Original Article

Influence of Different Depths of Finishing Lines of Single Crown Abutments on Marginal Definition and Emergence Profile Reproducibility in Intraoral Scanning: An *In Vitro* Pilot Study

Wei Jyun Ciou,[a*] Yao Ning Lei,[b*] Ting Wei Lin,[c] Wei Hung He,[d]

[*] co-first authors

[a]Kaohsiung Chang Gung Memorial Hospital Dentistry School of College of Dental Medicine, Kaohsiung Medical University. D.D.S. (2011/9-2017/7)

[b]Kaohsiung Chang Gung Memorial Hospital
1. Dentistry School of College of Dental Medicine, Kaohsiung Medical University. D.D.S. (1991/9-1997/7)
2. Graduate Institute of Clinical Dentistry School of Dentistry, Kaohsiung Medical University. M.S. (2002/9-2004/7)

[c]Kaohsiung Chang Gung Memorial Hospital Dentistry School of College of Dental Medicine, Chung Shan Medical University. D.D.S.

[d]Kaohsiung Chang Gung Memorial Hospital
1. Dentistry School of College of Dental Medicine, Kaohsiung Medical University. D.D.S. (1999/9-2005/7)
2. Graduate Institute of Clinical Dentistry School of Dentistry, Kaohsiung Medical University. M.S. (2005/9-2007/7)
3. Herman Ostrow School of Dentistry of University of Southern California. Advanced Prosthodontics Certificate. (2015/6-2018/8)

Corresponding author:
Wei Hung He
Kaohsiung Chang Gung Memorial Hospital
1. Dentistry School of College of Dental Medicine, Kaohsiung Medical University. D.D.S. (1999/9-2005/7)
2. Graduate Institute of Clinical Dentistry School of Dentistry, Kaohsiung Medical University. M.S. (2005/9-2007/7)
3. Herman Ostrow School of Dentistry of University of Southern California. Advanced Prosthodontics Certificate. (2015/6-2018/8)

No. 123, Dapi Road, Niaosong District, Kaohsiung City, 833
Tel : 07-7317123-2378
Fax: 07-7317123
Email: hmj058@gmail.com

DOI: 10.6926/JPI.202303_12(1).0001

Abstract

Purpose: *This study aimed to evaluate the definition of the finishing line and emergence profile reproducibility of a single crown abutment, at different relative heights between the finishing line and the gingival crest, by intraoral scanning.*

Materials and methods: *A typodont upper right first molar was prepared for a single crown abutment. The tooth was mounted on the spindle of the spiral micrometer, and the artificial gingiva was fixed on the frame beside the spindle. Relative vertical position of the gingival crest and the finishing line of the abutment tooth were changed by rotating the spiral micrometer. The depth settings of the gingival margin were as follows: supra-gingiva, 0.5 mm (sup 0.5); equal gingiva (equ); sub-gingiva, 0.5 mm (sub 0.5); and sub-gingiva, 1.0 mm (sub 1.0). Two different brands of intraoral scanners (IOSs) were used in this experiment: 3Shape Trios 3 and Primescan to acquire each depth setting of five scans, and the scan results were output in STL format. 3D engineering software was used to align and superimpose the images. The angle between the finishing line slope of the abutment tooth and the root was measured in the same longitudinal section. The difference in angle between the scan results and the original model was compared and analyzed.*

Results: *For the 3Shape IOS, sub 1.0 (138.2±5.7°) < equ (150.3±1.0°) and supra 0.5 (149.7±2.7°) ($p<0.05$); sub 0.5 (142.9±2.5°) < equ (150.3±1.0°) and supra 0.5 (149.7±2.7°) ($p<0.05$) among all settings. For the Primescan IOS, there were no significant differences among all settings ($p>0.05$).*

Conclusions: *The submarginal contour and finishing line definition acquired by intraoral scanners were significantly affected by the vertical relationship between the finishing line and the gingival crest. Equal-gingival and supra-gingival finishing lines had clear scanning results and correct sub-marginal appearance in different intraoral scanners. However, when performing subgingival digital impressions, special attention must be paid to whether the intraoral scanner can provide the desired results.*

Introduction

A good impression should clearly record the entire finishing line of the preparation, along with some portion of the unprepared teeth below the finishing line. The structure above the finishing line may ensure marginal fit of the prosthesis, and the structure under the finishing line may help determine the appropriate extension of the prosthesis, such as the emergence profile.

