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Comparison of Patients' Satisfaction Between 2-dimensional and 3-dimensional Digital Smile Simulation

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Abstract

Objectives: To compare 2-dimensional (2D) and 3-dimensional (3D) smile simulation techniques from the perspective of patient preferences in comfort during data collection and the simulation outcome.

Methods: Twenty subjects (10 males and 10 females) with no experience with smile simulation participated in this study. Data collection was performed by using a DSLR camera (Nikon, Tokyo, Japan) for dentofacial photography, an intraoral scanner (3-Shape, Copenhagen, Denmark) for an oral scanning file, and a tablet device (iPad, Apple, CA, USA) for smile video recording. The subjects' perceptions of comfort towards each data collection process were evaluated using a standardized questionnaire. A week later, both 2D and 3D smile simulation outcomes were presented to participants, and subjects' preferences toward the simulation outcomes were evaluated. Statistical analyses were performed with Wilcoxon Signed Ranks Test and the one-sample chi-square test.

Results: A statistical implication presented the significant difference between 2D and 3D subjects' satisfaction in terms of time consumption for data gathering. The results showed that 90% of subjects were satisfied with 2D simulation rather than 3D simulation due to time (p=0.002). For satisfaction of the simulation outcome, there was a significant difference in the statistical implication (p<0.05). Even though preference and recommendation were significantly different factors, the subjects' overall satisfaction levels were not significantly different (p=0.74).

Conclusions: Although the satisfaction of recruited individuals in the 2D simulation was higher than that in the 3D simulation during the data collection process, there was no difference in patients' preferences between the 2D and 3D outcomes.

Keywords: digital smile simulation, patient comfort, patient preference, satisfaction

Introduction

Facial attractiveness is a significant influence in one's overall psychological and social health, and an appealing smile is a necessary component of the psychological well-being.[1,2] The number of people seeking the help of dentists in order to improve their smile is rising.[3] Skeletal systems, alveolar casing, teeth, and the underlying soft tissue covering all work together intricately to create the appearance of a beautiful smile and dental esthetics. The total effect of these factors seems to be what humans perceive to be a person's smile. Regularly, a person's success in social situations can be gauged by observing their smile, which reveals their ability to convey various emotions by the shape and movement of their teeth and lips.[4-6]

Traditionally, dentists have only used verbal explanations of treatment options, occasionally supplemented with pictures of patients who had comparable problems handled. Presenting a patient with a design wax-up is another classic method for informing them of treatment options.[6] However, modern computer design software has advanced for an effective demonstration to patients the range of options available to them for improving their smiles. Numerous conventional dental procedures can be benefited from the use of digital aids, which have the potential to improve esthetic outcomes and produce healthy, natural, beautiful, and self-confident smiles. Dental treatment planning software is becoming increasingly digital, which has the potential to strengthen diagnoses, improve communication/education, and increase treatment predictability.[7]

As a result, there is a development plan to bring a new set of tooth simulations to superimpose on patients' faces using computer applications such as PowerPoint and Photoshop. The results demonstrate the harmony between the new set of teeth, the characteristics of the lips, and the patients' face. For instance, Christian Coachman's Digital Smile Design[8] displays the design of a 2-dimension face smile that might potentially create a clear visualization, resulting expectation rather than replicated wax pattern. This method also improves communication between dentists and dental technicians.

Because most virtual diagnostic pictures are displayed in two dimensions and do not fully depict the potential changes to the extraoral appearance, the patient must review the treatment plan and outcome prior to initiating therapy. Even so, the real effects of any treatment on the patient's dental and facial appearances, particularly alterations in facial soft tissue, can be seen only at the completion of treatment. Three-dimensional virtual pretreatment diagnostics offer a viable solution for predicting tooth morphology and final position.[9] It is now possible to fulfill pretreatment evaluations on 3D reconstructions by stitching standard digital intraoral and extraoral photographs with specialized software and cloud computing to better plan the treatment for difficult dental and/or medical procedures.[8]

The majority of research focuses on the outcome and accuracy of smile simulation, as demonstrated by Delmonte's research in a systematic review of lay person's preferences for dento-gingival esthetic parameters[10] and Flores-mir, the layperson's perception of smile aesthetics in dental and facial perspectives.[11] Consequently, additional studies about patient satisfaction relative to present technological treatment are always driven by the emergence of new technologies. As an example, many studies have compared oral scanning, a relatively new technology, to the conventional functional impression approach. Research comparing 2-dimensional and 3-dimensional digital simulation in terms of patient satisfaction is still limited, but the new 3-dimensional digital simulation tends to greatly improved patient satisfaction. Moreover, DigiPro Smile (Tomorrow Smile, Bangkok, Thailand) has been launched since 2018, which simulates a 3D digital smile and correlates patient oral scanning with the 3D design. This software presented the outcome as a 3D videography to the patient for decision-making prior to definitive treatment.

