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Original Article

Effect of digital competence on scan time and scan error in intraoral scanning

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ABSTRACT

Objectives: This study aimed to test whether the digital competence of dental hygienists can affect their intraoral scanning potential in terms of scan time and error. **Methods:** Dental hygienists and dental hygiene students who had never used an intraoral scanner were surveyed to determine their digital competence. Individual data collected using an intraoral scanner was compared with reference data collected using a model scanner to identify scanning errors, and participants' scanning times were measured. **Results:** A significant decrease in scanning time was observed as the overall level of digital competence increased. The increase in digital skills and digital knowledge led to a decrease in scanning time by 3.73 and 3.98 minutes, respectively. **Conclusions:** This study found that digital competence was associated with reduced scan times, but less so with scan errors. This may be due to recent advances in scanning software, and future studies may need to develop a digital competence assessment tool that is more appropriate for the dental field.

Key Words: Data accuracy, Dental impression technique, Digital health, Professional competence, Time and motion studies

Introduction

In the era of the fourth industrial revolution driven by advanced information and communication technology, efforts are being made worldwide, including in Korea, to integrate digital technologies across various sectors of society [1,2]. The introduction of oral scanners represents one of the significant changes in digitized dental care [3]. Oral scanning is a modern method used for recording the positive and negative forms of oral tissues to fabricate dental prostheses [4]. Instead of using traditional impression materials, this technique captures intraoral surface data using light sources and forms a three-dimensional image [5]. Known as digital impression taking, oral scanning offers advantages over traditional methods by reducing patient discomfort and potentially lowering costs in the long run [4]. Furthermore, it facilitates easy data storage, improves the clinical environment, and has positive effects on dental care, leading to increased use of oral scanners [5,6].

Lack of competence in the acquisition of these digital impressions can lead to long scan times, and prolonged scans can be uncomfortable for patients [5]. Longer scan times result in a higher number of captures, which lead to more errors and reduce the accuracy of the data [7]. Therefore, to ensure the precise fabrication of dental prostheses, it is crucial to have the capability to perform oral scanning accurately within a short duration.

Digital competence refers to a set of attitudes, skills, and knowledge required to use various digital media and information and communication technologies [8]. This concept extends beyond the ability to operate digital devices to include managing digital

information and utilizing technologies more broadly. According to Jung [9], enhancing users' digital competence is essential for the effective use of digital devices. Therefore, it is necessary to investigate whether digital competence affects scanning ability in the context of oral scanners. However, to the best of our knowledge, no studies have been conducted in the field of dentistry on the impact of digital competence on the level of oral scanning, except for a study that investigated the association between computer-aided design (CAD) programs and digital literacy [10].

Therefore, this study aims to determine the effect of digital competence on scan time and error among dental hygienists and dental hygiene students.

Methods

1. Participants

This study was conducted on dental hygienists or dental hygiene students who had never used an oral scanner before. Sample size was calculated using a dedicated program (G*power 3.1.9.7, Germany) with an effect size of 0.35, a significance level of 0.05, and a power of 85%. Thirty-five participants recruited via announcements were included in this study.

2. Methods

This study was conducted from July 2023 to September 2023 with ethical approval (EU23-013) from the Institutional review board (IRB) of Eulji University. The process of this study is shown in <Fig. 1>.

1) Measurement of digital competence

First, digital competence was measured using a self-report survey. The scale was adapted from a previous study [11] with some modifications for this study (Cronbach's α=0.903-0.978). It consisted of 29 questions in total, including 'digital attitudes', 'digital skills (basic skills, life utilization, production sharing)', and 'digital knowledge (information judgment, security and safety)'; the reliability (Cronbach's α) in this study was 0.754 for digital attitudes, 0.844 for digital skills, and 0.758 for digital knowledge. Each question was rated on a 4-point Likert scale, with higher scores indicating higher digital competence.