In the case of traditional impressions, clinically acceptable results can be obtained by proper gingival management before taking impressions [1,2]. Digital impressions are now widely used clinically and studies have confirmed that they can achieve a clinically acceptable marginal fit [3, 4].

It is difficult to acquire accurate information about the tooth structure under the gingival margin for full crowns with equal-gingival or sub-gingival margins because of interference by the gingiva. Studies involving digital impressions have shown that accuracy of the margin obtained by intraoral scanning is affected by the relative position of gingiva and finishing line of the abutment.[5]

Keeling et al.[5] performed a study to simulate the different confounding factors affecting the marginal quality of an intraoral scan. The study pointed out that subgingival scanning is often easily deformed. Deformation is characterized by obtuse angles and unclear margins. Cagidiaco et al.[6] attempted to divide 60 intraoral single crown abutment teeth according to the depth of the finishing line: supra-gingival margin, 0.5–1.0 mm into the sulcus and 1.5–2.0 mm into the sulcus. Digital impressions are not recommended when the crown margin is 1.5–2.0 mm into the sulcus. In this study, it is difficult to accurately control the marginal gingival height. Therefore, we designed an experiment to precisely control the height of the gingival margin and evaluate the accuracy of the finishing line by intraoral scanning under quantitative conditions.

The purpose of this study was to evaluate and determine the relative position between the finishing line of a single crown abutment and the marginal gingival height that can be used to achieve acceptable accuracy and reproducibility of the emergence profile during intraoral scanning. Understanding these parameters may help surgeons better determine the appropriate depth of gingival margin when using intraoral scanners clinically, which is conducive to acquiring clear margins and good emergence profiles during the subsequent production of the prosthesis.

Material & methods

Fabrication of the standard model

1. A typodont upper right first molar was prepared for a single crown abutment (Figure 1). The tooth was mounted on the spindle of a spiral micrometer with a disk-shaped magnet embedded at the bottom of the tooth.
2. An acrylic artificial gingiva (Hygenic Repair Acrylic, Coltene Whaledent) was fixed on the frame beside the spindle with the contour of the gingival crest parallel to the abutment margin, 0.5 mm apart horizontally (Figure 2).

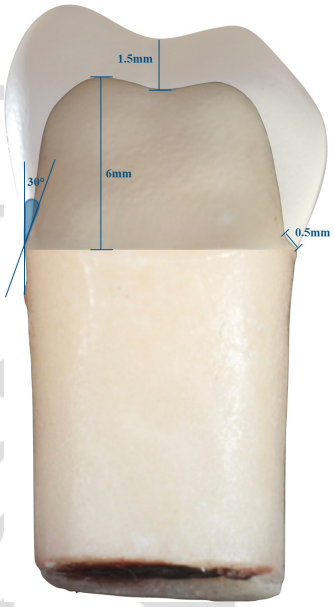

Figure 1. Right maxillary first molar single crown abutment (height: 6 mm; occlusal reduction: 1.5 mm; marginal width: 0.5 mm; marginal pattern: 30°light chamfer)

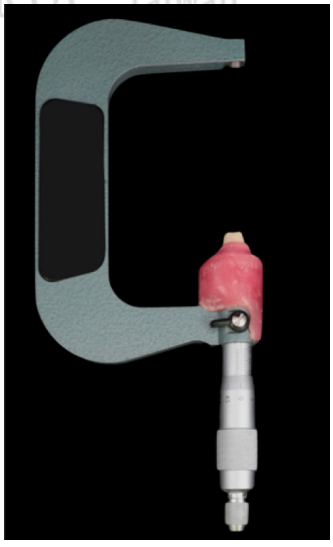

Figure 2. Fabrication of acrylic artificial gum (Hygenic Repair Acrylic (Coltene Whaledent) on the frame of a micrometer

3. As the spiral micrometer rotates, the spindle (tooth) moves relative to the frame (gingiva), thereby simulating the relative position of the finishing line from the supra-gingiva to sub-gingiva. (Figure 3)
4. The spiral micrometer was rotated according to the reading to accurately control the vertical distance between the gingiva and the finishing line.
5. The depth settings of the gingival margin were as follows: supra-gingiva, 0.5 mm (sup 0.5); equal gingiva (equ); sub-gingiva, 0.5 mm (sub 0.5); sub-gingiva, 1.0 mm (sub 1.0).

Acquisition of the digital model using an intraoral scanner

Two different brands of intraoral scanners (IOSs) were used in this experiment: 3Shape Trios 3 (3Shape) and Primescan (Dentsply Sirona) to acquire each depth setting of the five scans, and the scan results were output in STL format, for a total of 40 samples.

