치의과학박사 학위논문

Clinical evaluation of time efficiency and fit accuracy of lithium disilicate single crowns fabricated from intraoral digital impressions

디지털 인상으로 제작한 리튬 디실리케이트 단일금관의 시간적 효율성과 보철물 적합도 평가에 관한 임상연구

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박 지 수

Abstract

Clinical evaluation of time efficiency and fit accuracy of lithium disilicate single crowns fabricated from intraoral digital impressions

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Objectives: The purpose of this study was to compare the clinical effectiveness of chairside-fabricated lithium disilicate single crowns by digital impression and conventional methods.

Materials and methods: Thirteen patients requiring a single crown on the maxillary or mandibular premolar or first molar were assigned as study subjects. The impressions were obtained after tooth preparation using the conventional method and two digital methods with intraoral scanners: AEGIS.PO (Digital Dentistry Solution, Seoul, Korea) and CEREC Omnicam (Sirona, Bensheim, Germany). The time required for each impression method was recorded. Two types of lithium disilicate single crowns were fabricated with IPS e.max CAD (Ivoclar Vivadent, Amherst, NY, USA) based on the data obtained from the laboratory scanner (Identica Hybrid; Medit, Seoul, Korea) and the intraoral scanner (AEGIS). The total time taken for fabricating the chairside crown was recorded. After 4 weeks, the reference crown was completed, and the replica technique was performed to compare the marginal and internal fit of the two types of crowns. In addition, accuracy of the intraoral scanners was evaluated by the best-fit alignment method. The difference between the groups was analyzed using the two-tailed paired t-test or one-way ANOVA, followed by the Student-Newman-Keuls test for multiple comparisons. Statistical significance was accepted at $P<.05$ for all statistical tests.

Results: The time required to obtain the impressions by the AEGIS (7:16 ± 1:50 min:sec) and CEREC (7:29 ± 2:03 min:sec) intraoral scans was significantly lower than the conventional method (12:41 ± 1:16 min:sec) ($P<.001$). There was no significant difference between the intraoral scanners. The total working time to fabricate the chairside crown averaged 30:58 ± 4:40 min:sec. The average marginal gap was not significantly different between the reference (107.86 ± 42.45 μm) and chairside (115.52 ± 38.22 μm) crowns ($P>.05$), based on results of replica measurement. The average internal gaps were not significantly different. The average value of the root mean square between the AEGIS (31.7 ± 12.3 μm) and CEREC (32.4 ± 9.7 μm) scans was not significantly different (P>.05).

Conclusions: Intraoral scans required a significantly shorter impression time than the conventional method, and it was possible to fabricate a lithium disilicate crown in a single visit. There were no statistically significant differences in the fit of the restorations and accuracy of the intraoral scanners compared to the conventional workflow.

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Keywords : lithium disilicate, digital impression, time efficiency, replica technique, best fit alignment

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CONTENTS

I. INTRODUCTION

Several new systems, with the goal of digitizing workflow, have been developed to provide digital dental models directly in the clinic.[1] The delivery of restorations in a single visit has become a treatment option with advances in computer-aided design/computer-aided manufacturing (CAD/CAM) systems.[2] In 1985, the CEREC system was first introduced as a chairside CAD/CAM system, which enabled the design and fabrication of restorations in the dental office.[3] Chairside CAD/CAM procedures are more advantageous than the conventional methods in terms of fabrication efficiency of the prostheses.[4,5] Digital workflow does not require time-consuming laboratory procedures and transportation, and improves patient comfort.[6,7]

The restorative materials used in the chairside CAD/CAM systems must be milled immediately, usually within 20 minutes, to be delivered on the same day of tooth preparation. Manufacturers have adopted a wet grinding process on preformed blocks to minimize damage to the materials during milling and to achieve efficient post-milling time. With the exception of zirconia, which takes 6 to 8 hours for the post-milling process, feldspathic, leucite-reinforced, lithium disilicate ceramics, and composite resin are considered for chairside CAD/CAM restorations. Among them, lithium disilicate is most often used as a monolithic restoration owing to its improved strength.[8] In 2006, Ivoclar introduced IPS e.max CAD as a lithium disilicate CAD/CAM material, which has 2 to 3 times more flexural strength compared to the esthetic ceramics.[9] The precrystallized block has a blue violet color and can be milled easily as a partially crystallized state. After milling, the restoration undergoes firing processes for 20 to 25 minutes in a porcelain oven under vacuum and converts to a crystallized state of lithium disilicate.[10] The monolithic application for a full veneer crown was reported to prevent complications such as chipping.[11] Accordingly, several studies have been conducted on the clinical effectiveness and long-term performance of monolithic lithium disilicate restorations.

Gehrt et al.[12] and Sailer et al.[13] compared the survival rate of lithium disilicate single crowns on the anterior and posterior teeth and concluded that the position of the crown did not significantly affect the survival rate. Van den Breemer et al.[14] showed that the cumulative survival rate of lithium disilicate single crowns in premolars and molars was 92% for 5 years, 85.5% for 10 years, and 81.9% for 15 years, indicating that the monolithic lithium disilicate crown is a reliable long-term clinical material. Studies that tested chairside CAD/CAM single crowns on the posterior teeth using IPS e.max CAD blocks also concluded that lithium disilicate single crowns demonstrated clinically satisfactory results.[11,15]

An important factor for the longevity of dental restorations is marginal fit, which is affected by both vertical and horizontal discrepancies.[16,17] The marginal gap is the perpendicular distance from the finish line of the prepared tooth to the internal surface of the restoration, as defined by Holmes et al.[18] Cements can fill the marginal discrepancy; however, considering their rough and porous nature, cements can dissolve when exposed to the oral environment, resulting in microleakage and plaque accumulation.[19] Therefore, poor marginal fit of the restoration results in gingival inflammation, dental caries, and pulpal lesions.[20,21] Although there is ongoing controversy regarding the acceptable values of marginal discrepancy, various studies have suggested that a 50 μm to 120 μm gap is clinically acceptable.[22–24] McLean and von Fraunhofer[25] conducted an in vivo study and demonstrated that restorations with cement thickness below 120 μm were more likely to succeed.

In clinical studies, the quality of adaptation of the restoration can be estimated by intraoral radiographs, tactile evaluation, and the replica technique.[25–27] In particular, the replica technique involves measuring a silicone replica of the space between the tooth and the restoration using a microscope, and allows reliable prediction of the cement thickness regardless of the location.[28–30]

The majority of the literature published before 2014 argued that the marginal fit of conventionally fabricated lithium disilicate crowns was better than crowns fabricated with the CAD/CAM technology.[31] However, papers published after 2014 showed a tendency of improved marginal fit of CAD/CAM crowns. Several studies that compared lithium disilicate crowns showed no significant differences in the marginal discrepancy and internal discrepancy volume between the conventional and CAD/CAM methods.[32–35] An in vitro study by Alfaro et al.[36] that measured the internal adaptation of lithium disilicate crowns by a micro-CT scan, reported that CAD/CAM crowns fabricated by the Lava COS digital impression system demonstrated better internal fit than those fabricated by the conventional impression technique. Haddadi et al.[37] conducted an in vivo study and reported that the marginal and internal gaps in CAD/CAM crowns were significantly lower than those in conventional crowns in all regions, except the cusp tip. Another important factor affecting the fit of the prostheses, when deciding to use lithium disilicate as the chairside CAD/CAM material, is the intraoral scanner. Accurate digital data from intraoral scans should be the basis for favorable prostheses.

Dentists can use the intraoral scanner to capture tooth surfaces and soft tissues in three dimensions to instantly analyze digital models. With the development of the chairside CAD/CAM technology, intraoral scanners have been widely used and advanced with reliable accuracy.[38,39] Direct digital impressions overcome the disadvantages of the commonly used elastomeric impression materials, including technique sensitivity, patient discomfort, dimensional changes, and laboratory errors.[40,41] However, the digital impression may also be associated with potential distortions caused by limitations in the scanning technology and accumulation of the datasets while scanning a longer arch.[42,43] To overcome these shortcomings, devices based on various non-contact optical technologies such as confocal microscopy, active stereovision, and triangulation are under development or have already been introduced in the dental market.[44,45] New digital impression techniques and devices have been compared with current reliable devices and standard processes to evaluate their accuracy and feasibility.

There are two ways to evaluate the precision of different workflows; one by comparing the fit of the resulting restorations and the other by analyzing the correspondence between the scanned and reference datasets.[45] Currently, the three-dimensional best-fit analysis is the most common and reliable method used for precision analysis of intraoral scanners. Each dataset is converted to the standard tessellation language (STL) dataset to be aligned, and the distance difference in the x, y, and z axes between the reference and test models is calculated using best-fit algorithms. The differences are represented by a color map such that the error of each area can be estimated at a glance.[42,45,46] However, research on the accuracy of the chairside CAD/CAM system remains inadequate.

The aims of this clinical study were to demonstrate whether lithium disilicate crowns fabricated with digital workflow was time-effective, compare the marginal and internal fit of lithium disilicate crowns based on direct or indirect digitalization, and to test the accuracy of the impression by comparing the laboratory scanner with two intraoral scanners.

II. MATERIALS AND METHODS

1. Clinical study design

This clinical study was performed at the Department of Prosthodontics, School of Dentistry, Seoul National University, Seoul, Korea. The study protocol was approved by the Institutional Research Board (IRB No. CDE17003), and all procedures were performed according to the Declaration of Helsinki on experimentation involving human subjects (Association 2013).

The participants in need of a single crown were recruited based on the following inclusion and exclusion criteria:

Inclusion criteria:

(1) Patients aged 19-70 years

(2) Patients in need of a tooth-supported crown in the posterior region (premolar or first molar)

(3) Presence of healthy abutment and adjacent teeth without the need for additional treatment

(4) Normal occlusal plane of the opposite teeth

(5) Tooth with a finishing line that could be formed supragingivally

(6) Absence of temporomandibular or occlusal disorders

(7) Patients who participated voluntarily in this clinical trial and signed the informed consent

Exclusion criteria:

(1) Pregnancy

(2) Mental illness

(3) Allergy to the restorative material

(4) Symptomatic teeth requiring additional endodontic treatment

(5) Periodontally involved teeth

(6) Presence of parafunctional habits

(7) Inadequate crown height

The required sample size was calculated based on the superiority test using paired t-test formulas.[47]

$$N_t \ = \ \frac{\sigma_d^2(Z_{\alpha/2}+Z_\beta)^2}{d^2} \ \fallingdotseq 9.621 \approx \ 10\,subject$$

$$N = N_t/(1-0.2) = 12.5 \approx 13\,subject$$

where N_t was the number of patients in the test group, Z_α was the type I error(5%), Z_β was the type II error(20%), σ_d was the standard deviation of difference, and d was the mean of the difference. Zhang et al.[48] compared the superiority of the intraoral scan and plaster model with the paired t-test. The LR6-LL6 measurement showed a statistically significant difference in the transverse measurement in the arch; therefore, σ_d was 0.31 mm and d was -0.28 mm. Subject and clinical evaluation dropout rates of 10% each were estimated. Considering the total dropout rate (20%), the actual number of patients required in the test group (N) was 13.

