# Accuracy of a cast fabricated with the i-Tero digital impression system

Yeon-hui Kim

Department of Dentistry
The Graduate School, Yonsei University

# Accuracy of a cast fabricated with the i-Tero digital impression system

Directed by Professor Hong Seok Moon

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Thesis supervisor : Hong Seok Moon

Thesis committee : Jae-Hoon Lee

Thesis committee : Sung tae Kim

The Graduate School

Yonsei University

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# 감사의 글

본 논문을 완성하기까지 한결 같은 사랑과 관심으로 지도 편달을 아끼지 않으신 문홍석 교수님께 깊은 감사를 드립니다. 그리고 심사를 통해 많은 조언과 격려로 이끌어 주신 이재훈 교수님, 김성태 교수님의 노고에도 진심으로 감사 드립니다. 학생으로 시작해 석사 과정 이수에 이르기 까지 깊은 조예와 지속적인 지도로 학문 연구에 큰 도움을 주신 정문규 교수님, 한동후 교수님, 이근우 교수님, 심준성 교수님, 박영범 교수님, 김지환 교수님께도 감사를 드립니다.

더불어 본 연구의 실험을 위해 물심양면으로 도움을 주신 치과 재료학 교실의 김광만 교수님과 연구원 선생님들께 감사를 드립니다.

담임 교수님으로서 늘 저의 든든한 후견인이 되어주시고 계시는 서정택 교수님, 유윤정 교수님께 늘 감사한 마음을 이 자리를 빌어 꼭 전해드리고 싶습니다.

여러모로 크고 작은 도움을 주고, 배려를 아끼지 않았던 보철과 의국원들과 함께 어려움과 즐거움을 함께 나누었던 김태경 선생님, 안신영 선생님 이하 많은 동역자들에게도 감사의 마음을 전하고 싶습니다.

또한 본 논문이 완성될 수 있도록 여러가지 어려움에도 불구하고 늘 격려해주시고 지지와 배려를 아끼지 않으셨던 연치과 김재훈 선생님께도 이 자리를 빌어 감사의 인사를 드립니다.

마지막으로 항상 사랑으로 저를 응원해주시고 지지해주시는 사랑하는 아버지와 어머니, 언니 영희, 그리고 곁에서 물심양면 배려를 해준 동생 동후에게 감사의 마음을 전합니다.

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김연희 올림

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**ABSTRACT**

# Accuracy of a cast fabricated with the i-Tero digital impression system


Yeon-hui Kim, D.D.S.

Department of Dentistry

The Graduate School, Yonsei University

*(Directed by prof. Hong Seok Moon, D.D.S., M.S.D., PhD.)*



A decisive factor in the prognosis of dental prostheses is the degree of accuracy in reproducing the intraoral condition. Various impression materials and techniques have been developed to achieve accurate reproducibility in dental casts. However, none have completely overcome the distortions in cast dimensions caused by polymerization of the impression material. A new digital impression technique was recently introduced that was convenient for both the clinician and patient, avoided the errors inherent in an analog impression, and enhanced the accuracy of the corresponding cast. The purpose of this study was to evaluate the accuracy of casts made with this digital impression system compared to casts made with conventional techniques.

For comparisons, we used a standardized, stainless steel model that simulated two abutments for a fixed partial denture. Casts were fabricated based on either the i-Tero digital impression system (n=15) or the conventional impression technique, with addition silicone impression material and a die stone (n=15). The abutment and inter-abutment distances were measured on the casts made from the two different types of impressions. Statistical analysis was performed with the ANOVA test ($p<0.05$), followed by Tukey's HSD test.

The distances measured on the polyurethane casts based on the digital impression technique were not statistically different from those measured on the standardized models. The distances measured on the gypsum cast based on the conventional impression technique were not significantly different from the standardized model, except in height.

The major limitation of this investigation was that it was performed in vitro. Thus, the evaluations did not include affects of fluids and soft tissues present in the human oral condition. Within these limitations, we showed that the cast fabricated with the digital impression system displayed reproducibility and accuracy similar to the cast made with the conventional impression technique.