3-dimensional digital model superimposition and analysis:

3D engineering software (Geomagic Control X) was used to align and superimpose the images (Figure 4). The angle between the slope of the finishing line of the abutment tooth and the root was measured in the same longitudinal section (Figure 5). The difference between the angles of the scan results and the original model was compared and analyzed.

Statistical Analysis

Statistical analyses using one-way ANOVA was performed to record the following:

1. The influence of the depth of gingival margin on the accuracy of scanning.
2. Comparison of the accuracy of two intraoral scanners at different depths of the gingival margin.

Results

Table 1 shows the difference between the angles of each group and the real angle using nonparametric statistics. The clinically acceptable threshold of the emergence profile angle was defined as ±10° in this experiment. We think there may be insufficient clinical reference value if the emergence profile angle deviation is greater than 10°.

Using one-way ANOVA nonparametric statistics, the following observations were recorded:

1. 3Shape: With sup 0.5, equ, sub 0.5, and sub 1.0 settings, the means were 149.7±2.7°, 150.3±1.0°, 142.9±2.5°, and 138.2±5.7°, respectively, where sub 1.0 (138.2±5.7°) < equ (150.3±1.0°) and supra 0.5(149.7±2.7°) ($p<0.05$); sub 0.5(142.9±2.5°)<equ(150.3±1.0°) and supra 0.5 (149.7±2.7°) ($p<0.05$) (Figure 6).
2. Primescan: With supra 0.5 (148.6 ± 3.1°), equ (151.1 ± 3.5°), sub 0.5 (141.9 ± 2.0°), and sub 1.0 m (148.2 ± 1.5°), there was no significant difference between the groups ($p >0.05$) (Figure 7).
3. 3Shape sub 0.5 and sub 1.0 were observed to be significantly different from the other groups in this experiment ($p<0.05$) (Figure 8).

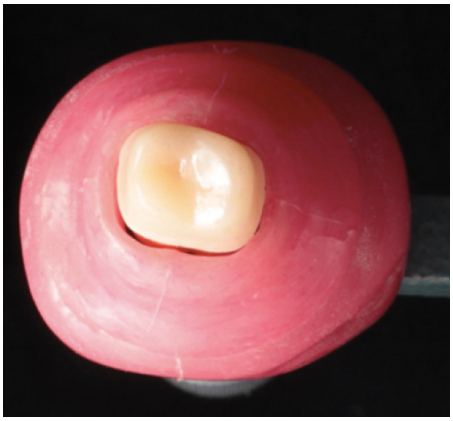

Figure 3.
On the micrometer, the main axis (tooth) moves relative to the frame (gum), and this is used to simulate the relative position of the finishing line from supra-gingiva to sub-gingiva.

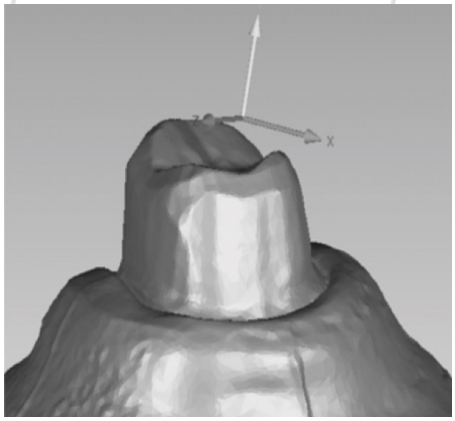

Figure 4.
A three-dimensional engineering software (Geomagic Control X) is used for image superimposition and alignment

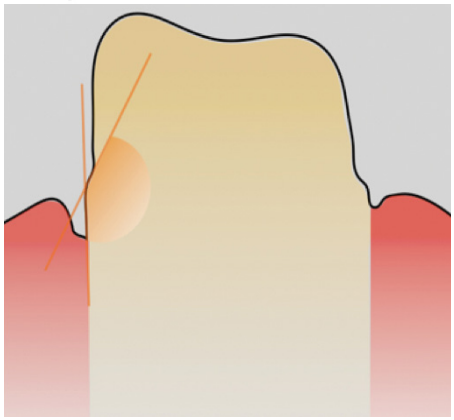

Figure 5.
The angle between the slope of the finishing line of the abutment tooth and the root is measured in the same longitudinal section

Table 1. Nonparametric statistics of angular differences between each group and actual angle. The clinically acceptable threshold of the emergence profile angle was defined as ±10° in this experiment.