A total of 15 potential participants were recruited via subway car advertising and two of the screened candidates were excluded based on the aforementioned criteria. One clinician (J.S.P.) performed the clinical procedures. All caries and defective restorations were removed and replaced from the teeth of the participants.

2. Clinical procedures

Figure 1 illustrates the flow diagram of the clinical processes. Panoramic and periapical radiographs of all participants were taken. A preliminary alginate impression was made, and the study model was fabricated prior to tooth preparation.

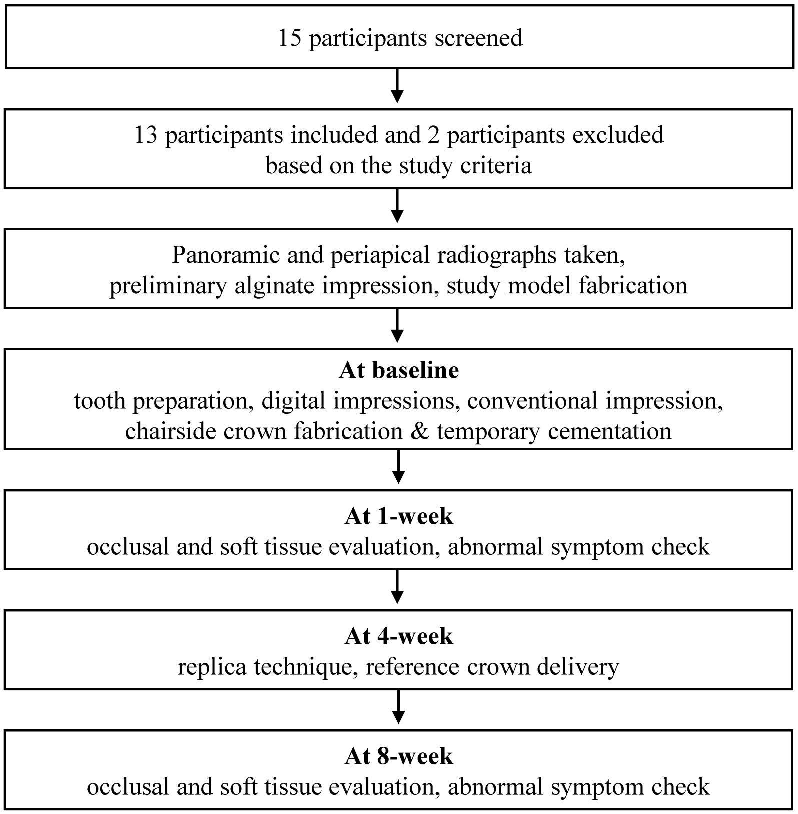


Figure 1. Flow-chart depicting included patients, timeline, and evaluation items

2.1. Tooth preparation

The study abutment teeth were prepared to receive full-coverage ceramic crowns. The finish line was located 0.5–1.0 mm supragingivally and the preparation consisted of a shoulder margin with a rounded internal line angle. Occlusal and circumferential reductions of 1.5–2.0 mm and 1.0–1.2 mm were performed. All sharp edges were rounded off (Figure 2).

One conventional and two digital impressions were acquired from the prepared teeth in each of the 13 participants. The order of acquisition was as follows, first scan with AEGIS.PO (Digital Dentistry Solution, Seoul, Korea), followed by the conventional method, and finally with CEREC Omnicam (Sirona, Bensheim, Germany).

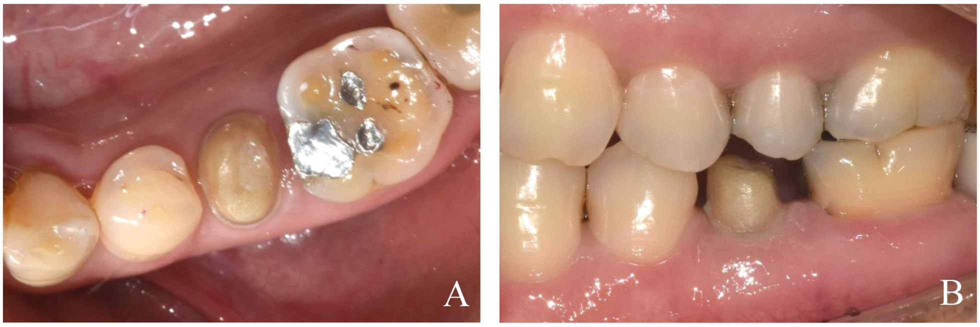


Figure 2. Prepared abutment tooth, A, Occlusal view, B, Buccal view

2.2. Conventional impression

Since the abutment finish line was formed 0.5–1.0 mm above the gingival line, all impressions were obtained without cord insertions. Impression of the associated quadrant was obtained using a perforated plastic ready-made tray. VPS tray adhesive (Kerr, Romulus, MI, USA) was applied to the tray. The impression was made using light-body polyvinyl siloxane (Imprint II Garant; 3M ESPE, Seefeld, Germany) and putty (Exaflex Putty; GC, Tokyo, Japan) using a one-step technique (Figure 3). The impression material was set in the patient's mouth considering the safety time recommended by the manufacturer. Impression of the opposing jaw was obtained using alginate (Aroma fine plus; GC, Tokyo, Japan) and the interocclusal record was acquired using polyvinyl siloxane (O-bite; DMG, Hamburg, Germany). The time taken to obtain the impression was recorded using a digital stopwatch (HS3V-1B; Casio Computer Corp., Seoul, Korea). The VITA classic shade guide (VITA Zahnfabrik, Bad Säckingen, Germany) was used to obtain the shade for the crowns.

Figure 3. Conventional impression of the abutment tooth using light-body polyvinyl siloxane and putty

2.3. Digital impressions

Two digital systems, namely the AEGIS.PO and CEREC Omnicam, were tested to obtain intraoral optical impressions. The intraoral scanner was calibrated before each patient was scanned. Quadrant scans were performed, and the scan sequences were chosen according to the manufacturer's guidelines. The abutment, antagonist, and interocclusal records were scanned with the AEGIS and CEREC systems. Before scanning with AEGIS, a VITA powder scan spray (VITA Zahnfabrik, Bad Säckingen, Germany) was applied to the tooth surface. Each scan time was measured with a digital stopwatch.

The time taken to obtain one conventional impression and two digital impressions were assessed (Figure 4.A). The time needed to obtain the conventional impression was recorded from the beginning of application of the tray adhesive to the end of the bite material removal from the patient's mouth. The time taken to obtain digital impressions was recorded from software startup to data processing (Figure 5).

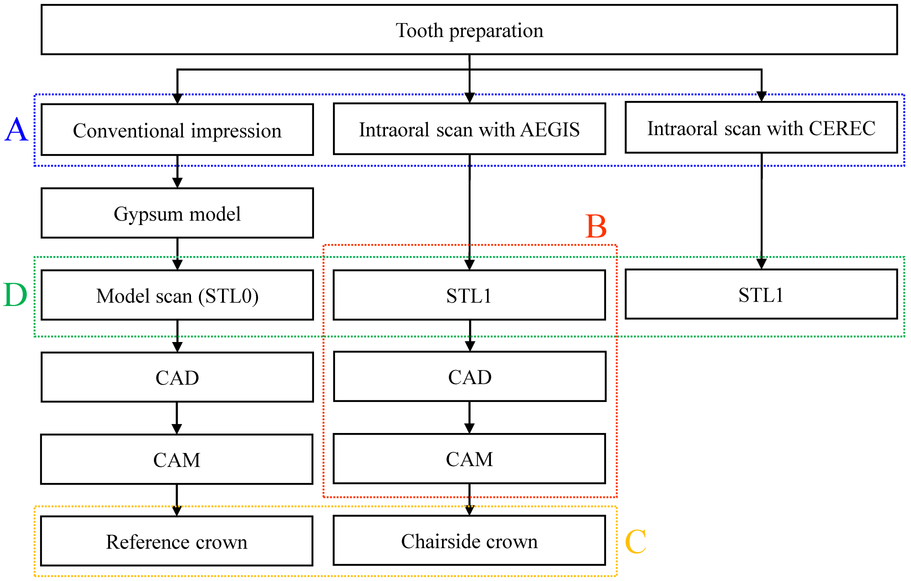


Figure 4. Overview of this study, A, Impression time; comparison of the time taken to obtain impressions by the conventional and intraoral scanning methods, B, Total working time; total working time for fabricating the chairside crown, C, Replica measurement; evaluation of marginal and internal fit of the two crowns, D, Best fit alignment; evaluation of the accuracy of intraoral scanners

Procedure	**Sequences of time measurement**					
Conventional impression	Applying tray adhesive	Abutment impression	Antagonist impression	Bite registration		
Digital impression	Software startup	(Coating)	Abutment scan	Antagonist scan	Bite scan	Data processing
Design	Software startup	Data import	Restoration design	Data processing		
Milling	Data sending	Material placement	Restoration manufacture			

Figure 5. Specific steps in the procedure for time measurement

2.4. Chairside crown fabrication

Using the file from the AEGIS intraoral scanner, a lithium disilicate crown was designed using the design software (DESIGN+ Suite, Digital Dentistry Solution, Seoul, Korea) (Figure 6.A). All crowns were designed with the same settings (cement gap: 70 μm, layer thickness: 600 μm, edge reinforcement: 200 μm). The design file was sent to the chairside milling machine (SPEED+, Digital Dentistry Solution, Seoul, Korea), and single crowns were fabricated with lithium disilicate glass-ceramic blocks (IPS e.max CAD; Ivoclar Vivadent, Amherst, NY, USA) (Figure 6.B). Each design and milling time was recorded with a digital stopwatch and the total time for digital workflow was investigated (Figure 4.B, Figure 5).

After the final sintering procedure, the crowns were tried intraorally and adjusted if necessary, except for the internal surface, and cemented with a eugenol-free temporary cement (Tempbond NE; Kerr, Romulus, MI, USA). All procedures were performed in one treatment appointment.

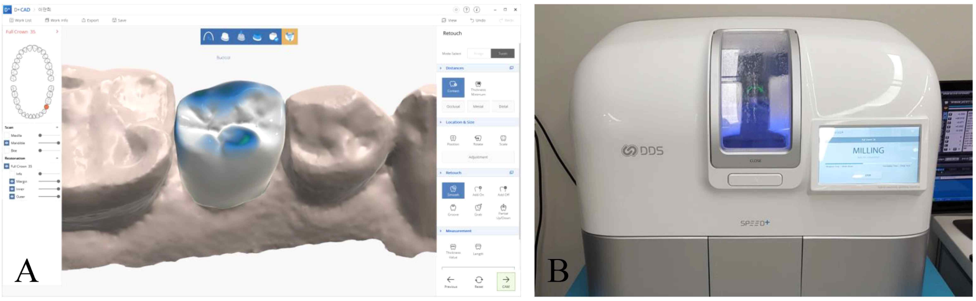


Figure 6. Chairside CAD/CAM procedure, A, Planning a chairside crown with the design software, B, Manufacturing a lithium disilicate crown with the milling machine

2.5. Reference crown fabrication and delivery

Conventional impression materials were disinfected and type IV dental stone (Fujirock; GC, Tokyo, Japan) was poured. The master casts were scanned with a laboratory scanner (Identica Hybrid; Medit, Seoul, Korea) (Figure 7). Subsequently, the restorations were designed using the DESIGN+ Suite software with the same settings as the chairside CAD process. IPS e.max CAD blocks were milled using SPEED+ machine and all laboratory procedures were performed by a single technician.