2) Oral scanner training

We provided theoretical and demonstration training on the definition, structure, working principle, operating methods, and strategies of oral scanners to participants who had never used an oral scanner before. Subsequently, the participants practiced using a real oral scanner (i700, Medit, Seoul, Korea) and an oral model (TKY-403, TuoKang Medical, China).

3) Measurement of scan time

The participants were scanned a total of three times using the same oral scanner and oral model used in the previous training. Each scan was taken of the maxilla first, followed by the mandible, and the sequence was as per the manufacturer's instructions: occlusal surface of the right posterior teeth–incisal edge of the anterior teeth–occlusal surface of the left posterior teeth–lingual surface of the left posterior teeth–lingual surface of the anterior teeth–lingual surface of the right posterior teeth–buccal surface of the right posterior teeth–labial surface of the anterior teeth–buccal surface of the left posterior teeth–occlusal surfaces of both sides. Scanning time was measured from the time the participant first pressed the 'Start scan' button to the time the last data were saved, for each of the first and third occlusal planes. The training, scanning, and measurement processes were all performed in a uniform manner by the same researcher.

4) Analysis of scan error

The reference images for error analysis were acquired with a model scanner (Freedom UHD, DOF Inc, CA, USA). The oral model used was the same as the model used to measure the scan time, and the storage format of the reference image and 1-3 individual images was unified in standard tessellation language (STL) format. All processes related to file extraction and analysis were performed by the same researcher using a uniform method.

The error relative to the reference image was then analyzed in three dimensions for each of the individual scanned images (primary and secondary scan errors) and for the image merged from the individual scans into one (average scan error). The three-dimensional error analysis was performed using Geomagic Control X (3D systems, USA). In the program, the error was displayed as a color map and root mean square (RMS), and the color spacing on the color map was set to 100 μm.

3. Data analysis

The normality of each dataset was confirmed using the Shapiro-Wilk test. Descriptive statistics were used to summarize the general characteristics of the participants, digital competence, scan time, and scan errors. Differences in these dependent variables based on the general characteristics of the participants were analyzed using independent t-tests and one-way analysis of variance (ANOVA). Differences in scan time and errors according to the number of scans were analyzed using repeated measures ANOVA. Differences in scanning ability based on levels of digital competence were analyzed using independent t-tests. The impact of general characteristics and digital competence on scan time and scan errors was analyzed using multiple regression analysis. The data were statistically analyzed using IBM SPSS program (ver. 25.0; IBM Corp., Armonk, NY, USA), with the significance level set at 0.05.
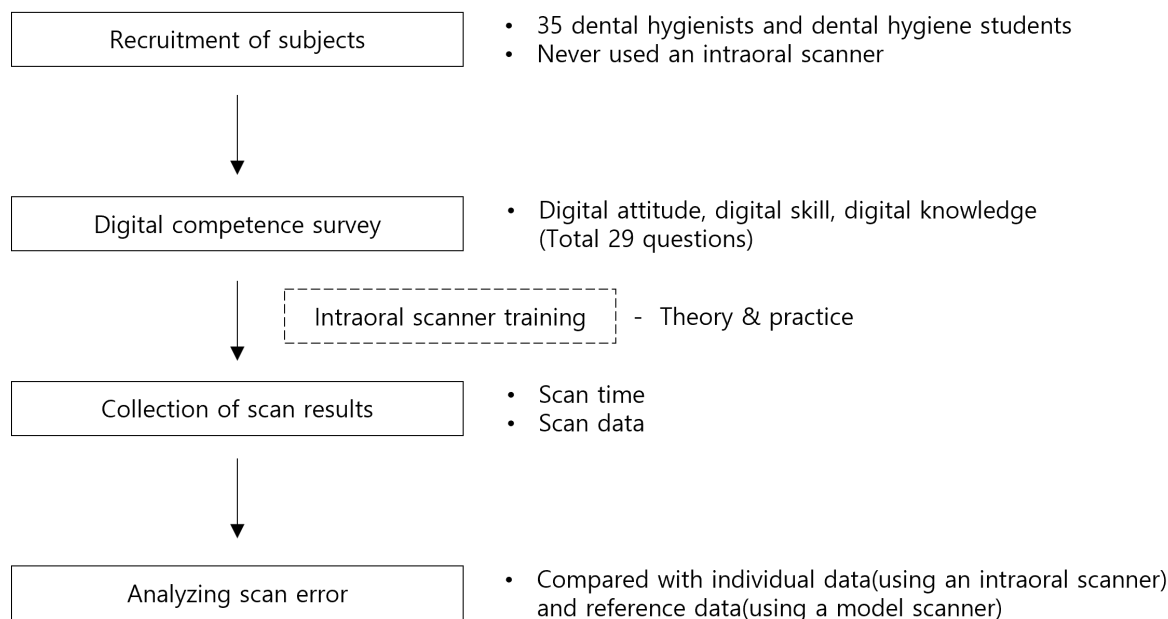
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┌──────────────────────────┐      • 35 dental hygienists and dental hygiene students
│  Recruitment of subjects │      • Never used an intraoral scanner
└──────────────────────────┘
            │
            ▼
┌──────────────────────────┐      • Digital attitude, digital skill, digital knowledge
│ Digital competence survey│        (Total 29 questions)
└──────────────────────────┘
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     ┌ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┐
     │ Intraoral scanner training │  -  Theory & practice
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            │
            ▼
┌──────────────────────────┐      • Scan time
│ Collection of scan results│     • Scan data
└──────────────────────────┘
            │
            ▼
┌──────────────────────────┐      • Compared with individual data(using an intraoral scanner)
│   Analyzing scan error   │        and reference data(using a model scanner)
└──────────────────────────┘
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Fig. 1. Experiment procedure