Intraoral scanner \ Depth	sub 1.0	sub 0.5	equ	sup 0.5
3Shape (Clinically acceptable)	**-11.8±5.7** (Unacceptable)	**-7.1±2.5** (Acceptable)	**0.3±1.0** (Acceptable)	**-0.3±2.7** (Acceptable)
Primescan (Clinically acceptable)	**-1.8±1.5** (Acceptable)	**-0.9±2.0** (Acceptable)	**1.1±3.5** (Acceptable)	**-1.4±3.1** (Acceptable)

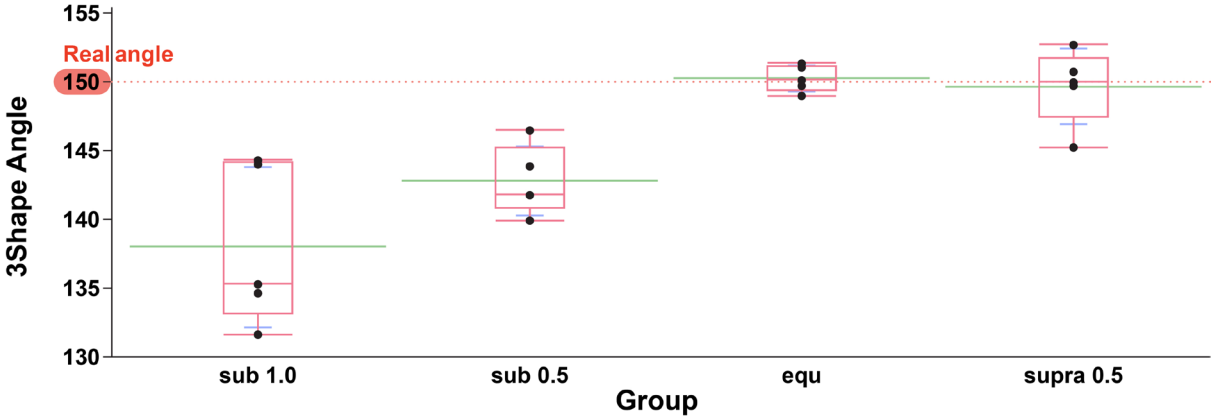

Figure 6. 3Shape scan box plots of different finishing line depths.
sub 1.0 < equ and supra 0.5, which is a statistically significant difference (p<0.05).
sub 0.5<equ and supra 0.5, which is a statistically significant difference (p<0.05).

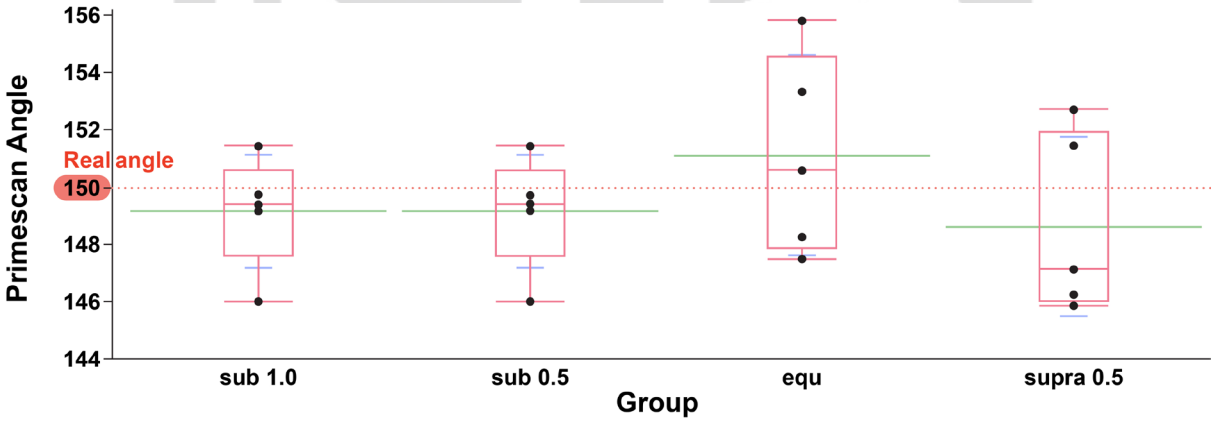

Figure 7. Primescan scan box plots of different finishing line depths
No significant difference between the groups (p >0.05)