Thus, the objective of this study was to analyze the difference in treatment comfort during data collection and the difference in patients' preference between 2D and 3D smile simulation outcomes. We hypothesized that there was no difference in patient comfort between 2D and 3D smile simulation, and there was no difference in patient's preference between 2D and 3D smile simulation.

Material and Methods

Clinical trial design

A cross-over design was used for this experiment. Each participant received each simulation procedure in turn. This research was registered with the Thai Clinical Trials Registry (TCTR20221206002) and received approval from the Human Experimentation Committee at the Faculty of Dentistry, Chiang Mai University (No. 17/2020). All participants signed assent and informed consent forms to participate in the study.

Sample size calculation and participants

This study calculated sample size based on previous study by Yuzbasioglu *et al.*[12] Considered with the power of 90% at level of significance 5%, this research calculated the target population to classify into two independent group with 20 samples, allowing for a loss to drop out of 10%.

Twenty volunteers were participated by using inclusion and exclusion criteria. The inclusion criteria of this study were: 1) an age range of 18-25 years old; 2) American Society of Anesthesiologists (ASA) classification I and II; 3) good oral hygiene; 4) some smile appearance defects (mild crowding, spacing, and fracture); 5) digital friendly: and 6) literacy in the Thai language. Criteria for exclusion of this study were moderate to excessive dental anxiety, previous experience of orthodontic treatment, low lip line and smile line, Angle's classification III, loss of anterior teeth, experience with knowledge of smile design and smile simulation, craniofacial anomalies, maximum mouth opening lower than 35 mm, hyperactive gag reflex, and current oral lesion.

Questionnaire

Participants were required to complete the questionnaire on their first and second visits. Following the research objectives, a questionnaire was created to examine two aspects of patient satisfaction: the perception survey and the comparative survey. To confirm the validity of the survey questions, the questionnaire used in this study was pretested, revised, and retested before use. The suggested questionnaire was administered to three dental specialists. The finalized questionnaire after adjustments and corrections to the survey instrument, consisted of four parts in Thai language: the first was basic information and importance criteria confirmation, second was comfort during data collection, including pain, nausea, discomfort, stress, and time based on scoring and comparison of 2D and 3D simulations; the third was comparison-based simulation outcome, and the last part was an overall assessment of comfort and simulation outcome. To assess the patients' comfort, a Likert scale survey with a conventional five-level item (5 = very high, 4 = high, 3 = moderate, 2 = low, and 1 = none) was utilized. The survey included questions about the patients' opinions of simulation recommendations and preferences.

Intervention and procedure

In first visit, the patient's basic data acquisition was randomly collected and 2D image files of extraoral and intraoral photographs were taken via DSLR camera (Nikon D610, Tokyo, Japan) and mouth retractor under the same environmental, and lighting conditions by one calibrated operator (S.M.). In 3D data acquisition, a tablet device (iPad Pro 11, Apple, CA, USA) and an oral scanner (3-Shape, Copenhagen, Denmark) were used to collect the facio-dental motional video of motional smiling activities and intraoral scanning files sequentially by one calibrated operator (W.A.). Prior to this clinical trial, all operators had been repeatedly trained in their assigned roles to perform with the same duration of data collection, scanning time, and mouth retractor protocol. After image collection, those 2D image files was designed and created 2D digital smile simulation by Keynote software (iWork, Apple, CA, USA). Then, intraoral scanning files were superimposed with facio-dental motional video to generate 3D smile simulation by DigiPro Smile software (Tomorrow Smile, Bangkok, Thailand). After a week, the outcomes of 2D and 3D smile simulation (Figure 1C and 2C) were presented to all participants individually in second visit.