**Key Words :** i-Tero, digital impression, linear dimension, reproducibility, dimensional accuracy

# Accuracy of a cast fabricated with the i-Tero digital impression system

**Yeon-Hui Kim, D.D.S.**

**Graduate School,**
**Department of Dental Science, Yonsei University**

***(Directed by prof. Hong Seok Moon, D.D.S., M.S.D., PhD.)***

## 1. INTRODUCTION

The durability of fixed dental prostheses is primarily determined by the accuracy in reproducing intraoral conditions, including the anatomy and surface details of the teeth and adjacent structures. To improve the accuracy of reproduction, various impression materials and techniques have been developed.[1-3, 14-16] The most common materials used to make impressions of abutment teeth for fixed dental prostheses are polyether, mercaptan polysulfide, addition silicone, and condensation silicone. Among these materials, addition silicone was reported to provide the best accuracy and dimensional stability.[14-1614-16] Some studies have indicated that, as impression materials improved, dimensional accuracy has been influenced more by the technique than by the material used. [3-4] The most commonly used impression techniques are known as the 1-step putty and wash, the 2-step putty and wash, and the monophase impression approach. [2,3,24-26] Some studies have shown that the 2-step putty and wash technique provided more accurate reproducibility than the others; [3,24] however, other studies reported that the 1-step putty and wash technique was most accurate or that there was no significant difference between the 1-step and 2-step putty and wash techniques. [25] A modification of the impression method was tested in an attempt to compensate for dimensional changes, but it did not improve the dimensional distortion that occurred after polymerization, due to by-products in the physical materials. Thus, controversies remain unresolved, despite a number of studies on the accuracy and dimensional stability of impressions made with different impression materials and/or impression techniques. In general, because the conventional impression making method is a manual procedure, it has inherent errors that occur during tray selection, impression material and tray adhesion, tray seating on the abutment, impression material polymerization, and gypsum pouring. [23-26] In addition, unfavorable odors, tastes, and mess associated with many impression materials can cause discomfort to the dentist and the patient. Thus, there is a need for an alternative to conventional impressions that can provide appropriate clinical reproducibility and stability.

In response to this need, a digital intraoral impression system, known as CEREC (Sirona Dental, Bensheim, Germany), was introduced in 1987. The CEREC system uses a three dimensional scanner and optical powder on the teeth to create a virtual model. This computer aided design/computer aided manufacturing (CAD/CAM) technology has been adopted in the clinic. [8] The introduction of this system to dentistry promoted the development of automated, computerized dental impression making methods. The introduction of the CEREC system was followed by the introduction of the E4D Dentist System (D4D tech., TX, USA), the Lava Chair side Oral Scanner (C.O.S) (3M ESPE, Lexington, USA), and the i-Tero digital impression system (Cadent, Calstadt, NJ).

The digitalization of dental impression making has many advantages. [4-7, 19, 27] First, the digital impression method eliminates the uncomfortable experience of making a physical impression. Second, any marginal deficiency or insufficient occlusal reduction can be checked by displaying a three dimensional model on the monitor, and then it can be corrected chair-side. Moreover, long term storage of data recordings is more convenient than storing impression materials and casts in the clinic. Also, there is no need for the complicated disinfection protocols used in preparing the impression material and tray. However, the disadvantages are that digitalized impression making requires expensive equipment and dentists lack familiarity with the technology. [6,19] Nevertheless, it was demonstrated that digitalization of dental impressions would be economically efficient, considering the time and cost required for adjusting or remaking dental prostheses and maintaining associated materials.[5, 6, 19]

Several studies have reported that digital impression techniques were more beneficial and acceptable clinically compared to conventional impression techniques.[8,18] Syrek et al. [8] demonstrated that the intraoral scanning method with the Lava C.O.S. provided significantly better marginal fits for crowns compared to the silicone impression technique. However, they could not rule out an effect from inaccuracy in the casting technique, because the zirconia coping was designed from the uploaded scan data without an intermediate model. Henkel[18] conducted a blind study to assess clinical parameters for crowns generated with the digital impression system compared to crowns made with the conventional technique, coupled with a traditional laboratory protocol. The results demonstrated that the crowns based on the digital impression system were better accepted and required less time for adjustment than crowns based on conventional impressions. Other studies compared several digital impression systems [12,21] and discussed the pros and cons of various systems.[4-7,19] Those findings favorably supported the utility of the digital impression technique as a substitute for conventional impressions. Nevertheless, most studies only provided subjective evaluations by a few clinicians; relatively few studies tested the accuracy of the digital impression method based on objective data. Therefore, the present study aimed to evaluate the accuracy of different impression making techniques and make comparisons based on numerical data.

