

Precision and accuracy of digital smile analysis in removable complete denture

Shady M. EL Naggar^a, Eman Helal^b, Mai F.F. Khalil^b, Ahmed M. Esmat^b

^aDepartment of Removable Prosthodontics, Faculty of Oral and Dental Medicine, Badr University in Cairo, Egypt, ^bFixed and Removable Prosthodontics Department, Oral and Dental Research Institute, National Research Centre

Correspondence to Ahmed M. Esmat, PhD, Department of Fixed and Removable Prosthodontics, Oral & Dental Research Institute, NRC, Dokki, Cairo 12622, Egypt. Tel: +20 111 516 7653; Fax: +20 233 371 635; e-mail: dr_sisynrc@yahoo.com

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Background/aim

Digital Smile Design (DSD) software is a beneficial approach to the potential of patient smile enhancement by producing an esthetic treatment plan. This study aimed to evaluate the precision and accuracy of hand calibrated, photo analysis, and DSD method in removable complete dentures and correlate them with different types of denture teeth.

Patients and methods

This study was conducted on 29 completely edentulous patients selected from the Outpatient Clinic of Prosthodontic Department, Faculty of Oral and Dental Medicine, Badr University, Egypt. Each patient received two sets of complete dentures as follows: the first denture was constructed from a conventional complete denture with cross-linked resin teeth and served as the control group (group I), and the second denture was constructed from conventional complete denture with nanohybrid composite teeth and served as the test group (group II). Each group was further subdivided into three subgroups, according to the different smile analysis techniques performed: subgroup A, hand calibrated method; subgroup B, photo analysis method, and subgroup C, DSD method. Then, precision and accuracy were evaluated for each smile variable.

Results

Mean absolute difference was calculated between group I and group II for each smile analysis technique, revealing that the least amount of difference between groups was illustrated in the subgroup A followed by subgroup C and finally subgroup B, which revealed the maximum amount of difference between groups ranged from 0.0031 to 0.2623. Cronbach's α was calculated for group I and group II between each smile analysis technique, revealing that all was less reliable (less accurate), except lower teeth exposure in group II was rather reliable (rather accurate) ranging from 0.023 to 0.784.

Conclusion

With the respect to limitations of this study regarding individualized anatomical variations and distortion liability of the image, it was concluded that nanohybrid resin composite denture teeth had less deviation (higher precision) than the conventional acrylic resin denture teeth regarding the ratio of different smile parameters with facial proportions.

Keywords:

accuracy, digital smile analysis, precision, removable complete denture

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Introduction

Esthetics in dentistry has attained higher consideration and significance in modern articles. Patients' desires and higher expectations have been affected by social media as smile design and their esthetic role to general appearance have participated in personal appearance improvement [1]. Dental esthetics has therefore been introduced by different dental protocols to accomplish higher esthetic expectations [1,2].

For this reason, Digital Smile Design (DSD) software is a beneficial approach to reveal the potential of patient smile enhancement by producing an esthetic treatment plan [3]. This software undergoes exceptional communication between the

prosthodontist and the patient while serving the prosthodontist with advanced communicative abilities with the laboratory technician by performing an accurate treatment plan through algorithms [4].

DSD enables a systematic workflow mimicking a patient's analysis by basically beginning with properly calibrated images. The frontal and profile facial assessments were commonly investigated using

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reference lines, from which standardized parameters have been assembled. The inter-pupillary and intercommissural lines, which bring a total logic of agreement and horizontal standpoint to an esthetically attractive face, are employed as horizontal reference lines in the frontal view. The essential shortcoming of this type of therapeutic approach, on the contrary, is related to the numerous anatomical sides involved in rehabilitation. The different anatomical parts involved in the treatments, such as the teeth, gingiva, mucosa, lip, skin, and soon, which rely on symmetry, shape, and golden proportions, are associated with the treatment for giving patients an 'esthetic smile' [5].