Four weeks after preparing the abutment, a replica technique[25,29,49] was performed to register the marginal and internal fit of the two groups (Figure 4.C). A reference crown (control group) was obtained by conventional workflow and a chairside crown (test group) was obtained by digital workflow. The internal surface of the crowns was filled with low-viscosity silicone (Fit-checker II; GC, Tokyo, Japan) and seated on the abutment tooth by applying maximum finger pressure for 3 seconds (Figure 8.A). The patients were continuously instructed to bite on the cotton roll. The crowns were carefully removed after 2 minutes with the silicone film adherent to the internal surface. The film was stabilized by injecting a light-body polyvinyl siloxane (Examixfine Injection type; GC, Tokyo, Japan) (Figure 8.B). After setting of the second material, the base of the replica was reinforced with heavy-body polyvinyl siloxane (Imprint II Garant; 3M ESPE, Seefeld, Germany).

Subsequently, a reference crown fabricated by the conventional impression method was cemented using a dual-cure resin cement (Variolink N; Ivoclar Vivadent AG, Schaan, Liechtenstein) according to the manufacturer's guidelines.

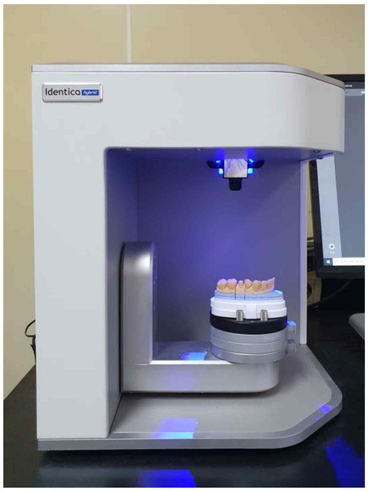


Figure 7. The laboratory scan of the master cast obtained by the conventional method

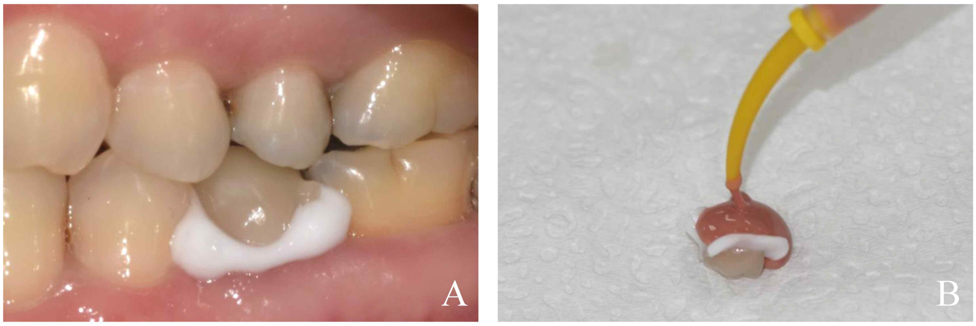


Figure 8. Replica technique, A, The cement space was replicated with low-viscosity silicone. B, The silicone film was stabilized by injecting a light-body polyvinyl siloxane.

3. Replica measurement

Each replica was sectioned into four parts, buccolingually and mesiodistally, using a sharp scalpel (Figure 9). The thickness of the replica film corresponding to the discrepancy between the crown and the abutment tooth was measured using a stereomicroscope (SMZ168, Motic, Wetzlar, Germany) at 50X magnification (Figure 10.A). The specimen images were transferred to an analysis software (Motic Images Plus 3.0, Motic, Wetzlar, Germany) using a digital microscope camera (Moticam 3+, Motic, Wetzlar, Germany). The widths of the marginal, axial, cuspal, and occlusal areas were measured on all aspects of the sectioned replica (Figure 10.B).

The marginal gap was recorded as the perpendicular distance from the finish line of the prepared tooth to the internal surface of the restoration, as defined by Holmes et al.[18] The internal gaps were measured at the midpoint of each wall (Figure 11). All replicas were cut and measured by the same trained operator.

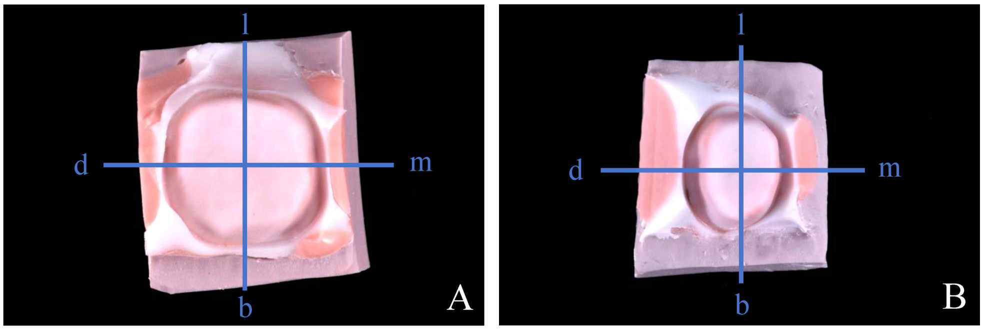


Figure 9. Silicone replicas were sectioned in the mesiodistal and buccolingual directions. m, mesial; d, distal; b, buccal; l, lingual, A, molar replica, B, premolar replica

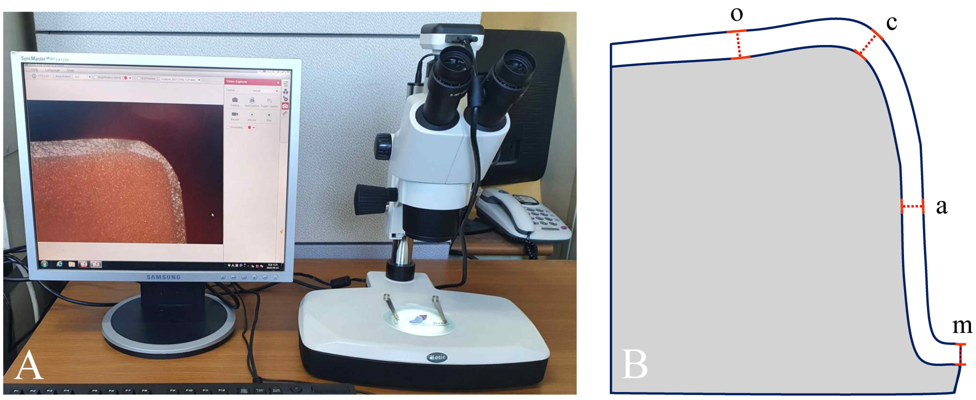


Figure 10. A. The replica was observed by stereomicroscope (magnification 50X) and a digital microscope camera. B, Schematic diagram of the points measured on each cross-section, o, occlusal gap (midpoint of occlusal wall); c, gap of cusp tip (axio-occlusal transition point); a, axial gap (midpoint of axial wall); m, marginal gap

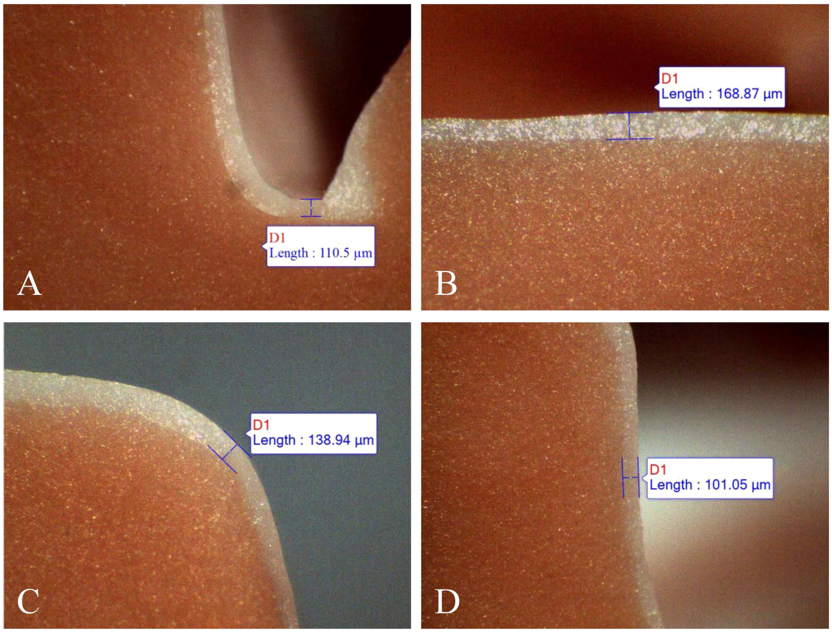


Figure 11. The blue lines represent the measurement discrepancies between the crown and the abutment tooth by the analysis software. A, marginal discrepancy, B, axial discrepancy, C, discrepancy of the cusp tip, D, occlusal discrepancy

4. Best-fit alignment

Accuracy of the intraoral scanners was compared by overlaying the scan images obtained with AEGIS (STL1) and CEREC (STL2) with those of the laboratory scanner (STL0) (Figure 4.D). Each dataset was converted to an STL format and then imported into the 3D analysis software (Geomagic Control X; 3D Systems, Rock Hill, USA). The datasets were trimmed to the field of interest, including the prepared area of the abutment teeth and all artifacts and unrelated areas below the preparation lines were eliminated by the 3D modeling software (Rhinoceros 6.0; Robert McNeel & Associates, Seattle, WA, USA). The trimmed datasets from STL1 and STL2 were separately superimposed with the STL0 dataset using a best-fit algorithm (Figure 12). The software calculated the three-dimensional divergences between each test and reference dataset, and produced results of mean positive and negative deviations and root mean square values. The 3D differences were represented by a color-coded image.

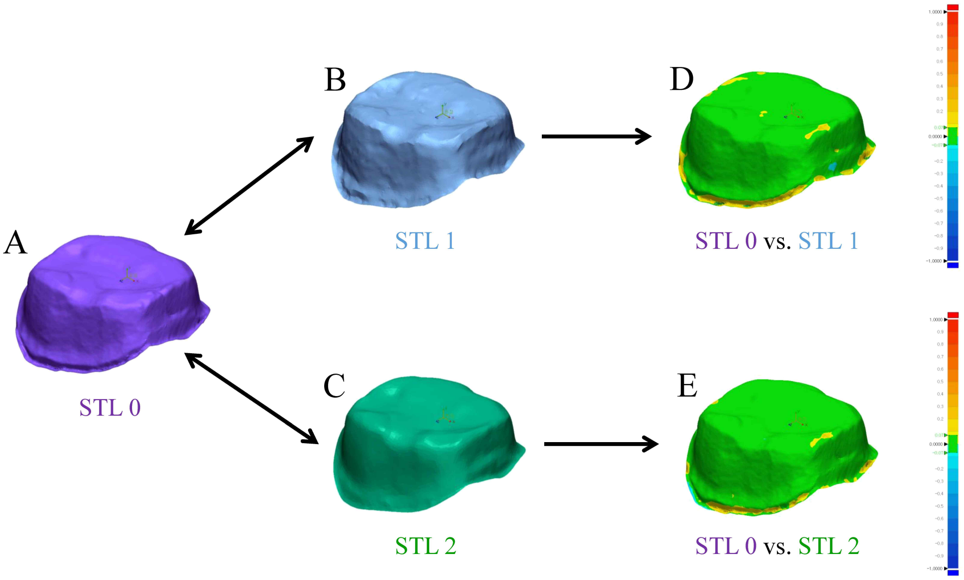


Figure 12. Simplified graphic representation of the analysis by best-fit alignment, A, Scan data of the gypsum model by laboratory scanner, B, Scan data using the AEGIS intraoral scanner, C, Scan data using the CEREC intraoral scanner, D, Deviation after superimposition of A and B displayed in a color-coded map. E, Deviation after superimposition of A and C displayed in a color-coded map.