Statistical analysis

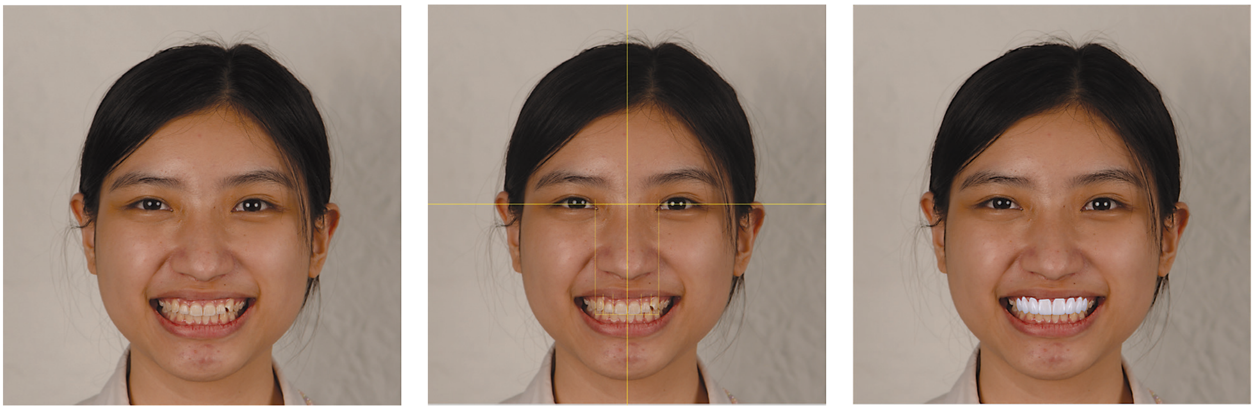
Because the assumptions of parametric statistical analysis were not met, the data were analyzed using nonparametric tests. These data were analyzed using the nonparametric Wilcoxon Signed Ranks test and one-sample chi-square with a simultaneous p value adjustment, with <0.05 as the level for statistical significance. Data analysis was performed using the SPSS 24.0 software (SPSS Inc., Chicago, IL, USA).

Results

The number of participants was 20, who matched the research's setting criteria without follow-up absences. The participants were ten males and ten females, and the age range was between 19 and 21 years. All of the participants had never experienced a smile simulation, orthodontic

Example of 2D digital smile simulation

A 2D digital smile simulation was shown in Figure 1.



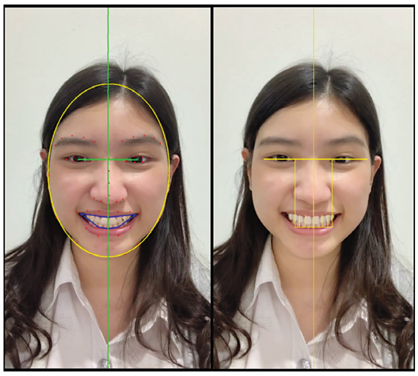
(A) Prerequisite photography (B) Simulation process (C) Outcome

Figure 1: 2D digital smile simulation. (A) Prerequisite photography, (B) Simulation process, (C) Outcome. The full frontal photographs of this volunteer were granted in the form of written consent

Example of 2D digital smile simulation

A 3D digital smile demonstration was shown in Figure 2.

(A) Prerequisite videography



(B) Simulation process. The simulation analysis procedures included the recognition of facial landmarks and the calculation of head posture.

(C) Outcome

Figure 2: 3D digital smile simulation. (A) Prerequisite videography, (B) Simulation process, (C) Outcome. The full frontal photographs of this volunteer were granted in the form of written consent

treatment, or extra-intraoral photography with a mouth retractor.

Comfort during data collection

First, the satisfaction scores for 2D, and 3D simulations based on twenty subjects and five topics were collected. Pain, nausea, discomfort, stress, and time were among the topics addressed, with frequency and percentages provided (Table 1). The answers in the questionnaire including none, low, moderate, high, and very high, however, only none, low, and moderate level responses were given by all participants to the five topics. It was found statistical analysis results that the significant difference between 2D and 3D subjects' satisfaction in terms of time consumption for data gathering (p=0.002). Notably, the result showed that more than 90% of participants were satisfied with the time consumption of data collection in 2D simulation.

In the second section, the comparison based on overall satisfaction during data collection indicated that 60% of participants were satisfied with 2D, 20% were satisfied with 3D, and 20% had no difference in overall satisfaction between the 2D and 3D systems during data collection (Table 2).