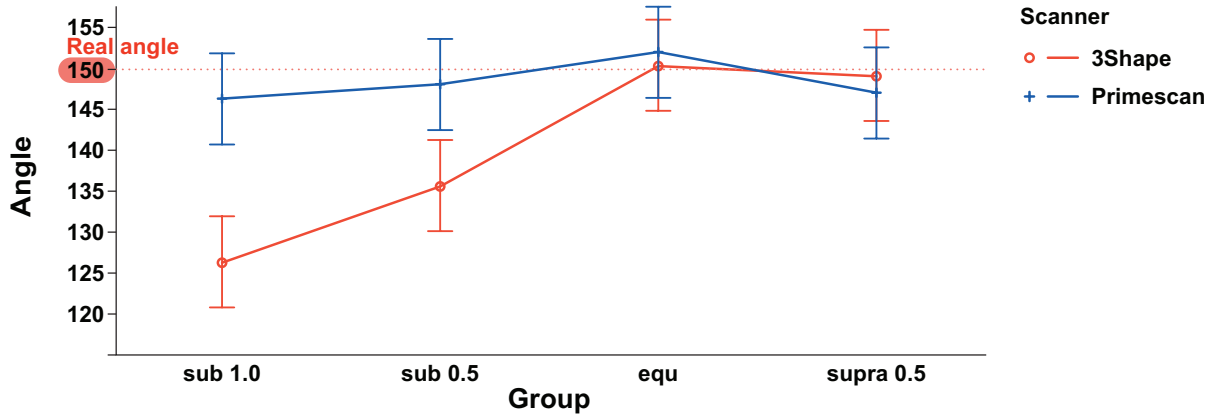

Figure 8. At sub 0.5 and sub1.0, 3Shape scan results were significantly different from other groups in this experiment.

Discussion

According to our results, the deeper vertical position of the finishing line we set, the less accurate of the emergence profile we would get with digital impression.

The present study shows that the angle deviation that can be used clinically to estimate the emergence profile was determined to be 10°, and the results of each experimental group were acceptable except for four scan samples out of the five samples in the 3Shape sub 1.0 group. Du et al.[7] measured 148 upper incisors and found that the angle between the cervico-enamel junction and the root surface was 11.30°–15.26°, which shows that the angle deviation that can be used clinically to estimate the emergence profile was determined to be 10°. The results of our each experimental group were acceptable except for four scan samples out of the five samples in the 3Shape sub 1.0 group (Table 1). Acquiring the emergence profile contributes to determining where the real finishing line is based on the angle transition, which reduces the chance of incorrect margin setting during prosthesis fabrication. The depth of the finishing line should be set according to the data recommended by our study when using an intraoral scanner clinically.

Zimmermann et al.[8] performed an in vitro study to determine the local accuracy of single crown preparations with different intraoral scanners and concluded that the accuracy of Primescan (Dentsply Sirona) is not significantly different from the traditional impression at the gingival margin but is significantly better than Trios 3 (3Shape). Although only the equal gingival abutment margin was evaluated, the results were similar to the different accuracies of the sub-gingival settings with the two different brands of intraoral scanners used in this experiment. This may be the result of different acquisition techniques and software algorithms used in various systems. The measurement principles of the intraoral scanners used in this experiment were as follows: Trios 3 (3Shape), confocal method; Primescan (Dentsply Sirona), triangulation method[9]. Many brands of intraoral scanners are available in the market and if the manufacturers do not provide relevant information, surgeons must determine whether the scanners meet their requirements.

These experimental results indicate that deeper sub-gingival digital impressions are more inaccurate and that different brands of intraoral scanners perform differently in the sub-gingival areas. This study recommended that the depth of the subgingival finishing line should not exceed 0.5 mm to ensure that the supra-gingival finishing line and emergence profile are more accurate; therefore, it is recommended that the margin of the digital impression be maintained above the gingiva, and if necessary, 0.5 mm within the gingiva. In case the margin is deeper, the dentist must either clinically perform a gingivectomy or make a traditional impression to meet the requirements.

Keeling et al.[5] scanned the typodont abutment tooth, and the results showed that the curvatures of the supra-gingival and equal-gingival finishing lines were significantly different. Compared with the supra-gingival finishing line, the image of the equal-gingival finishing line had a larger curvature and poorer definition. Our experimental design further analyzed the subgingival margin and quantified its different depths.