5. Statistical analyses

Descriptive statistics were computed for all variables with software (Sigma Plot 14.0, Systat Software Inc., San Jose, CA, USA). As the data were normally distributed (Shapiro-Wilk test), differences between the groups were analyzed using two-tailed paired t-test or one-way ANOVA, which was followed by the Student-Newman-Keuls test for multiple comparisons. The data distributions were represented with boxplots, and the data were reported using means, standard deviations (SD), ranges, and 95% confidence intervals. Statistical significance was accepted at $P<.05$ for all statistical tests.

III. RESULTS

Thirteen patients (4 men and 9 women) participated in the study. The mean age of the patients was 49.0 ± 13.4 (range, 22–67) years. Two maxillary second premolars, three maxillary first molars, four mandibular second premolars, and four mandibular first molars were treated. The demographic data and clinical characteristics of the study population are presented in Table 1.

Table 1. Demographic data and clinical characteristics of participants

	Variables	Number of participants	Percentage of participants
Participants (N=13)	Age (Mean ± SD)	49.0 ± 13.4	
	20–29	1	7.7
	30–39	3	23.1
	40–49	3	23.1
	50–59	2	15.4
	over 60	4	30.8
	Sex		
	Male	4	30.8
	Female	9	69.2
	Tooth position		
	Mx. 2nd premolar	2	15.4
	Mx. 1st molar	3	23.1
	Mn. 2nd premolar	4	30.8
	Mn. 1st molar	4	30.8

Data, except for mean age, are presented as the number of participants. The unit of age is years.
SD, standard deviation

1. Comparison of time taken for the impressions

In all participants, the time taken to obtain impressions by the conventional method was longer than the time required for digital impressions. The mean time taken to obtain the impression was 12:41 ± 1:16 min:sec by the conventional method, 7:16 ± 1:50 min:sec by AEGIS intraoral scan, and 7:29 ± 2:03 min:sec by CEREC intraoral scan (Table 2). The average time taken to obtain the impressions by the AEGIS and CEREC intraoral scans were significantly lower than that taken by the conventional method (P<.001) (Figure 13). The difference between the AEGIS and CEREC intraoral scans was not statistically significant (P=.767).

Table 2. Comparison of the time required for each impression method

	Conventional (min:sec)	AEGIS (min:sec)	CEREC (min:sec)
Mean	12:41	07:16	07:29
Maximum	14:09	10:38	11:32
Minimum	10:44	04:03	04:12
SD	01:16	01:50	02:03

SD, standard deviation

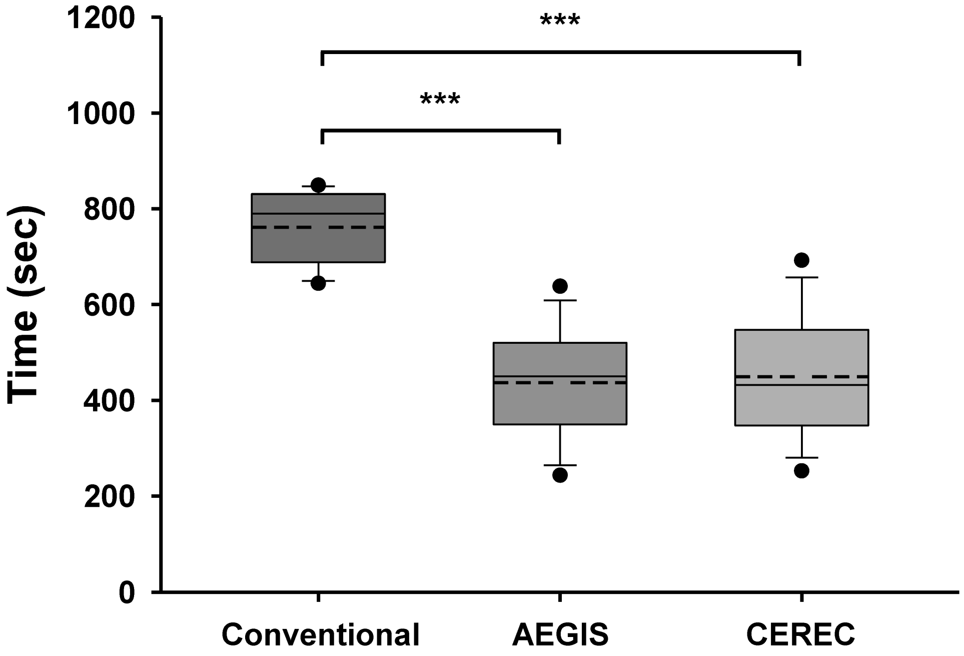


Figure 13. Box plot of the time required for each impression method (***, $P<.001$)

2. Total working time for the chairside crown

The milling process took the longest time on average among the procedures for fabricating the chairside crown, and the mean scan time was longer than the mean design time. The mean scan time with the AEGIS intraoral scanner was 7:16 ± 1:50 min:sec. The mean design time with DESIGN+ Suite software was 6:50 ± 2:15 min:sec. The mean milling time with the SPEED+ machine was 16:51 ± 3:30 min:sec. The total working time for scanning, designing, and milling averaged 30:58 ± 4:40 min:sec. The maximum total working time was 39:16 min:sec (Table 3).

Table 3. The time required for each step and the total working time for chairside fabrication of the single crowns

	Scan (min:sec)	Design (min:sec)	Milling (min:sec)	Total (min:sec)
Mean	07:16	06:50	16:51	30:58
Maximum	10:38	12:20	22:00	39:16
Minimum	04:03	04:28	11:38	24:33
SD	01:50	02:15	03:30	04:40

SD, standard deviation

3. Marginal and internal fit

The replica measurements, including the mean, standard deviation, median, 95% confidence interval, and maximum and minimum values for both the reference and the chairside crowns are presented in Table 4. The Shapiro-Wilk test revealed a normal distribution of the data in the two groups (P>.05). The mean marginal gap was 107.86 ± 42.45 μm in the conventional workflow and 115.52 ± 38.22 μm in the chairside workflow (Figure 14.A). The mean marginal gap in the conventional workflow was lower than that in the chairside workflow; however, the difference was not statistically significant (P>.05). The mean gap in the axial wall was 110.84 ± 33.43 μm in the conventional workflow and 113.05 ± 35.67 μm in the chairside workflow (Figure 14.B). The mean gap in the cusp tip was 151.04 ± 52.58 μm in the conventional workflow and 146.38 ± 46.78 μm in the chairside workflow (Figure 14.C). The mean occlusal gap was 198.92 ± 77.04 μm in the conventional workflow and 207.54 ± 60.42 μm in the chairside workflow (Figure 14.D). The average internal gaps, including those of the axial wall, cusp tip, and occlusal regions, were not significantly different between the two workflows (P>.05). Analyses of the significances between the regions revealed significant differences in all correlations, with the exception of the marginal gap with the axial gap (P<.001) (Table 5).

Table 4. Results of the replica measurements in micrometers at four locations: marginal gap, axial wall, cusp tip, and occlusal gap

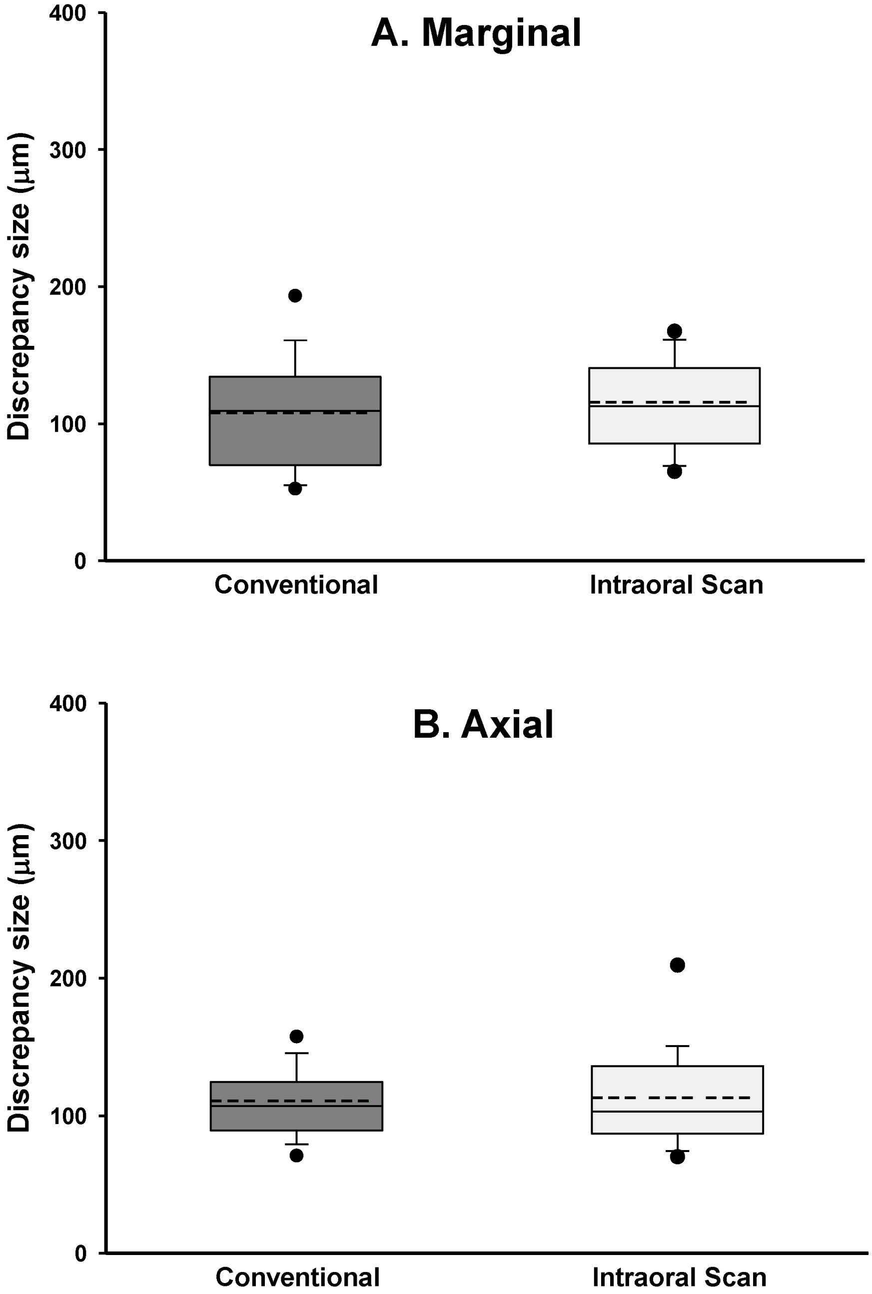
Region	Method	Mean ± SD (Median)	95% Confidence interval (Range)	Normality	*P* value
Marginal	CI	107.86 ± 42.45 (109.13)	82.21-133.51 (49.87-219.90)	.544	.381
	IOS	115.52 ± 38.22 (112.64)	92.42-138.62 (27.08-244.32)		
Axial	CI	110.84 ± 33.43 (107.14)	90.64-131.05 (67.07-276.76)	.057	.582
	IOS	113.05 ± 35.67 (102.98)	91.50-134.61 (57.90-219.34)		
Cusp	CI	151.04 ± 52.58 (143.32)	119.27-182.81 (71.37-294.22)	.452	.577
	IOS	146.38 ± 46.78 (139.83)	118.11-174.65 (58.77-246.93)		
Occlusal	CI	198.92 ± 77.04 (190.66)	152.37-245.48 (96.81-386.78)	.053	.442
	IOS	207.54 ± 60.42 (198.84)	171.03-244.05 (101.82-344.20)		