There are numerous aspects related to smile esthetics. This concept in prosthodontics was first published in 1958 [6]. Researchers observed the lip-teeth relationship during smiling for cosmetic objectives [7]. They observed the smile line ratio, smile symmetry ratio, buccal corridor ratio, upper lip height, and upper lip curvature, and found that a smile line ratio of around 1.00 provided an attractive smile. The curvature of the incisal edges of the maxillary incisors and canines parallel to the curvature of the lower lip when smiling was defined by other studies as the ideal smile arc [8].

Other studies have used subjective esthetic evaluation to analyze smiles, in which evaluators were asked to rank the beauty of the participants' smiling [9].

Because they hold the lips and face musculature in the right physiologic posture, the teeth, and their supporting bases are responsible for maintaining a pleasant and natural facial expression. Even when teeth are lost, special attention to clinical and laboratory methods of complete denture creation can help maintain an appealing smile [10].

Conventional resin denture teeth have two limitations: conventional resins do not interrelate with light and the reduced wear resistance of acrylic resin artificial teeth is considered a major disadvantage for complete denture prosthesis. The production of nanohybrid composite denture teeth signified an accurate advance in the prosthetic field. This denture tooth anatomy was considered to bring extra topographies over conventional resin teeth [11].

Researchers created silanized silicon inorganic nanofillers of less than 50 nm for the composite matrix of urethane dimethyl methacrylate and polymethyl methacrylate, allowing for the introduction of nanocomposite teeth with improved mechanical performance and esthetics [12].

Multiple facial outlines have been discovered in research about tooth forms; as a result, it was traditionally suggested to link the tooth form to the patients' look, as described by the Dentogenic concept. Sex influences tooth shape, with females' teeth being more rounded and ovoid and men's teeth being more angular or square [13].

Commercially available photogrammetry systems give a novel measuring approach for edentulous patients, owing to the advancement of digital technology. According to several case studies, the photogrammetry technology can be employed efficiently with complete-arch implant imprints, resulting in high framework fit and accuracy [14]. However, there is recent research on the accuracy of photogrammetry systems, and the results are diverse [15].

The goal of this study was to compare and contrast the precision and accuracy of hand calibration, photo analysis, and DSD methods in removable complete dentures and correlated them with different types of denture teeth.

Patients and methods

Patients

The study was considered a self-controlled trial in which individualized variations were eliminated for more accurate measurements. Completely edentulous patients were selected from the outpatient clinic, College of Oral and Dental Surgery, Misr University for Science and Technology and Faculty of Dentistry, Badr University in Cairo according to the following definite inclusion criteria: participants had been completely edentulous in the maxillary arch for a minimum period of 1 year, normal maxilla-mandibular relationship, healthy mucosa, normal salivary flow, and middle-aged patients.

Patients having a ridge or soft tissue pathology or severe ridge undercut were excluded. In addition, female patients, heavy smokers, or patients who had received radiation to the head and neck region were also excluded from this study. The selected patients were informed about the nature of this research work. Only motivated patients participated in the study after signing a written consent.

Ethical approval

The present study was conducted with the Code of Ethics of the World Medical Association, according to the principles expressed in the Declaration of Helsinki

in 1975. This study has been approved by the Medical Research Ethical Committee of National Research Center, Cairo, Egypt, with approval number 02026072021. All patients were informed about the practical steps of this study and signed a written approval consent.

Sample size calculation

The minimally accepted sample size was 29 patients per group when the response within each participant group was normally distributed with a standard deviation of 0.053; the true mean difference was 0.04 when the power was 80% and the type I error probability was 0.05 according to the previous study [16].

Study design

Each patient received two sets of complete dentures according to the type of artificial teeth:

First set: patients received conventional complete dentures with cross-linked resin teeth (Acrostone, Cairo, Egypt) and served as the control group.