Simulation outcome

When the two simulations were compared, it was discovered that 20% were satisfied with the 2D simulation, 75% were satisfied with the 3D simulation, and only 5% were satisfied with both equally. While the comparison-based outcome in simulation system recommendation was selected by 35% of participants in 2D simulation and 60% in 3D simulation, participants recommended both 2D and 3D systems to 5% (Table 3). The outcomes of the 2D and 3D simulations showed significantly different simulation results (p<0.001) and suggestions (p<0.05).

Overall satisfaction

A comparison-based questionnaire of two simulation systems revealed that the overall satisfaction of 2D systems was 40%, whereas 3D systems were 50%, with 10% satisfied equally (Table 4). Consequently, there was no significant difference in the overall satisfaction of the simulation systems.

Discussion

The statistical analysis of this investigation revealed that there was no difference in treatment comfort throughout data collection for 2D and 3D smile simulations. The study found that the target group was equally satisfied with 2D and 3D simulations. In terms of the time required for data collection, however, 2D simulation proved to be more efficient than 3D simulation. In consequence, 90% of the target participants was satisfied with the 2D simulation. Intraoral scanning was found to be time-consuming in the 3D simulation data collection process, with participants spending more minutes than in the 2D simulation. Also, there is a learning curve for using the intraoral scanner in the dental clinic, and this must be carefully considered.[13-17]

It was agreed that there is no difference in patients' preferences between the outcomes of 2D and 3D smile simulations. In terms of smile simulation design, about 75% of the target group preferred 3D simulation over 2D simulation. The main reason was that 3D simulation presented many distinct facial angles, resulting in an accurate outcome and an efficient treatment plan. Furthermore, the 3D system facilitated patient communication. According to the findings of the Daher *et al.* study[18], the benefit of a 3D system was the ability to provide esthetic outcomes from all possible view angles, which would surely enhance the realism of digital smile simulations.

The well-known software applications are DSDApp 3D[19] (DSD, Madrid, Spain) and IvoSmile App[20] (Ivoclar Vivadent, Schaan, Liechtenstein). These 3-dimensional digital smile is a new technology development that has the potential to have a significant impact and benefit on dental clinics all over the world. The file demonstrates harmony between dental and face scanning photos or films, allowing dentists to understand more about specific treatment problems and build a more successful treatment plan. This solution is more effective than other simulation models. For example, IvoSmile App, a smile simulation software that aims to simulate real-time 3D visualization of teeth, which could potentially enhance the communication efficiency of patients.[20] Similar to Digipro Smile, IvoSmile App and DigiPro Smile simply mimics tooth alignment without modifying the shape of the teeth. The DigiPro Smile software also provides the 3D smile simulation in motion for virtualization on a mobile device. To minimize data collection errors for the smile

Table 1: Patients' comfort during data collection in 2D and 3D smile simulation process

	Scale	2D simulation		3D simulation		*p*-value
		frequency	%	frequency	%	
Pain	1 (None)	17	85	13	65	
	2 (Low)	2	10	5	25	0.190
	3 (Moderate)	1	5	2	10	
Nausea	1 (None)	19	95	19	95	
	2 (Low)	1	5	1	5	1.000
	3 (Moderate)	0	0	0	0	
Discomfort	1 (None)	12	60	8	40	
	2 (Low)	7	35	12	60	0.317
	3 (Moderate)	1	5	0	0	
Stress	1 (None)	16	80	14	70	
	2 (Low)	3	15	6	30	0.655
	3 (Moderate)	1	5	0	0	
Time	1 (None)	18	90	6	30	
	2 (Low)	1	5	8	40	0.002*
	3 (Moderate)	1	5	6	30	

The data was analyzed using the one-sample chi-square test.
*Statistically significant at $p<0.05$

Table 2: Comparison of satisfaction during data collection

	2D Simulation		3D simulation		No difference		*p*-value
	frequency	%	frequency	%	frequency	%	
Less pain	5	25	3	15	12	60	0.035*
Less nausea	7	35	0	0	13	65	0.263
Less discomfort	15	75	1	5	4	20	<0.001*
Less stress	6	30	5	25	9	45	0.522
Less time	18	90	0	0	2	10	<0.001*
Overall	12	60	4	20	4	20	0.041*

