the marginal fit for a fully acceptable CAD/CAM full veneer crown was between 50 and 100 μm [20,21]. However, some researchers have stated a clinically acceptable marginal gap magnitude is <120 μm [4,22,23].

This study found no significant differences in the accuracies of the marginal fit between the all-ceramic crowns fabricated from the direct and indirect digital scans at four dental measurement points. It can be concluded the location of the measurement point and the number of measurement points on the tooth surface did not affect the measurement results for accuracy of the marginal fit for a specimen. In this study, the measurement of marginal fit accuracy was only performed at the buccal, lingual, mesial, and distal points (four points). Because there were no significant differences in the accuracies of marginal fit at the four points, the marginal fit accuracy value for each specimen could be calculated from the average of the measurement results at the four points [18].

The marginal fit in an all-ceramic crown fabricated from direct digital scanning was measured at a distal point from the marginal fit that was 6–9 μm (76.2 m) greater than that at the buccal, lingual, and mesial points. The reason for this is because the direct scanning method was performed intraorally. The intraoral scanning device has a larger shape than an intraoral camera; therefore, it is more difficult to insert into the mouth to scan the posterior teeth. The proximal portion of the tooth, especially the distal part, is more difficult to scan because of space constraints for positioning the scanners to allow capture of the cervical peripheral borders of prepared teeth. The measurement can also be influenced by the prepared tooth surfaces because the tooth must be coated with titanium powder dioxide before digital scanning. After the entire surface of the tooth to be scanned has been coated with titanium dioxide, the tooth surface must remain in a dry state in which is free from saliva contamination. If saliva contamination occurs at the time of scanning, the scanning results will change and become inaccurate. Distal part of the cervical area in a tooth is more susceptible to this contamination, which causes clotting of the titanium dioxide. This phenomenon affects the cervical margin scanning of the
distal section, which results in a larger measured marginal gap value. Because of limited space in the oral cavity, titanium powder dioxide can be removed when exposed to surface friction, such as caused by the tongue, buccal mucosa, dental instruments, a suction tip, or the surface of an intraoral digital scanning device. Scrubbed surfaces will not be captured by the scanner, which results in a irregular picture of the shapes and uneven boundaries that affect the accuracy of the dental surface record [9]. The movement of patients and operators during scanning can affect the accuracy of the scanned images, but in this study, the intraoral optical digital scanning device used had shaken detection and a foot switch scanning method to allow for unshaded images. In addition, the device used performs optical scanning with blue light projection that can improve accuracy and uses a tilted lens to reduce the elimination of image detail (filtering) and improve the reproduction of detail [7,8].

The marginal fit measurements on the all-ceramic crowns made by indirect digital scanning were obtained by using a slightly different mean value. The buccal, mesial, distal (± 82 μm) points showed a difference of ± 1 μm, with a mean gap at the lingual point of 80.8 μm. This relatively small disagreement was caused by digital scanning of the working model that could be positioned according to the need for shooting for all sides of the tooth surface. In addition, in this study, dental stone materials were used specifically for digital scanning, which made it possible to scan the entire surface of the working model evenly without the need for titanium dioxide coating (Optispray) [9].

The all-ceramic crowns fabricated by the direct digital scanning gave higher marginal fit accuracy (70.1 μm ± 13.3) than that of the indirect scanning (82.3 μm ± 12.2) because the scanning was performed directly on the prepared tooth in the patient’s mouth. In contrast, indirect recording was performed on a working model obtained from impression of tooth using PVS impression material, showed a 12.2-μm greater marginal gap values than from the direct scanning. This large gap difference was likely influenced by the materials and impression method in the mouth as well as by the materials and manipulation of the material in the working models fabrication [24].

The PVS material can produce a more accurate working model with better detail than the irreversible hydrocolloid (alginate) and polyether materials. PVS materials are also available in a variety of viscosities that can be adapted to the impression needs; for example, very LV materials to reach small portions at the cervical margin of the prepared tooth. PVS is hydrophobic, so to obtain accurate surface detail, the teeth must be dry at the time of taking impression [15]. At the time taking impression with this material, because of the physiological condition of the oral cavity of the patient, such as salivary production and secretion and the possibility of bleeding gums, it is still possible the tooth surface may be contaminated with fluid (such as saliva and blood.). Such contamination may cause sufficient detail and accuracy cannot be obtained when taking impression with PVS material [24].

Some things must be considered when taking impression of the marginal gap to fabricate silicone replica of marginal fit specimen to be measured in this study. Since sufficient detail and accuracy are highly needed for specimen fabrication, therefore PVS material with a very LV, XLV should be used in taking impression using the all-ceramic crown to the prepared tooth. This material is also more easy to remove from the prepared tooth. When removing the all-ceramic crown, the silicone must be completely adhere to the intaglio of the all-ceramic crown to avoid the possibility of being distorted. The removal of all-ceramic crown can be accomplished with the aid of an excavator held by hand, care should be taken to start from the silicone part of the crown cervical and to remove in the same direction as the insertion [24].

When taking impression with PVS, there are several factors that can influence the accuracy of the result. Single-step impression techniques provide higher accuracy than that of the two-step technique with a spacer or two-step without a spacer [16]. In this study, a single-step impression technique was used with putty materials and LV materials, also XLV. PVS impression materials have excellent long-term dimensional stability and allow for repeatable casting and high-accuracy impression results [14,16,25,26]. Immersion with disinfectant material does not affect the dimensional stability of PVC material [13]. Techniques and conditions when casting a working model and stone gypsum materials
can affect the accuracy of the result. The use of vibrators at high speed at the time of casting can provide casting models with few air bubbles and improve the accuracy of the working model [27].

5. Conclusion
This study demonstrated a significant difference in the accuracy of the marginal fit of all-ceramic crowns fabricated with direct and indirect digital scans between four measuring points on dental surfaces.

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