CI, conventional impression

IOS, intraoral scan

Table 5. Significances between regions of the replica

Region		Marginal	Axial	Cusp	Occlusal
Marginal		Conventional	P=.800	P<.001	P<.001
		Intraoral scan	P=.278	P<.001	P<.001
Axial		P=.800	Conventional	P<.001	P<.001
		P=.278	Intraoral scan	P<.001	P<.001
Cusp		P<.001	P<.001	Conventional	P<.001
		P<.001	P<.001	Intraoral scan	P<.001
Occlusal		P<.001	P<.001	P<.001	Conventional
		P<.001	P<.001	P<.001	Intraoral scan


A. Marginal
Discrepancy size (μm)
400
300
200
100
0
Conventional
Intraoral Scan
B. Axial
Discrepancy size (μm)
400
300
200
100
0
Conventional
Intraoral Scan

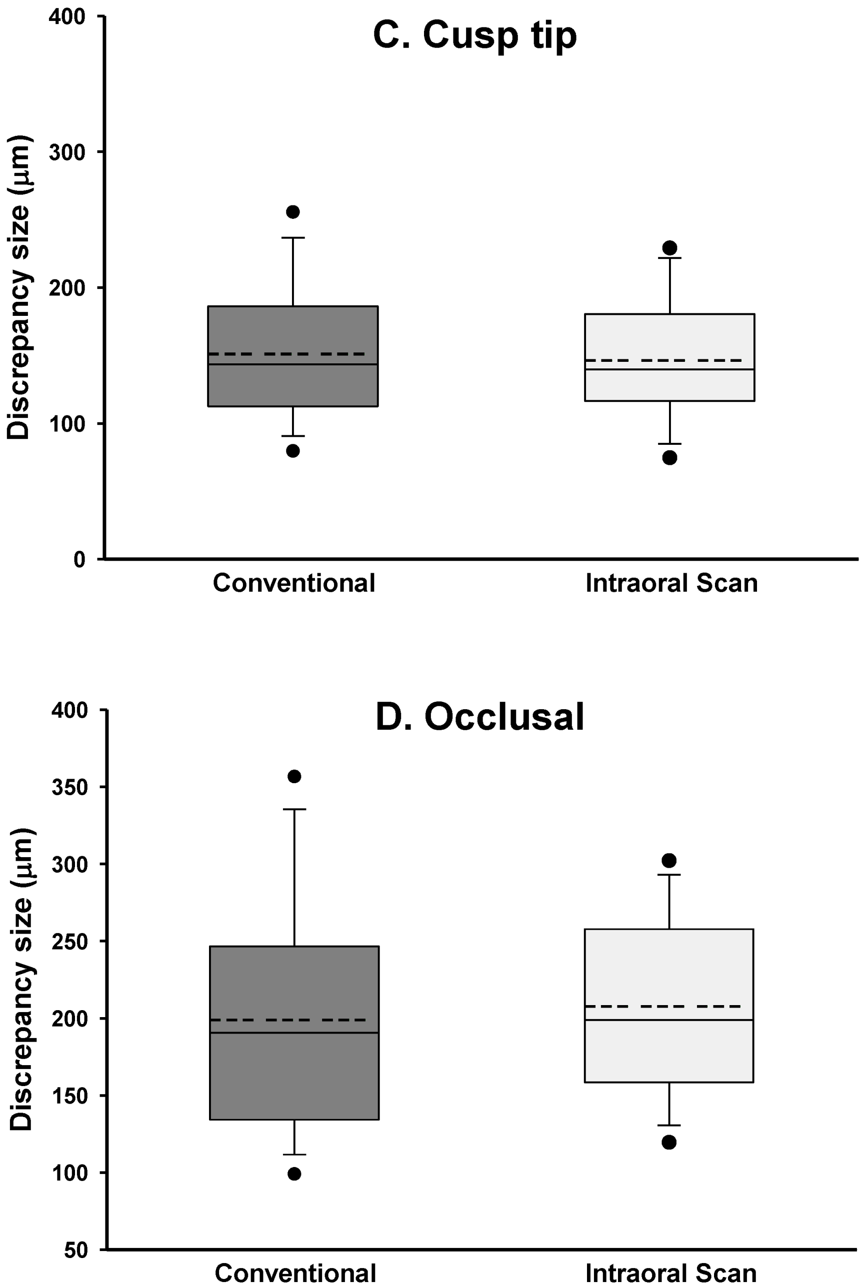


Figure 14. Box plots of discrepancies in the four regions of interest, A, marginal discrepancy, B, axial discrepancy, C, discrepancy in the cusp tip, D, occlusal discrepancy

4. Accuracy of intraoral scanners

Table 6 presents the average and standard deviation values of the mean positive and negative deviations and the root mean square of each experimental dataset after superimposition with the reference dataset. The Shapiro-Wilk test revealed that the two test groups had a normal distribution (P>.05). The average value of the mean positive deviation of the AEGIS scan (25.5 ± 11.0 μm) was higher than that of CEREC scan (24.9 ± 9.2 μm). The average value of the mean negative deviation of the CEREC scan (−19.2 ± 6.2 μm) was lower than that of the AEGIS scan (−17.6 ± 5.4 μm) (Figure 15). The average value of the root mean square of the CEREC scan (32.4 ± 9.7 μm) was higher than that of the AEGIS scan (31.7 ± 12.3 μm) (Figure 16). However, none of the parameters between the AEGIS and CEREC scans were significantly different (P>.05). Figure 17 and 18 show the color-coded maps and deviation values after each superimposition of all abutment teeth.

Table 6. Results (in micrometers) obtained by superimposition of the CI dataset with datasets obtained using the AEGIS and CEREC scans

Group	AEGIS	CEREC	Normality	*P* value
	Mean ± SD	Mean ± SD		
Mean positive deviation	25.5 ± 11.0	24.9 ± 9.2	.774	.738
Mean negative deviation	−17.6 ± 5.4	−19.2 ± 6.2	.262	.409
Root mean square	31.7 ± 12.3	32.4 ± 9.7	.894	.760

SD, standard deviation.

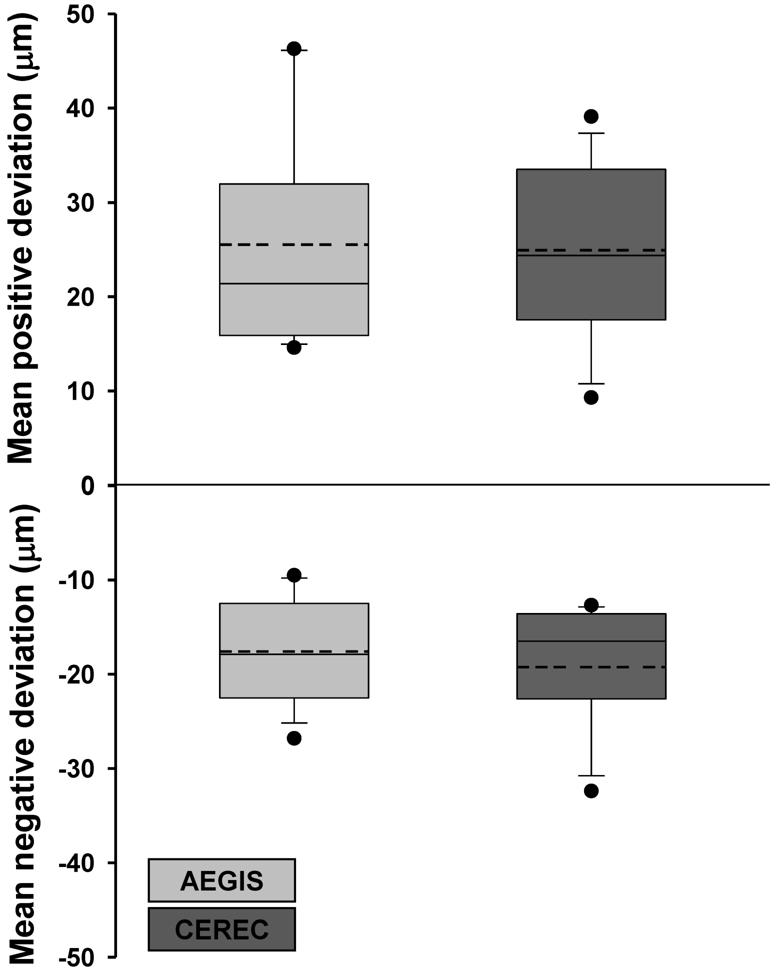


Figure 15. Box plot of the mean positive and negative deviations after superimposition of the CI dataset with datasets obtained from the AEGIS and CEREC scans