Results

1. General characteristics

The majority of participants were female (89%), with 83% under 30 and 17% over 30. In terms of education, 51% were in college, 32% graduated from a 3-year or 4-year college, and 17% had a master's degree or higher. In terms of years of experience, 51% were college students, 29% had 1-3 years of experience, and 20% had ≥ 4 years of experience. Finally, 71% had a computer certification <Table 1>.

2. Digital competence, scan time, and scan error according to general characteristics

Differences in digital competence, scan time, and scan error according to general characteristics were analyzed, and age was the only significant factor. Specifically, digital competence and scan time significantly differed according to age ($p<0.05$), but scan error did not ($p>0.05$). Digital competence was higher in the younger age group, with a score of 3.09 for those under 30 and 2.74 for those aged 30 years and over ($p<0.05$). The mean scan time was shorter in the younger age group, with a score of 22.12 minutes for those under 30 and 26.45 minutes for those aged 30 years and over ($p<0.01$) <Table 1>.

3. Digital competence by domain

The mean overall digital competence score was 3.03. More specifically, the scores were 2.76 for digital attitude, 3.48 for digital skills, and 3.16 for digital knowledge. In the digital skills domain, the score was the highest for basic skills (3.59) and the lowest for production sharing (3.04). In the digital knowledge domain, the score was 3.22 for information judgment and 3.10 for security and safety.

Table 1. Digital competence, scan time, and scan error by general characteristics