Second set: patients received conventional complete dentures with nanohybrid composite teeth (SR Phonares II Typ, Ivoclar Vivadent, Liechtenstein) and served as the test group as shown in Fig. 1.

Each group (I and II) was divided into three subgroups (A, B, and C) according to the different smile analysis techniques.

Methods

Complete denture construction

New maxillary and mandibular complete dentures were fabricated using custom impression trays and

elastomeric final impressions. The jaw relationship records were obtained using record bases with wax occlusion rims. Esthetic tooth evaluation was completed to obtain patient approval.

Occlusion blocks were constructed to record a new jaw relation record. The occlusal plane was adjusted intraorally using a bite fork for occlusal alignment and the maxillary cast was mounted on a semiadjustable articulator (Bio-art semiadjustable articulator A7 Plus, BIOART Company, Brazil) using maxillary face bow transfer (Bio-art face bow; Brazil), whereas the lower cast was mounted using centric relation record following check bite technique at the predetermined VDO (vertical dimension of occlusion). The protrusive record was done following the wax-wafer technique to modify the horizontal guidance of the articulator. The articulator with the mounted casts was sent to the laboratory for the artificial teeth setup. Each complete denture was constructed twice with different types of artificial teeth.

Smile analysis techniques

Smile analysis techniques for each group were done as follow:

Hand calibration method (subgroup A): smile analysis of patients by hand calibration method was done according to Cheng and Cheng [17]. Direct measurements were made of each individual's smile with a hand-held portable digital caliper according to the smile variable listed in the Table 1.

A standardized photographic procedure was used to obtain images of the face and maxillary central incisors and was performed as follows: each participant was made to sit upright on a chair with the occlusal plane of the maxillary teeth parallel to the floor. Two standardized photographs were taken for each participant: portrait (social smile) and smile photograph (social smile). For each photograph, standardized distances (portrait: 100 cm, smile photograph 12 cm) were used (from the tip of the participants' nose to the center of the camera lens).

Figure 1.



Nanohybrid composite resin denture teeth.

Table 1. Measured smile variables during smile analysis

Smile Variable	Definition
Lower Teeth Exposure	Distance from the incisal edge of the maxillary central incisor to the upper border of the lower lip/mesiodistal width of the mandibular central incisor
Smile Index	Intercommissure width/interlabial gap
Buccal Corridor Ratio	Intercommissure width/intercanine width

A fixed focus of 1 : 1 was used for each participant, with the electric field 100 mm f/2.8 macroultrasonic focus motor lens. The height of the Canon electric optical system (EOS) 1100 D Digital Single Lens Reflex camera mounted on a tripod (Traveler Mini Pro Tripod for Canon EOS 1100 D, CANON Company, Japan) was adjusted individually according to the position of the participants' faces and teeth.

Digimizer Software (subgroup B): smile analysis of patients was done by photo analysis method using Digimizer Software Ver. 4.3.1, MEDCALC Company, Belgium. In the Digimizer software, the full face photograph was assessed first and then the smiling photograph was assessed, as shown in Fig. 2.

DSD software subgroup (C): smile analysis of patients by the digital smile analysis method was done using Visagi Smile Software, Serberia. Three photographic views were taken. Photographs with full face and only teeth were taken: the first at a maximum smile, and the second at rest. Third, a retracted full maxillary arch photograph is taken. In addition, at the same time, a video containing all feasible tooth and smile situations, including 45 degrees and profile views, was taken. Then the recorded photos and videos were exported in DSD software for further analysis, as shown in Fig. 3.

Statistical analysis

Data were analyzed using IBM SPSS Version 21.0 (SPSS Inc., Chicago, Illinois, USA) as mean and SD.

Figure 2.