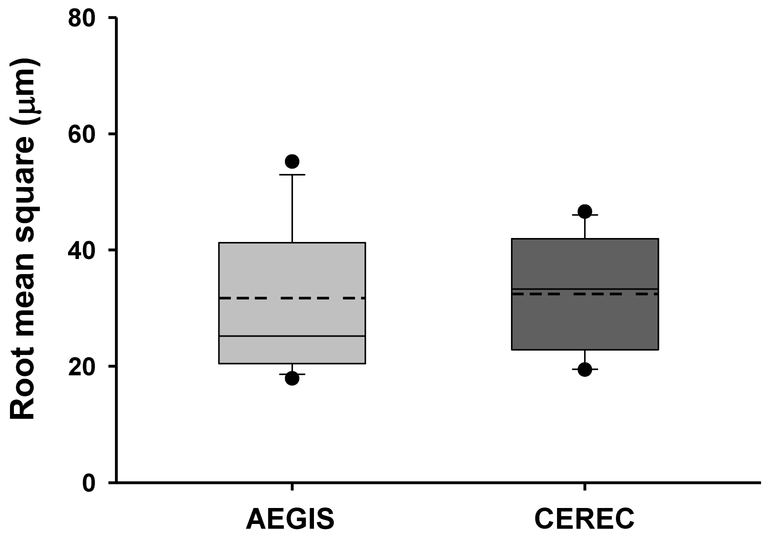
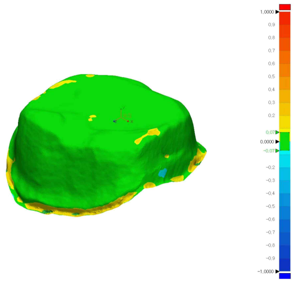
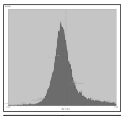
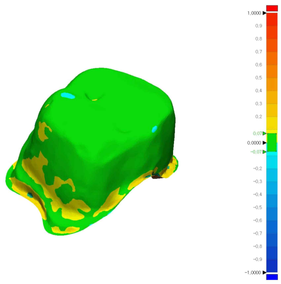
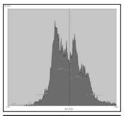


Figure 16. Box plot of root mean square between the CI dataset and datasets obtained using the AEGIS and CEREC scans

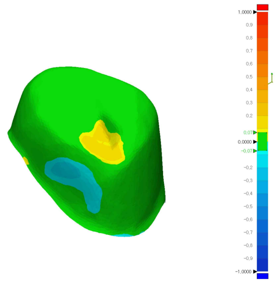
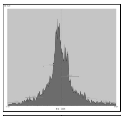
Min.	-0.1749
Max.	0.179
Avg.	0.0076
RMS	0.0383
Std. Dev.	0.0375
Var.	0.0014
+Avg.	0.0312
-Avg.	-0.0169
In Tol. (%)	91.8566
Out Tol. (%)	8.1434
Over Tol. (%)	7.0582
Under Tol. (%)	1.0851

A

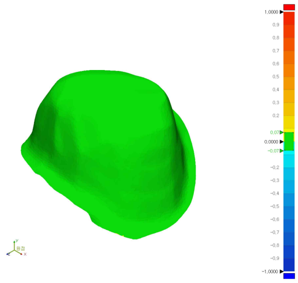
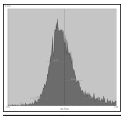
Min.	-0.1093
Max.	0.2194
Avg.	0.0203
RMS	0.0496
Std. Dev.	0.0453
Var.	0.0021
+Avg.	0.0463
-Avg.	-0.0224
In Tol. (%)	86.5623
Out Tol. (%)	13.4377
Over Tol. (%)	12.5944
Under Tol. (%)	0.8434

B

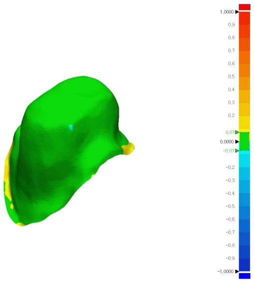
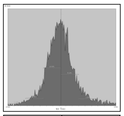
Min.	-0.1324
Max.	0.1676
Avg.	-0.0026
RMS	0.0422
Std. Dev.	0.0422
Var.	0.0018
+Avg.	0.0327
-Avg.	-0.0268
In Tol. (%)	89.3674
Out Tol. (%)	10.6326
Over Tol. (%)	5.5989
Under Tol. (%)	5.0336

C

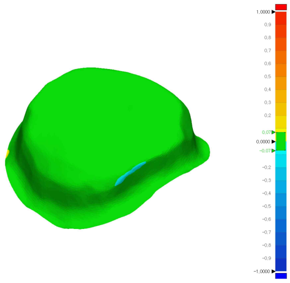
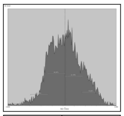
Min.	-0.075
Max.	0.0791
Avg.	0.0026
RMS	0.0179
Std. Dev.	0.0177
Var.	0.0003
+Avg.	0.0155
-Avg.	-0.0095
In Tol. (%)	99.5826
Out Tol. (%)	0.4174
Over Tol. (%)	0.3806
Under Tol. (%)	0.0368

D

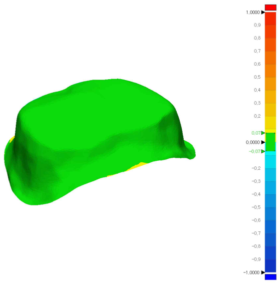
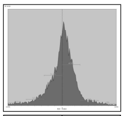
Min.	-0.1563
Max.	0.1534
Avg.	-0.0023
RMS	0.0334
Std. Dev.	0.0333
Var.	0.0011
+Avg.	0.0248
-Avg.	-0.0226
In Tol. (%)	94.5946
Out Tol. (%)	5.4054
Over Tol. (%)	3.2767
Under Tol. (%)	2.1287

E

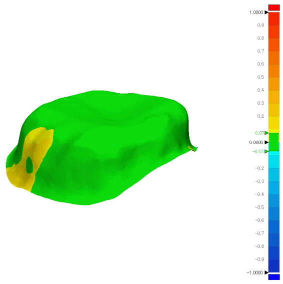
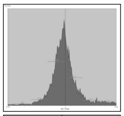
Min.	-0.0856
Max.	0.085
Avg.	0.0032
RMS	0.0211
Std. Dev.	0.0209
Var.	0.0004
+Avg.	0.0178
-Avg.	-0.0151
In Tol. (%)	99.5551
Out Tol. (%)	0.4449
Over Tol. (%)	0.1335
Under Tol. (%)	0.3114

F

Min.	-0.1167
Max.	0.1165
Avg.	-0.0004
RMS	0.0247
Std. Dev.	0.0247
Var.	0.0006
+Avg.	0.0146
-Avg.	-0.0179
In Tol. (%)	96.8948
Out Tol. (%)	3.1052
Over Tol. (%)	1.3672
Under Tol. (%)	1.738

G

Min.	-0.169
Max.	0.1693
Avg.	0.0068
RMS	0.0403
Std. Dev.	0.0397
Var.	0.0016
+Avg.	0.0296
-Avg.	-0.0215
In Tol. (%)	90.8452
Out Tol. (%)	9.1548
Over Tol. (%)	7.0453
Under Tol. (%)	2.1095

H

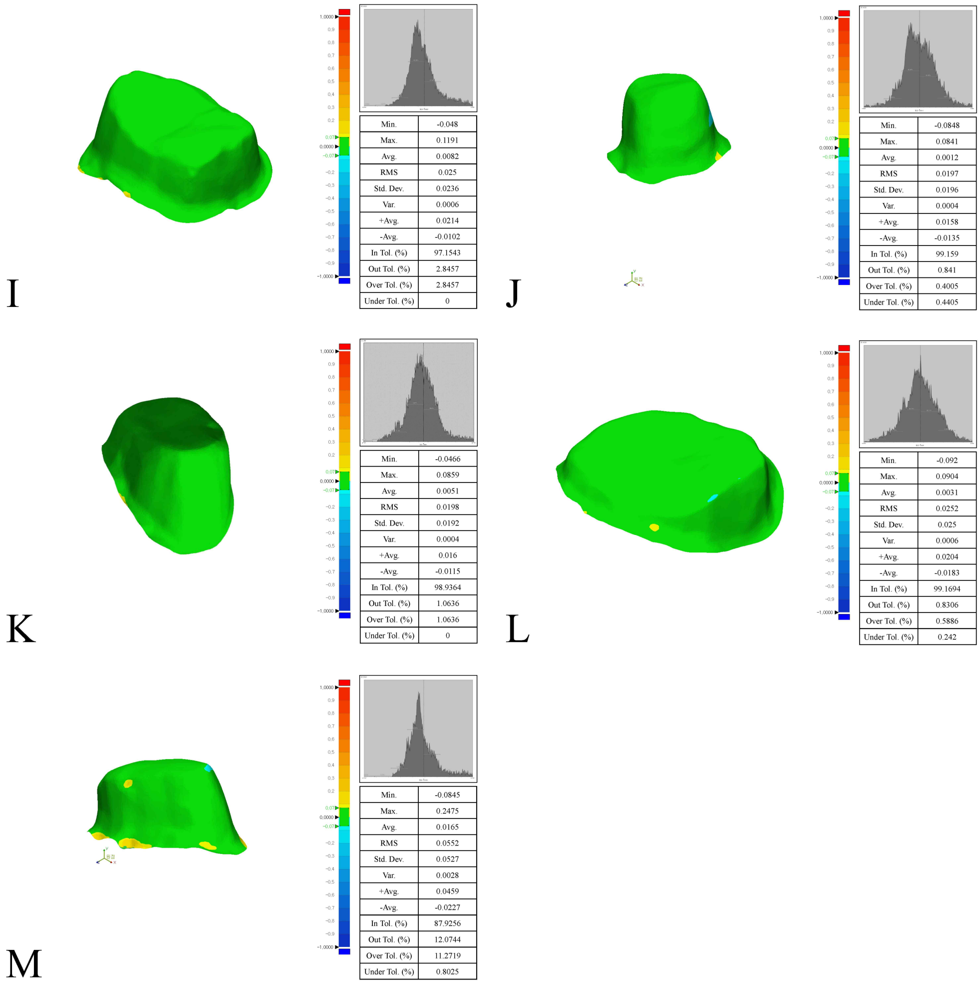
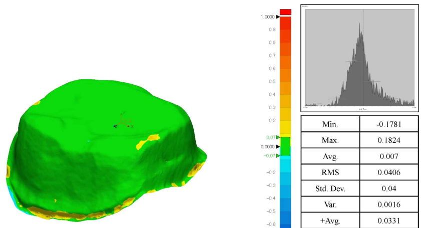
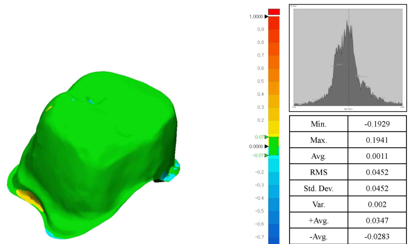


Figure 17. A–M, All 13 datasets generated by overlapping STL0 and STL1, Min., Minimum; Max., Maximum; Avg., Average; RMS, Root mean square; Std. Dev., Standard deviation; Var., Variance; Tol., Tolerance



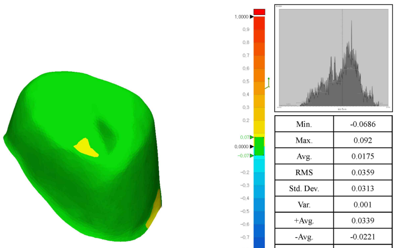
A

Min.	-0.1781
Max.	0.1824
Avg.	0.007
RMS	0.0406
Std. Dev.	0.04
Var.	0.0016
+Avg.	0.0331
-Avg.	-0.0213
In Tol. (%)	91.457
Out Tol. (%)	8.543
Over Tol. (%)	7.2185
Under Tol. (%)	1.3245