Characteristics	Division	N(%)	Average digital competence (score) Mean±SD	p*	Average scan time (min) Mean±SD	p*	Average scan error in maxillary (μm) Mean±SD	p*	Average scan error in mandible (μm) Mean±SD	p*
Sex	Male	4(11.0)	3.22±0.21	0.316	19.57±1.79	0.055	28.00±0.84	0.448	28.20±0.63	0.757
	Female	31(89.0)	3.01±0.40		23.29±3.65		28.26±0.62		28.07±0.81	
Age (yr)	<30	29(83.0)	3.09±0.37	0.038	22.12±3.48	0.007	28.20±0.65	0.529	28.02±0.83	0.137
	≥30	6(17.0)	2.74±0.33		26.45±2.31		28.38±0.63		28.40±0.46	
Educational level	Students	18(51.0)	3.02±0.41	0.650	22.68±3.59	0.870	28.06±0.64	0.237	27.99±0.89	0.773
	Graduate	11(32.0)	3.10±0.42		23.36±4.28		28.38±0.62		28.20±0.80	
	≥Graduate school	6(17.0)	2.92±0.25		22.52±3.24		28.48±0.61		28.15±0.39	
Clinical experience (yr)	None	18(51.0)	3.02±0.41	0.538	22.68±3.59	0.071	28.06±0.64	0.157	27.99±0.89	0.775
	1-3	10(29.0)	3.13±0.16		21.38±3.37		28.54±0.53		28.20±0.64	
	≥4	7(20.0)	2.91±0.55		25.47±3.34		28.24±0.68		28.16±0.77	
Computer-related certifications	Yes	25(71.0)	3.08±0.39	0.282	22.60±3.62	0.515	28.14±0.63	0.183	28.03±0.80	0.554
	No	10(29.0)	2.92±0.36		23.52±3.93		28.46±0.63		28.21±0.78	
Total / Average		35(100.0)	3.03±0.39		22.86±3.67		28.23±0.64		28.08±0.79	

*by t-test or ANOVA

4. Scan time and scan error according to the number of scans performed

Scan time was 25.20 minutes for the first scan, 22.60 minutes for the second scan, and 20.80 minutes for the third scan, showing a significant decrease in scan time with increasing number of scans performed ($p<0.001$). Maxillary scan error was 28.39 μm for the first scan, 28.15 μm for the second scan, and 27.67 μm for the third scan ($p<0.001$), and the mandibular scan error was 28.09 μm for the first scan, 28.05 μm for the second scan, and 27.77 μm for the third scan ($p<0.05$), showing slight decreases in error with increasing number of scans <Table 2>.

Table 2. Scan time and errors depending on the number of scans   Unit: Mean±SD

Number of scans	Scan time (min)	Scan error (μm)	
		Maxillary	Mandible
1st	25.20±4.88[a]	28.39±0.65[a]	28.09±0.49[a]
2nd	22.60±3.73[b]	28.15±0.88[ab]	28.05±0.65[a]
3rd	20.80±3.69[c]	27.67±0.99[b]	27.77±0.63[a]
p^*	<0.001	<0.001	0.039

[*]by one-way repeated measures ANOVA
[a,b,c]The same characters was not significant

5. Scan time and scan error according to digital competence

Differences in scan time and scan error according to digital competence were analyzed. After dividing the participants into two groups based on the mean score of overall digital competence (3.03), we found a statistically significant difference in scan time: 21.02 minutes for the high score group and 24.60 minutes for the low score group ($p<0.01$). However, no significant difference was observed in the upper and lower scan errors between the groups ($p>0.05$) <Table 3>.

Table 3. Intraoral scanning skills by digital competence   Unit: Mean±SD

Variables	Average scan time (min)	Average scan error (μm)	
		Maxillary	Mandible
High	21.02±3.61	28.11±0.71	27.95±0.94
Low	24.60±2.85	28.34±0.55	28.20±0.62
p^*	0.003	0.287	0.358

[*]by t-test, Variables were divided based on the mean score of digital competence (3.03 out of 4).

6. Impact of detailed digital competence on average scan time and error

The predictors of average scan time and error were analyzed using regression analysis. First, none of the general characteristics predicted scan time or error, but digital skills and knowledge scores predicted mean scan time. That is, the mean scan time decreased by 3.73 minutes and 3.98 minutes with 1-point increase in digital skills score ($p<0.05$) and digital knowledge score ($p<0.01$), respectively. The model explained 60.0% of the variance, and variance inflation factor (VIF) was under 10, confirming the absence of multicollinearity ($p<0.001$). On the other hand, none of the general characteristics and digital competence factors predicted mean scan error ($p>0.05$) <Table 4>.