To that end, we investigated the accuracy of the i-Tero digital impression system by examining the linear dimensions of the abutment diameter and inter-abutment distances. We compared the cast fabricated with the i-Tero digital impression system to that made with the conventional impression making method. We hypothesized that there would be no significant difference in the linear dimensions of the cast fabricated with i-Tero digital impression system and a standardized stainless steel model.

# 2. MATERIALS AND METHODS

## 2.1 The control group

We used a stainless steel model (SS model) that complied with the International Standardization Organization. The SS model simulated two prepared abutment teeth for a fixed partial denture (Fig.1). The SS model had a 6.96 mm diameter at the occlusal surface, a 7.99 mm diameter at the cervical area, and a height of 4.98 mm. The inter-abutment distance was 12.99 mm at the occlusal surface and 11.98 mm at the cervical area (Fig. 3). This was used as the definitive standardized model for comparing two different impression techniques in the present study.

## 2.2 The test group

Fifteen polyurethane casts were fabricated based on data acquired with the i-Tero digital impression system, and 15 gypsum casts were fabricated based on an impression made with the 2-step putty and wash technique. The latter impression was made with addition silicone (Aquasil; DENTSPLY Intl, York, USA) and soft putty material, according to the manufacturer’s instructions. The gypsum cast was generated with improved type IV stone (GC Fugirock, GC, Belgium), vacuum mixed.

## 2.3 Measurements

Linear dimensions were measured between reference points on each cast with the MITUTOYO projector (MITUTOYO PJ - A3000, MITOTOYO INC, Kanagawa, Japan) at a magnification of 100× and a precision of 1 μm (Fig.2).

We set the following reference points: *a* was the distal point of the occlusal surface; *a´* was the mesial point of the occlusal surface; *b* was the point of intersection of a diagonal line drawn from the occlusal surface to distal, and distal line angle; *b´* was the intersection of the diagonal line and the mesial line angle; *c* was the distal point of the cervical area; *c´* was the mesial point of the cervical area; *d* was the distal point of the occlusal surface on the adjacent abutment of the model; and *e* was the distal intersection point of a diagonal line and the distal line angle on the adjacent abutment (Fig. 3). The distances between the reference points were measured with a MITUTOYO projector, described above. The measurements were *a*-*a*' for the diameter of the occlusal surface, *b*-*b*' for the diameter under the occlusal surface, *a*-*c* (vertical length) for the height of the abutment, *a*-*d* for the inter-abutment distance on the occlusal surface, and *b*-*e*, assuming that was equal to the inter-abutment distance at the cervical area.For control group measurements, the SS model was measured 15 times to generate 15 datasets for analysis. For each test group, the dimensions between reference points were measured in triplicate on 15 casts, and the corresponding mean values were considered the representative values. Thus, 15 datasets for each group were used to evaluate and compare the two different impression making methods.

## 2.4 Statistical Analysis

Statistical analysis was carried out with PASW 18 software (SPSS Inc., Chicago, USA). For each dimension, a one-way analysis of variance (ANOVA) was used to assess the significance of differences in the absolute dimensional measurements between groups. Subsequently, multiple pairwise comparisons between the groups were performed with the Tukey's HSD test ($p=.05$).