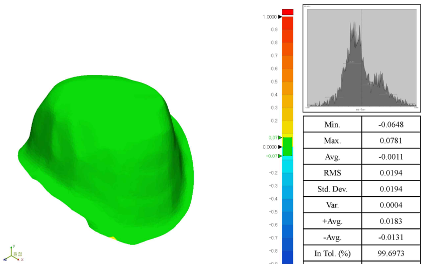
B

Min.	-0.1929
Max.	0.1941
Avg.	0.0011
RMS	0.0452
Std. Dev.	0.0452
Var.	0.002
+Avg.	0.0347
-Avg.	-0.0283
In Tol. (%)	89.4339
Out Tol. (%)	10.5661
Over Tol. (%)	6.4908
Under Tol. (%)	4.0753



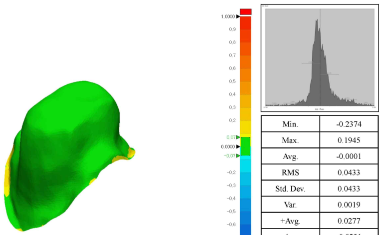
C

Min.	-0.0686
Max.	0.092
Avg.	0.0175
RMS	0.0359
Std. Dev.	0.0313
Var.	0.001
+Avg.	0.0339
-Avg.	-0.0221
In Tol. (%)	96.4736
Out Tol. (%)	3.5264
Over Tol. (%)	3.5264
Under Tol. (%)	0



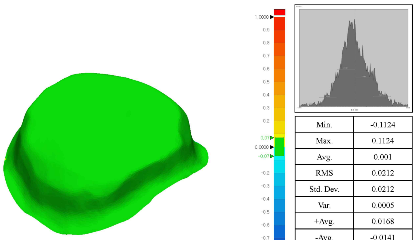
D

Min.	-0.0648
Max.	0.0781
Avg.	-0.0011
RMS	0.0194
Std. Dev.	0.0194
Var.	0.0004
+Avg.	0.0183
-Avg.	-0.0131
In Tol. (%)	99.6973
Out Tol. (%)	0.3027
Over Tol. (%)	0.3027
Under Tol. (%)	0



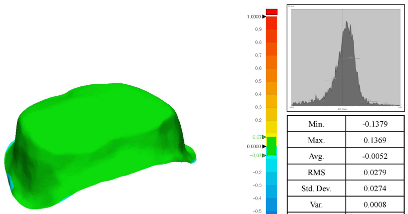
E

Min.	-0.2374
Max.	0.1945
Avg.	-0.0001
RMS	0.0433
Std. Dev.	0.0433
Var.	0.0019
+Avg.	0.0277
-Avg.	-0.0231
In Tol. (%)	91.1941
Out Tol. (%)	8.8059
Over Tol. (%)	4.9366
Under Tol. (%)	3.8692



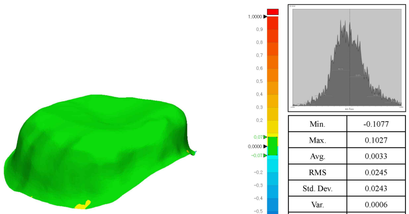
F

Min.	-0.1124
Max.	0.1124
Avg.	0.001
RMS	0.0212
Std. Dev.	0.0212
Var.	0.0005
+Avg.	0.0168
-Avg.	-0.0141
In Tol. (%)	98.7829
Out Tol. (%)	1.2171
Over Tol. (%)	0.7016
Under Tol. (%)	0.5155



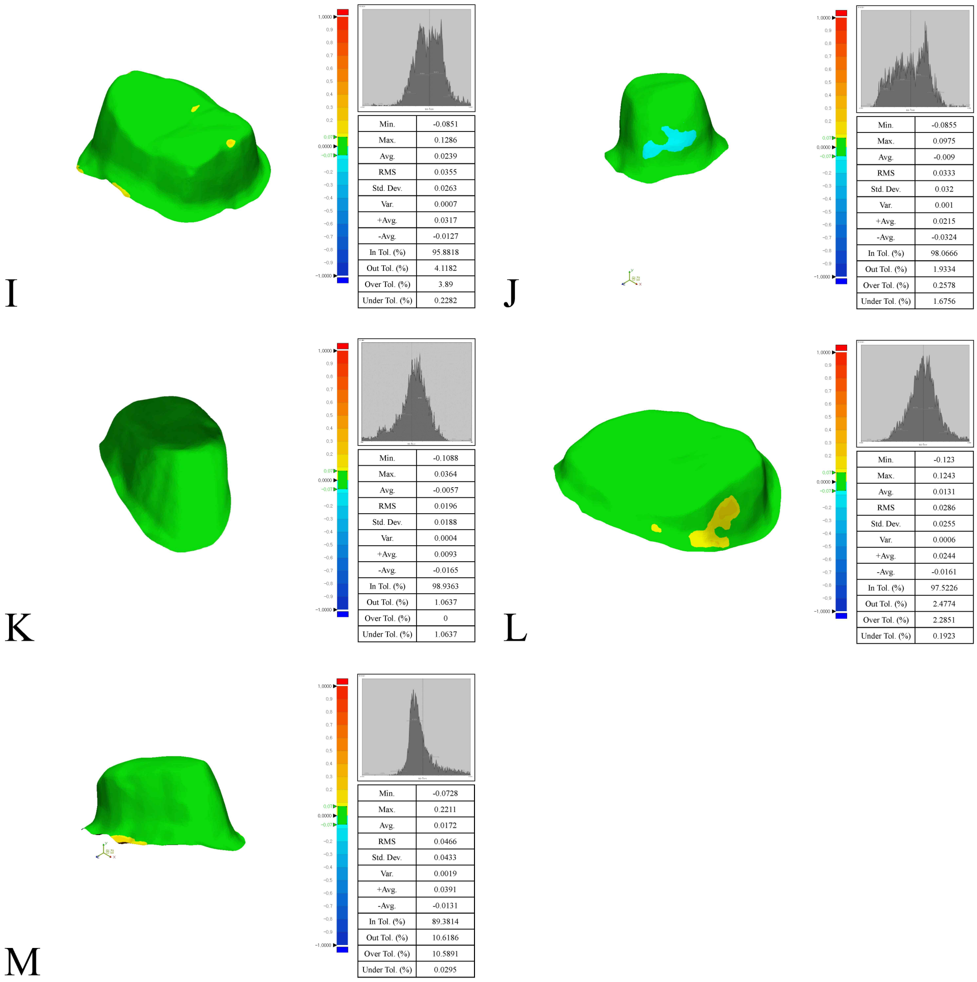
G

Min.	-0.1379
Max.	0.1369
Avg.	-0.0052
RMS	0.0279
Std. Dev.	0.0274
Var.	0.0008
+Avg.	0.013
-Avg.	-0.0215
In Tol. (%)	95.8616
Out Tol. (%)	4.1384
Over Tol. (%)	0.7014
Under Tol. (%)	3.437



H

Min.	-0.1077
Max.	0.1027
Avg.	0.0033
RMS	0.0245
Std. Dev.	0.0243
Var.	0.0006
+Avg.	0.0207
-Avg.	-0.0161
In Tol. (%)	98.6744
Out Tol. (%)	1.3256
Over Tol. (%)	0.9186
Under Tol. (%)	0.407



I

Min.	-0.0851
Max.	0.1286
Avg.	0.0239
RMS	0.0355
Std. Dev.	0.0263
Var.	0.0007
+Avg.	0.0317
-Avg.	-0.0127
In Tol. (%)	95.8818
Out Tol. (%)	4.1182
Over Tol. (%)	3.89
Under Tol. (%)	0.2282

J

Min.	-0.0855
Max.	0.0975
Avg.	-0.009
RMS	0.0333
Std. Dev.	0.032
Var.	0.001
+Avg.	0.0215
-Avg.	-0.0324
In Tol. (%)	98.0666
Out Tol. (%)	1.9334
Over Tol. (%)	0.2578
Under Tol. (%)	1.6756

K

Min.	-0.1088
Max.	0.0364
Avg.	-0.0057
RMS	0.0196
Std. Dev.	0.0188
Var.	0.0004
+Avg.	0.0093
-Avg.	-0.0165
In Tol. (%)	98.9363
Out Tol. (%)	1.0637
Over Tol. (%)	0
Under Tol. (%)	1.0637

L

Min.	-0.123
Max.	0.1243
Avg.	0.0131
RMS	0.0286
Std. Dev.	0.0255
Var.	0.0006
+Avg.	0.0244
-Avg.	-0.0161
In Tol. (%)	97.5226
Out Tol. (%)	2.4774
Over Tol. (%)	2.2851
Under Tol. (%)	0.1923

M

Min.	-0.0728
Max.	0.2211
Avg.	0.0172
RMS	0.0466
Std. Dev.	0.0433
Var.	0.0019
+Avg.	0.0391
-Avg.	-0.0131
In Tol. (%)	89.3814
Out Tol. (%)	10.6186
Over Tol. (%)	10.5891
Under Tol. (%)	0.0295

Figure 18. A-M, All 13 datasets generated by overlapping STL0 and STL2, Min., Minimum; Max., Maximum; Avg., Average; RMS, Root mean square; Std. Dev., Standard deviation; Var., Variance; Tol., Tolerance.

IV. DISCUSSION

Comparison of the working time according to the impression methods used in this study revealed that the conventional method took significantly longer time than the intraoral scan method. In general, the scan range for a digital impression of a single abutment is limited to a quadrant in the arch. Thus, even in the conventional method, impression of the quadrant, rather than that of the full arch, was obtained using the partial tray. Therefore, the conventional method was not disadvantageous compared to the intraoral scan method.

Nevertheless, similar to the results of previous studies, more time was taken to obtain the impressions by the conventional method than the intraoral scan method. Yuzbasioglu et al.[6] and Schepke et al.[50] compared the time taken to obtain conventional and digital impressions of the complete arch. The studies used the CEREC Omnicam intraoral scanner to obtain the digital impressions. Both in vivo studies concluded that the digital impression technique was more time-efficient than the conventional method. Gjelvold et al.[51] evaluated the time taken to obtain impressions of tooth-supported single crowns. The mean impression times by the digital and conventional techniques were 7:33 min:sec and 11:33 min:sec, respectively. The study demonstrated that the digital technique took significantly less time than the conventional technique. In this study, one clinician trained in scanning devices could standardize the procedure of the abutment scan and time for the measurement, whereas inexperienced users may take longer to achieve the same. Lee and Gallucci[52] evaluated the time efficiency of digital and conventional impression techniques in a single implant restoration model. Novice users took 24:43 min:sec by the conventional approach and 12:29 min:sec by the digital approach. Thus, the digital impression technique was significantly faster even among inexperienced users.

The conventional process requires time for the preparation of impression trays and the setting time of impression materials is standardized. Furthermore, patients prefer the intraoral scan than the conventional impression method.[6,7,50,51] Patient discomfort associated with the conventional impression technique might influence the working time. However, fewer variables are involved in the clinical process of the conventional impression technique, thus the associated standard deviation may be small.

The AEGIS scan was marginally faster than the CEREC scan; however, there was no significant difference. The difference in scan times between intraoral scanners is related to the different scan software and hardware capabilities. In addition to the size of the scanned data associated with resolution of the device, the process of modifying, converting, and compressing the images in the software affects the scan time.