Cagidiaco et al.[6] performed an in vivo study in which the scanning results of Aadva IOS 100 (GC) and the laboratory-scanned traditional impression casting model were superimposed by Exocad software, applying the best-fit algorithm to align the scan of the conventional with the digital impressions. The authors concluded that digital impression is not recommended when crowns' margins are positioned deep (1.5–2 mm) into the sulcus. Our experiment applied two commonly used intraoral scanners to provide more references and the results are based on marginal definition and angle measurement. A similar result was obtained, in that for deeper subgingival finishing lines, their acquisition by intraoral scanners is more difficult.

Concerning traditional impressions, Finger et al.[2] performed an in vitro model study when the gingival retraction width was 200 μm; therefore, providing an opportunity to reproduce the 2 mm area under the gingiva crest due to fluidity of the precise elastic impression material. According to the results of our study, for a clinically subgingival marginal depth of 0.5 mm or more, it is uncertain whether the tooth preparation can be clearly scanned. In addition, when the emergence profile is important (such as the veneer cases in the anterior teeth), traditional impressions are recommended.

Our study has certain limitations. Firstly, although the typodont abutment and acrylic artificial gingiva can simulate the actual appearance of a tooth, these cannot display the true optical

characteristics. Secondly, the use of a typodont abutment and acrylic artificial gingiva in this study eliminates factors like gingival crevicular fluid, blood, saliva, and moisture during breathing.

The experiment by Keeling et al.[5] showed that factors such as marginal proximity to adjacent teeth, height of adjacent teeth will interfere with the viewing angle of the intraoral scan and affect the accuracy. However, our experimental design did not simulate adjacent teeth. In addition, Richert et al.[4] also pointed out that it is necessary to obtain higher accuracy of the intraoral scan model according to a specific scanning path; Keeling et al. [5] also showed that when making digital impressions, the simulated intraoral environment restricts the surgeon's hand holding posture and the scanner's access to the tooth. This factor was not considered in this experiment and the procedure may be more challenging clinically.

In the future, further research must be carried out to support our conclusions and overcome the challenges of clinical application of intraoral scanning systems.

Conclusions

1. The digital impression was based on supra-gingival preparation as much as possible so that more accurate margin and emergence profile could be obtained.
2. Different intraoral scanners showed different scanning details of the sub-gingival margin; therefore, surgeons must be attentive while using intraoral scanners to obtain satisfactory clinical results.
3. Primescan (Dentsply Sirona) was more suitable for digital impression of the sub-gingival finishing line, but the performance of the two intraoral scanners was similar to the recommended value of our experiment.

Conflicts of Interest:

There are no conflicts of interest.

References

1. Safari S, Ma VS, Mi VS, Hoseini GF, Hamedi M. Gingival Retraction Methods for Fabrication of Fixed Partial Denture: Literature Review. J Dent Biomater 2016; 3: 205-13.
2. Finger WJ, Kurokawa R, Takahashi H, Komatsu M. Sulcus reproduction with elastomeric impression materials: A new in vitro testing method. Dent Mater 2008; 24: 1655–60.
3. Ahlholm P, Sipila K, Vallit P, Jakonen M, Kotirant U. Digital versus conventional impressions in fixed prosthodontics: a review. J Prosthodont 2018; 27: 35–41.
4. Richert R, Goujat A, Venet L, Viguie G, Viennot S, Robinson P, et al. Intraoral scanner technologies: a review to make a successful impression. J Healthc Eng. 2017;2017:8427595 Available at: https://www.hindawi.com/journals/jhe/2017/8427595/. Accessed September 05, 2017.
5. Keeling A, Wu J, Ferrari M. Confounding factors affecting the marginal quality of an intra-oral scan. J Dent 2017; 59: 33-40.
6. Cagidiaco EF, Zarone F, Discepoli N, Joda T, Ferrari M. Analysis of The Reproducibility of Subgingival Vertical Margins Using Intraoral Optical Scanning (IOS): A Randomized Controlled Pilot Trial. J Clin Med. 2021;10: 941-50.
7. Du JK, Li HY, Wu JH, Lee HE, Wang CH. Emergence angles of the cementoenamel junction in natural maxillary anterior teeth. J Esthet Restor Dent 2011; 23: 362-9.
8. Zimmermann M, Ender A, Mehl A. Local accuracy of actual intraoral scanning systems for single-tooth preparations in vitro. J Am Dent Assoc 2020; 151: 127-35.
9. Medina MR, Rubio MR, Salido MP, Pradíes G. Digital Intraoral Impression Methods: An Update on Accuracy. Curr Oral Health Rep 2020; 7: 361-75.