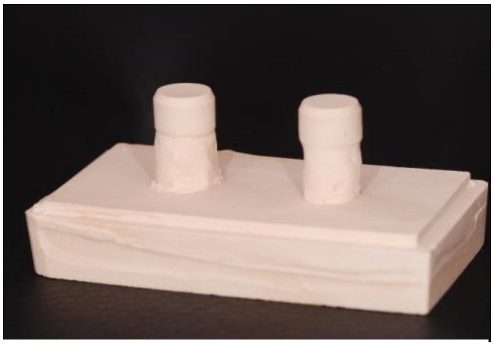

**Fig. 1. Standardized model**


**Fig. 2. MITUTOYO projector**

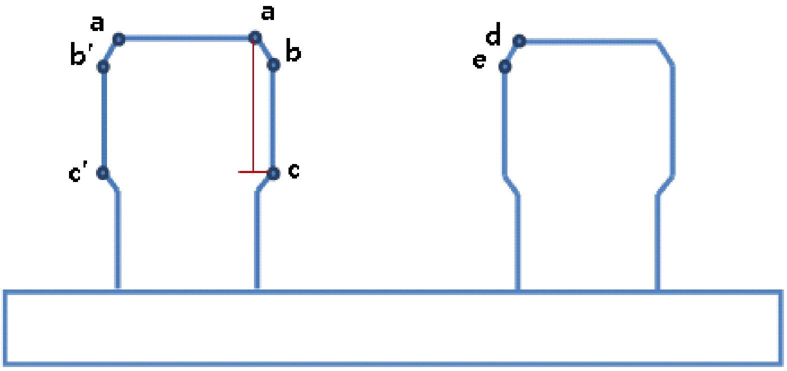


**Fig. 3. Reference points and measured values**.

① **Diameter of occlusal surface(a-a')**

② **Diameter of cervical area(c-c')**

③ **Height (a-c verticallength)**

④ **Inter abutment distance on occlusal surface(a-d)**

⑤ **Inter abutment distance on cervical area(b-e)**

# 3. RESULTS

Table 1 shows the measured and calculated mean values and standard deviations of five linear dimensions for each of the 15 models for each impression technique.

There was no significant difference within or between groups ($p>.05$) for four of the five dimensions. However, the height was significantly different between groups ($p<.0001$). Table 2 shows the result of the one-way ANOVA analysis ($p<.05$).

The multiple comparison with Tukey's HSD test revealed that the height was significantly different between the SS model and the gypsum cast made with the conventional impression technique ($p<.0001$) (Table 3).

**Table 1. Mean dimensions (SD) of standardized model and the casts according to different impression techniques (n=15)**

| Diameter(mm) | ①**a-a'** | ②**c-c'** | ③**a-c** | ④**a-d** | ⑤**b-e** |
|---|---|---|---|---|---|
| SS model | 6.96(.02) | 7.99(.01) | 4.98(.01) | 12.99(.02) | 11.98(.03) |
| i-Tero polyurethane model | 6.95(.05) | 7.97(.05) | 4.98(.04) | 12.98(.05) | 11.98(.03) |
| Conventional stone model | 6.96(.04) | 7.95(.07) | 4.93(.02) | 12.98(.05) | 11.99(.05) |

**Table 2. One-way ANOVA among the control group and test groups (*p*<.05)**

| *p*-value | ①**a-a’** | ②**c-c’** | ③**a-c** | ④**a-d** | ⑤**b-e** |
|---|---|---|---|---|---|
| Among groups | | | * | | |

*: p-value <.0001

**Table 3. Tukey’ HSD test for multiple pairwise comparison between groups(*p*<.05)**

| *p*-value | ①**a-a’** | ②**c-c’** | ③**a-c** | ④**a-d** | ⑤**b-e** |
|---|---|---|---|---|---|
| i-Tero polyurethane model | | | | | |
| Conventional stone model | | | * | | |

*: p-value <.0001

# 4. DISCUSSION

This study was designed to estimate the utility of the digital impression system in the clinic based on its accuracy and reproducibility. We evaluated the accuracy of five linear dimensions on casts made with two different impression techniques. Our results supported the hypothesis that there was no statistically significant difference between the linear dimensions of the cast fabricated with the i-Tero digital impression system and the SS model.

The measurements performed with the MITUTOYO projector, based on the magnified shadow of the cast, minimized the potential errors could be taken during measuring the distances between the references in other methods by marking reference points or grooves on the abutment, as shown in previous studies.[3, 14]

Statistically, the cast fabricated based on the i-Tero digital impression method displayed acceptable accuracy and reproducibility in the abutment. However, the gypsum cast fabricated based on the conventional impression displayed a significant difference in height from the standardized SS model. Several factors might explain the lower height of the gypsum cast. First, the error could be made during the procedure for pouring and hardening the gypsum cast. The gypsum cast has hardened with the occlusal surface up and the base plate on the bottom.

During the hardening process, unset gypsum material might settle to the bottom, and cause the dimensional change in height. The second possibility was that there may have been an influx of bubbles. The height was measured from the point *a* at the occlusal surface to point *c* in the cervical area (Fig. 2). Point *c*, which corresponded to the margin of abutment for the prosthesis, conform to the negative form in the impression body. It was predisposed to take influx of bubbles. Third, a contraction could have occurred when the impression body was pressed out of the cast; this pressure may have caused a dimensional change [3] in the final cast. Due to the root convergence of the natural tooth, the error mentioned above may easily have occurred in the cast fabricated with conventional impression. Thus, the digital impression system would provide more consistent measurements, because it is free from the errors inherent in conventional impression procedures.