Table 4. Factors influencing average scan time

Variables	Division	B	SE	β	t	p^*
(constant)		49.951	7.572		6.597	<0.001
Sex (male=0)	Female	1.184	1.377	0.104	0.860	0.398
Age		1.284	1.995	0.142	0.643	0.526
Educational level (student=0)	Graduate	0.765	1.136	0.098	0.674	0.507
	≥Graduate school	-1.212	1.643	-0.126	-0.738	0.467
Clinical experience (none=0)	≥4 years	-0.039	0.185	-0.053	-0.210	0.835
Computer-related certifications (no=0)	Yes	0.435	1.149	0.054	0.378	0.708
Attitude		-0.732	0.794	-0.116	-0.922	0.365
Skill		-3.726	1.717	-0.343	-2.170	0.040
Knowledge		-3.981	1.330	-0.463	-2.992	0.006

F=6.663 (p<0.001), R=0.840, adjusted R^2=0.600, DW=1.967

*by multiple regression analysis

Discussion

Currently, digital devices are used in many fields, including dentistry [3], and digital competence can influence the efficient use of digital devices [9]. This study aimed to determine whether the digital competence of operators influences their ability to use an intraoral scanner. For this purpose, scan times were measured among dental hygienists and dental hygiene students with no prior experience using intraoral scanners. Additionally, scan errors were assessed by comparing the individual data obtained from the intraoral scanner with the reference data acquired using a model scanner, leading to the following results.

The mean digital competence scores of the participants in this study were 2.7 for attitude, 3.5 for skills, and 3.2 for knowledge. According to Park and Kang [11], the digital competence level of the general population was lower than that of the participants in this study, with an attitude score of 2.6, skill score of 2.6, and knowledge score of 2.4. This difference may be attributed to the fact that the average age of the study participants was 25 years, and they were more familiar with digital equipment and environments due to their specialization in dentistry, unlike the general population in their 40s surveyed in previous studies.

In terms of digital competence, scan time, and errors based on the general characteristics of the participants, digital competence and scan time significantly differed only with respect to age. Specifically, the group under 30 years of age had statistically significantly higher digital competence scores and shorter average scan times than did the group aged 30 years and above. Previous studies on digital competence [12,13] also found that younger groups had higher competence scores and were more adept at handling devices, which was attributed to differences in device adaptability and educational effectiveness across age groups [12]. Therefore, it is essential to consider age when addressing digital competence and the use of intraoral scanners. For older individuals, additional time for device adaptation should be provided in training or research contexts.

In terms of scan times according to digital competence, we found that the average scan time was significantly shorter in the high competence group. Previous studies have reported that an increase in scan time can lead to inaccurate scans due to increased number of scans and accumulated errors [7]. Therefore, the decrease in mean scan time observed in this study can be attributed to a relatively higher ability to utilize the scanner, which is influenced by digital competence. Jung [9] highlights the importance of improving digital competence of the operator in order to facilitate effective digital device use. Park [14] suggests that high digital competence enables faster perception and response to uncertain environments, because it enables faster acquisition and analysis of information. Therefore, the lower scan times in the high digital competence group found in this study may be due to their ability to perceive and respond quickly.

On the other hand, no significant relationship was found between digital competence scores and scanning errors. Previous studies [15] have shown that recent developments in scanning software have incorporated artificial intelligence and automatic

segmentation of teeth, which has reduced the variation between scanner users. In this study, we used the latest oral scanner, and it is likely that these new technologies contributed to the lack of differences in scanning error among the participants.

Regarding the factors that contribute to shorter scan times, we found that the skills and knowledge domains of digital competence significantly predict shorter scan times. A study by Son and Lee [10] found that higher digital literacy, which includes both technical and knowledge aspects, can reduce the time spent on devices. Furthermore, Min and Shin [16] found a significant correlation between digital media utilization and digital skills and knowledge. To enhance oral scanning abilities, digital skills and knowledge competence should be improved through targeted support and education. On the other hand, there was no significant correlation between scan time and digital attitude [16]. This might be because actual device usage is less related to digital attitude. Nevertheless, a high digital attitude can increase the recognition of the importance of the digital environment and encourage active participation in device usage. Therefore, digital attitude should still be considered [17], and education aimed at fostering digital attitude is needed.