The data was analyzed using the one-sample chi-square test.
*Statistically significant at $p<0.05$

Table 3: Comparison of simulation outcome

	2D Simulation		3D simulation		No difference		*p*-value
	frequency	%	frequency	%	frequency	%	
Result	4	20	15	75	1	5	<0.001*
Recommendation	7	35	12	60	1	5	0.011*

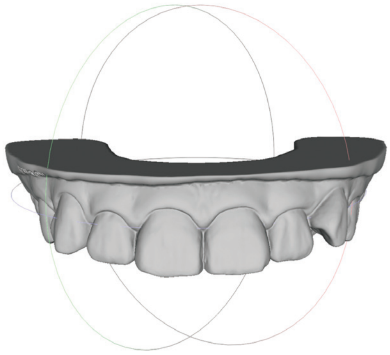
The data was analyzed using the one-sample chi-square test.
*Statistically significant at $p<0.05$

Table 4: Comparison of overall simulation system satisfaction

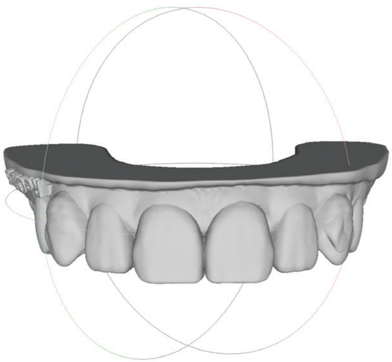
	2D Simulation		3D simulation		No difference		*p*-value
	frequency	%	frequency	%	frequency	%	
Overall	8	40	10	50	2	10	0.74

The data was analyzed using the one-sample chi-square test.

simulation process, the software developers created the artificial intelligence (AI) to analyze the vertical axis of the midface on videography based on the subject's facial anatomy (Figure 2B). After the vertical axis of the midface was adjusted, another component of artificial intelligence integrated the designed 3D model into the intraoral scanner's 3D model of the patient's tooth (Figure 3).



(A) Intraoral scanned model



(B) Designed 3D model

Figure 3: 3D model. (A) Intraoral scanned model, (B) Designed 3D model.

Nowadays, the digital transformation of healthcare is becoming increasingly important for both academics and clinicians.(21) Patients are also becoming active decision-makers in their medical care process as a result of the rise of digital technologies.(22) Many technologies emerge in every generation. Generation Z, or Zoomer, which was born in 2000 and refers to the young generation, becomes the main target group in this study. Regarding Ripton's article(23), it stated that generation Z and millennials are easily penetrating digital healthcare. For instance, more than 40% of that group tends to use online reservations for making a doctor's appointment. Likewise, approximately 25 million Americans use digital devices for healthcare lifestyle detection and status. Thus, this study encourages the development of dental digitalization for advanced benefits in the future.

In clinical settings, the utilization of a wide variety of digital tools to support treatment planning and rehabilitation has become increasingly common. The simulation of the smile design is possible with some of the software applications used in the esthetic planning process.(19) This helps to improve communication between patients, dental technicians, and clinicians. Utilization of digital technologies in the 3-dimensional design creates truly natural, individualized, and aesthetically attractive smiles. Digital smile simulation has become the standard for esthetic treatment plans.(24) Regardless of prosthodontic design, digital smile simulation has recently been reported to be beneficial to periodontal plastic treatment(25), orthodontic and interdisciplinary treatment plans.(26) However, there are still significant improvements to be made to this approach, primarily due to hardware and software limitations. It is a huge investment for contemporary dentistry practices, and there is a learning curve required to achieve ideal results.(27) Lastly, compared to conventional methods of smile design and wax-up, this digital system is still time-consuming and relies on clinician's experience.(28)

This is a study conducted in a single location. Some of the findings are in accordance with the existing literature, but more research is required prior to making definitive conclusions. Future studies should investigate into patients' satisfaction with alternative simulation software as well as other factors example comparing the outcomes of 2D and 3D smile simulation and the outcome of postoperative treatment. Furthermore, patient satisfaction studies with different generations of volunteers could be conducted.

Conclusions

Within the limitations of this study, patient preferences were not different between 2D and 3D digital smile simulation results, even though participant satisfaction in the 2D simulation was higher than in the 3D simulation during data collection.

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Conflicts of Interest

The authors declare no conflicts of interest.

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