The chairside CAD/CAM system of the Digital Dentistry Solution company is an all-in-one system to scan, design, and manufacture crowns, similar to CEREC chairside solutions. Studies reporting on the total working time of the chairside CAD/CAM system are limited. In the present study, the total working time to fabricate the chairside crown, combined with the scanning, designing, and milling times averaged 30:58 min:sec, and the maximum time taken was 39:16 min:sec. The post-milling process was the same for all crowns, which required a constant 20 minutes in the ceramic furnace. The total time for scanning, designing, milling, and post-milling processes is expected to be approximately 51 minutes and does not exceed 60 minutes. However, the total time for chairside crown delivery should include the times for tooth preparation, adjustment, and cementation. Nonetheless, standardization of these processes appears difficult due to involvement of several variables depending on patient management, abutment status, clinical situations, and the ability of the operator. The fact that the time required for the chairside process was within 60 minutes supports the possibility of delivering the crown in one day in the dental clinic.

The large marginal gap of the restoration has been reported to cause cement dissolution, eventually leading to microleakage, periodontal problems, and dental caries.[19-21] Previous investigations have demonstrated that marginal discrepancies below 120 μm are clinically acceptable.[22-25] Our results showed that both crowns fabricated by the conventional and digital workflows had a good marginal adaptation. The reference crowns were cemented after 4 weeks considering the time taken for transportation and laboratory procedures. Moreover, the delayed cementation was to eliminate potential symptoms of the abutment and adjacent teeth and to allow sufficient adaptation of the soft tissues. At 8 weeks, all crowns were clinically evaluated and no specific symptoms were observed.

Although the mean marginal gap of the reference crown was slightly smaller than that of the chairside crown, there was no statistically significant difference. In the present study, one dental technician used the same CAD/CAM system with standardized design and milling parameters for all restorations. The number of re-scans and errors can be reduced in the case of a single crown restoration. Hence, the digital workflow enables a favorable crown fit similar to the conventional workflow. In recent in vitro trials, lithium disilicate crowns fabricated by the conventional and CAD/CAM methods showed no significant differences in the marginal discrepancy.[32-34] In a clinical study, Berrendero et al.[53] compared the marginal discrepancy of all-ceramic crowns fabricated by the conventional and digital impression techniques. The study used the Trios scanner for intraoral scans, and no statistically significant differences were found between the conventional method (119.9 ± 59.9 μm) and the digital method (106.6 ± 69.6 μm). Zeltner et al.[35] evaluated the marginal fit of lithium disilicate single crowns based on a conventional workflow and four digital workflows. They found that the average marginal discrepancies were 90.4 ± 66.1 μm by the conventional workflow, 83.6 ± 51.1 μm by the CEREC infinident workflow, 94.3 ± 58.3 μm by the Lava COS scanner, 127.8 ± 58.3 μm by the iTero scanner, and 141.5 ± 106.2 μm by the CEREC inLab workflow. There were no significant differences between the conventional and digital workflows. Other studies have argued that crowns fabricated using the intraoral scanning technique had better marginal fit than those by the conventional impression technique.[37,54]

There were no significant differences in the internal discrepancies between the two groups. Both the axial and occlusal gaps in the reference crown were smaller than that in the chairside crown, as was the marginal gap. However, the cuspal gap in the reference crown was larger than that in the chairside crown. The marginal differences could have originated from the performance of the laboratory or the intraoral scanners because the same CAD/CAM system was used to fabricate the two types of crowns. Several errors could occur in the cusp tip area during scanning, which has more sharp angles compared to other parts. Furthermore, accurate reproduction of the internal surface was difficult using the milling bur. The occlusal mean value of the internal gaps was the largest in the crowns fabricated by both methods due to accumulation of errors such as the undercut of the axial wall and incomplete crown seating. Meanwhile, the axial wall is often smooth and straight without an angle. These characteristics facilitate scanning of the axial gap and result in the smallest value among the internal gaps.

Intraoral digitization is a step to prevent possible errors in advance at the beginning of the digital workflow. Our clinical study sought to evaluate datasets from two intraoral scanners by superimpositions. We adopted the "best fit alignment" methodology to overlap the test groups with the reference dataset. Best-fit alignment has already been used in other studies to compare 3D datasets.[55-57] Güth et al.[45] compared the accuracy of direct and indirect digitalization approaches using the best-fit methodology. This in vitro study reported that the mean absolute values of Euclidean distances were 15 ± 6 μm for direct digitalization and 36 ± 7 μm for indirect digitalization. Nedelcu et al.[58] performed best-fit alignment to compare the accuracy and precision of three intraoral scanners and the conventional impression method. In best-fit analysis, the mean positive and negative deviations and the root mean square value describe the spatial proximity between the test object and reference.

The term "accuracy" in this study actually meant trueness. Accuracy generally represents both trueness and precision.[59] Identica Hybrid scanner was used to obtain a true value to evaluate the two intraoral scanners. The laboratory scanner has a high accuracy of less than 7 μm and is popularly used in dental offices for various restorations.[60,61] There was no statistically significant difference in the AEGIS (STL1) and CEREC (STL2) datasets compared to the STL0 dataset. However, the absolute value of the mean positive deviation of AEGIS was higher than that of CEREC, and the absolute value of the mean negative deviation of CEREC was higher than that of AEGIS. This result indicated that the AEGIS dataset had more protruded surfaces and the CEREC dataset had more depressed surfaces compared to the reference dataset. AEGIS was a powder-type intraoral scanner, whereas CEREC was a powder-free intraoral scanner. Although the thickness of the powder was negligible, the use of powder may have influenced the increase in the positive deviation and decrease the negative deviation of the AEGIS dataset.

The root mean square value reflecting both deviations is related to the absolute Euclidean distance. There was no significant difference between the groups. Nevertheless, the root mean square value of the AEGIS dataset was marginally lower than that of the CEREC dataset. The two intraoral scanners used in this study work on different image-capturing technologies. The AEGIS scanner realizes a model by photographing still cuts under the principle of the stereo-structured light, whereas the CEREC scanner records a color image and a video of objects using optical triangulation and confocal microscopy.[44,46] Several in vivo as well as in vitro studies have reported a substantial difference in the accuracy of intraoral scanners from different manufacturers.[35,46,62,63] The marginal difference in the accuracy between the two scanners might be attributed to the different working principles.

Regarding the design of the present study, abutment teeth that could have a supragingival margin for favorable accessibility were mainly chosen. Our observations must be applied with caution in more challenging clinical situations. Since this study was limited to a single crown, further studies involving fixed partial dentures or full arches that comprise multiple abutments are necessary. Although the replica technique is a proven method for measuring the fit, it is technique sensitive and has a limited number of sections. Lastly, errors may occur when comparing the accuracy of intraoral scanners due to differences in the resolution.

V. CONCLUSIONS

The present study compared the clinical effectiveness of lithium disilicate single crowns fabricated at chairside by the digital and conventional impression techniques. Within the limitations of the present clinical study, intraoral scans demonstrated a significantly shorter impression time than the conventional method. The total working time to fabricate the chairside crown was up to 40 minutes. Thus, it is possible to fabricate a lithium disilicate crown in a single dental visit. The marginal discrepancy of the chairside crown was within the clinically acceptable range. There were no statistically significant differences in the fit of the restorations and accuracy of the intraoral scanners compared to the conventional workflow.

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국문초록

디지털 인상으로 제작한 리튬 디실리케이트 단일금관의 시간적 효율성과 보철물 적합도 평가에 관한 임상연구

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목적: 본 연구의 목적은 구강스캐너로 인상채득하여 당일 제작한 리튬 디실리케이트 단일금관을 종래형 인상 채득법과 비교하여 임상적 효용성에 관하여 평가하는 것이다.

재료 및 방법: 연구대상자로 상·하악 소구치 및 제 1 대구치에 단일금관 제작을 필요로 하는 13 명의 환자를 선별하였다. 지대치 삭제 후 종래형 인상법과 2 개의 구강스캐너 (AEGIS.PO, CEREC Omnicam)로 인상 채득하였으며, 각 인상 과정의 소요 시간을 측정하였다. AEGIS 로 스캔한 데이터를 이용해 Chairside crown 을 제작하였고, 당일 제작 과정의 소요 시간을 측정하였다. 종래형 인상법으로 얻은 주모형을 기공실 스캐너 (Identica Hybrid)로 스캔한 데이터 (STL0)로 Reference

crown 을 제작하였다. 두 종류의 금관은 동일한 CAD/CAM 시스템으로 제작되었으며, 세라믹 재료로는 IPS e.max CAD 블록이 사용되었다. 레플리카 테크닉을 시행하여 두 금관의 변연 적합도와 내면 적합도를 비교하였다. 구강스캐너의 정확도를 평가하기 위하여, AEGIS 로 스캔한 데이터 (STL1)와 CEREC 으로 스캔한 데이터 (STL2)를 STL0 와 최적 적합 중첩하여 비교하였다. 인상 시간 비교를 위해 일원배치 분산분석 시행 후 Student-Newman-Keuls 방법으로 사후검정하였다. 보철물 적합도와 구강스캐너의 정확도 평가를 위해 양측검정 대응표본 t 검정 시행하였다. 신뢰 수준은 95%로 하였다.

결과: 각 인상 방법에 따른 평균 소요 시간은 종래형 인상 채득 시 12 분 41 초 (± 1 분 16 초), AEGIS 스캔 시 7 분 16 초 (± 1 분 50 초), CEREC 스캔 시 7 분 29 초 (± 2 분 3 초)로 측정되었으며 통계적으로 유의하게 디지털 인상 채득 시 소요된 시간이 짧았다 (P<.001). 구강스캐너 간의 유의한 차이는 없었다. 리튬 디실리케이트 단일금관의 당일 제작 시 디지털 인상, 디자인 및 밀링 과정을 합한 총 제작 시간은 평균 30 분 58 초 (± 4 분 40 초)로 측정되었다. 두 종류의 금관에 대한 레플리카의 변연간극을 측정한 결과, Reference crown 의 경우 107.86 ± 42.45 μm, Chairside crown 의 경우 115.52 ± 38.22 μm 로 유의한 차이는 없었다 (P>.05). 내면간극의 경우 측벽, 교두정, 교합면 순으로 값이 커지는 경향을 보였으나, Reference crown 과 Chairside crown 간의 유의한 차이는 없었다. STL0 와 데이터 중첩 시 STL1 의 RMS 값은 31.7 ± 12.3 μm, STL2 의 RMS 값은 32.4 ± 9.7 μm 로 STL2 가 더 높은 값을 보였지만 통계적으로 유의한 차이는 없었다 (P>.05).

결론: 리튬 디실리케이트 단일금관을 디지털 인상을 통해 당일 제작하는 방법은 시간을 단축할 수 있으며, 종래형 제작 방법과 비교 시 보철물의

적합도와 구강스캐너의 정확도는 통계적으로 유의한 차이를 보이지 않았다.

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주요어 : 리튬 디실리케이트, 디지털 인상, 시간적 효율성, 레플리카 테크닉, 최적 적합 중첩법

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