Taken together, the results show that scanning time is shorter in operators under age 30 and with increasing digital skills and knowledge scores. Therefore, users aged 30 years old and over who want to improve their oral scanning skills should invest more time cultivating digital skills and knowledge as well as device training and adaptation training. However, this study used a measurement tool developed in a previous study [11] to measure digital competence, and the items are related to general digital devices rather than dental-specific devices. Therefore, developing a digital competence measurement tool tailored to the dental field is necessary for directly related results. In addition, we cannot exclude the influence of learning effects due to the fact that the three scans were performed in the same environment. Therefore, we suggest that future studies should experiment with different measurement environments between the first and third scans to control for the confounding factors. Finally, the study's age range of 21-42 years may have influenced the results; thus, future studies should include a broader age range. Despite these limitations, this study is the first to confirm the influence of digital competence on oral scanner competency, and we hope that the findings serve as valuable data for fostering digital competence and improving oral scanner utilization among dental hygienists.

Conclusions

This study analyzed the effect of digital competence on scan time and error in dental hygienists and dental hygiene students with no prior experience using an intraoral scanner. The conclusions of this study are as follows:

1. Digital competence and scan time significantly differed according to age ($p<0.05$).

2. Scan time was significantly shorter in the high digital competence group ($p<0.01$).

3. Digital skills ($p<0.05$) and digital knowledge ($p=0.01$) were identified as significant predictors of mean scan time and explained 60.0% of the variance.

These results highlight the need to improve digital competence to reduce scan times for intraoral scanners. When disseminating education about intraoral scanners, it is essential to emphasize digital skills and knowledge. We hope these insights contribute to fostering digital competence and enhancing oral scanner utilization among dental hygienists.

Notes

Author Contributions

Conceptualization: YW Kim, IH Jung; Data collection: YW Kim, IH Jung; Formal analysis: YW Kim, IH Jung; Writing-original draft: YW Kim, IH Jung; Writing-review & editing: DS Lim, HJ Lim, IH Jung

Conflicts of Interest

Funding

Ethical Statement

This study was approved by the Institutional Review Board (IRB) of Eulji University (EU23-013).

Acknowledgments

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디지털 역량이 구강스캐너의 스캔 시간 및 스캔 오차에 미치는 영향

초록

연구목적: 본 연구는 치과위생사 및 치위생(학)과 학생의 디지털 역량이 구강스캔 시간과 오차에 영향을 미칠 수 있는지를 확인하고자 시행되었다. **연구방법:** 구강스캐너 사용 경험이 없는 치과위생사 및 치위생(학)과 학생을 대상으로 디지털 역량에 대한 설문 조사를 시행하였다. 동일한 대상자들에게 구강스캐너 사용법을 교육한 후, 구강 스캔을 3회 시행시켰고 이때 각 회차별 스캔 시간을 측정하였다. 이후, 3D 분석 프로그램을 이용, 모델스캐너로 채득한 기준데이터와 구강스캐너로 앞서 채득한 개별데이터를 중첩 분석하여 스캔오차를 확인하였다. **연구결과:** 연령이 낮을수록 디지털 역량이 높고 스캔 시간이 적게 소요되었고, 디지털 역량 수준이 높은 그룹에서 스캔 시간이 짧았으며, 통계적으로 유의하였다. 세부 역량 중에서는 디지털 기술과 디지털 지식 역량 점수가 1점 증가 시, 스캔 시간이 각각 3.73분, 3.98분 감소하였다($p<0.05$). 반면, 스캔 오차는 디지털 역량의 영향을 받지 않았다. **결론:** 구강스캐너 연구 및 교육 시행 시, 연령과 디지털 역량을 고려해야 할 것이며, 추후 연구에서 치과 영역 맞춤형 디지털 역량 평가 도구 개발을 제안한다.

색인: 데이터 정확성, 치과 인상 기술, 디지털 건강, 전문 역량, 시간 및 동작 조사