The findings in present study favorably support the utility of the digital impression system, as reported in previous studies.

Nevertheless, this study had some limitations. First, the study was conducted under in vitro, extra-oral conditions, and neglected the potential effects of fluids and soft tissues that would be present in the human oral condition. In the digital impression technique, management of fluids and soft tissues is critical for acquiring an accurate image, as mentioned in previous studies. Thus, under intraoral conditions, it may be difficult to move the scanner into the appropriate angles without disturbing any anatomical structures. [5,6,8,13,24,28] Thus, further study is required to evaluate the accuracy of the digital impression system under in vivo conditions to determine its clinical feasibility and consistency. Second, the reproducibility was evaluated based on the linear dimension of a reference point selected by author. Thus, the margin of precision in reproducibility could not be assessed in the present study. Further investigation is needed to obtain a more reliable result that can support the marginal accuracy of casts made with the digital impression system. The final limitation was that one or two additional scans per model were required to correct distorted images on the virtual models because the images had been captured with the scanner tip placed at an inappropriate angle. We speculate that distortions might be avoided by targeting more localized areas in each scan.

# 5. CONCLUSION

Within the limitations of this in vitro study, we could conclude that:

1. there was no significant difference statistically between the two different impression systems; both systems showed adequate accuracy and reproducibility, except in height.
2. there was a statistically significant difference between the SS model and the conventional impression group in the height of the crown.
3. clinically acceptable accuracy was achieved in the linear dimensions of the cast fabricated based on the i-Tero digital impression system.

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## 국문 요약

# 디지털 인상 채득 방법으로 제작된 지대치 모형의 정확성

지대치와 인접 구조물을 포함한 구강 내 환경의 정확한 재현은 고정성 보철물의 안정적 예후에 영향을 미치는 중요한 요소이다. 이를 위해 많은 인상재와 기법들이 연구 및 개발되어왔으나, 경화과정에서 불가피한 체적 안정성의 저하가 발생하는 한계가 있다. 새로 도입된 디지털 인상 채득법은, 기존의 인상재를 이용한 인상 채득기법에서 발생하는 인상재의 경화 과정에 따른 체적 안정성의 저하 및 석고 주입 시 오류에 따른 오차 발생가능성을 줄이고, 환자와 술자 모두에게 적용하기 편리하다는 이점을 가진다.

이 연구의 목적은 기존의 인상 채득법과 비교하여 디지털 인상 채득법으로 제작된 모형의 정확도를 비교 분석하여 제시함으로써, 새로운 인상기법의 임상도입 가능성을 평가하기 위함이다.

고정성 보철물 제작을 위한 두 개의 지대치를 형상화한 stainless steel 모델을 표준 모델로 사용하였다. i-Tero digital impression system 을 이용한 polyurethane model(n=15)을 제작하고, 부가 중합형 인상재와 초경석고를 이용한 기존의 인상 채득법에 따른 석고 모형(n=15)을 제작하여 두 개의 실험군으로 설정한 뒤, 투영기를 이용하여 각 지대치의 직경과 인접치 간 거리를 측정하여 비교하였다. 표준 모델의 측정값을 대조군으로 하여 ANOVA 를 이용하여 두 개의 실험군과 비교하여 통계적 분석을 실시하였다($\alpha$=.05).

실험 결과 디지털 인상 채득 기법에 따른 polyurethane model은 모든 측정 수치에서 표준 모델과 통계적으로 유의한 차이를 보이지 않았다. 기존 인상 채득 기법을 사용한 석고 모델에서는 높이를 제외한 측정치에서 표준모델과 통계적으로 유의한 차이가 발생하지 않았으나, 높이의 측정치는 대조군과 유의한 차이를 나타내었다.

본 연구는 연조직과 타액의 영향을 배제한 in vitro 라는 한계를 가지며, 본 연구의 한계 내에서 디지털 인상 채득 방법에 따라 제작된 지대치 모형은 기존의 인상 채득기법에 의한 모형과 비교할 때, 유사한 정도의 정확도와 재현성을 가진다.

핵심어 : 디지털인상채득, i-Tero, 선형거리, 재현성, 거리정확도