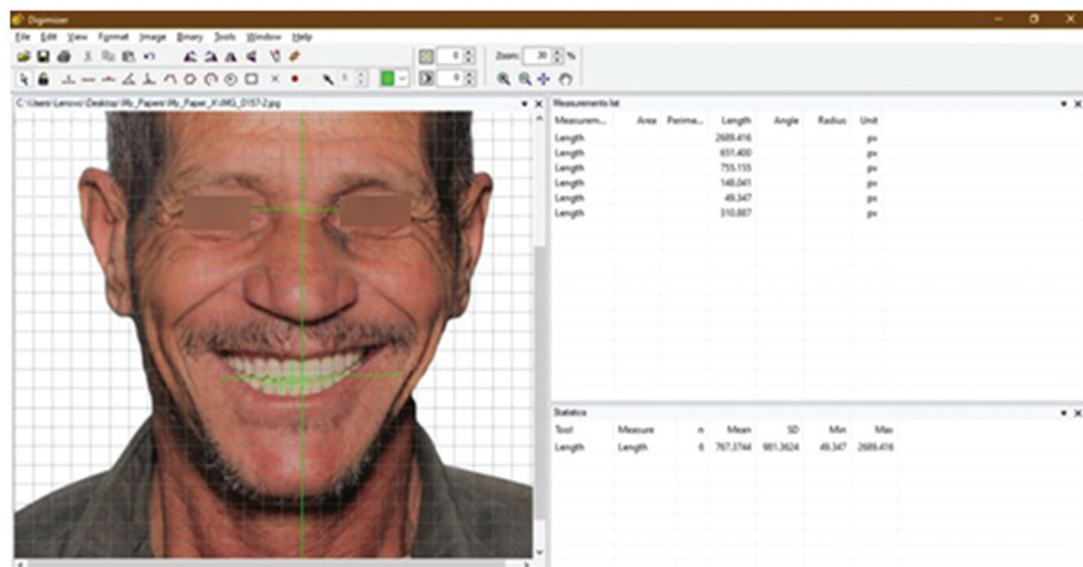


Photo analysis technique using Digimizer Software.

Figure 3.



Digital smile analysis technique.

Using different smile analysis methods, precision and accuracy were evaluated for each smile variable. To quantify precision, two sets of measurements taken with each method were compared using precision estimate: mean absolute deviation (MAD) in Fig. 4. MAD is a commonly reported precision estimate according to the following formula [18]:

Where n is the number of observed values, $\bar{x}$ is the mean of the observed values, and x_i is the individual values. All data were subjected to Cronbach's α as a reliability test score for accuracy assessment for each analysis by the reliability levels, listed in Table 2 [19].

Results

The present results indicated that in lower teeth exposure, the comparison using MDA (precision test) between group I and group II for each smile analysis technique revealing that the least amount of difference among groups was illustrated in the subgroup A (highest precision; 0.0031), followed by subgroup C (0.0038), and finally, subgroup B, which revealed the maximum amount of difference between groups (lowest precision; 0.0531), as listed in Table 3.

However, for smile index ratio, MAD comparison between group I and group II for each smile analysis technique revealed that the least amount of difference among groups was illustrated in subgroup A (highest precision; 0.0340), followed by subgroup C (0.2623) and finally subgroup B, which revealed the maximum amount of difference between groups (lowest precision; 0.315), as listed in the Table 3.

For buccal corridor ratio, MAD comparison between group I and group II for each smile analysis technique revealed that the least amount of difference among groups was illustrated in the subgroup A (highest precision; 0.0132), followed by subgroup C (0.0408), and finally, subgroup B, which revealed the maximum amount of difference between groups (lowest precision; 0.0625), as listed in the Table 3.

Regarding the level of accuracy in lower teeth exposure, using Cronbach's α for each group (group I and group II) between the different used smile analysis techniques revealed that it was 0.423 in group I, being quite reliable (quite accurate), and 0.784 in group II, being reliable (accurate), as listed in the Table 3.

Figure 4.

$$MD = \frac{1}{N} \sum_{i=1}^N |x_i - \bar{x}|$$

Precision estimate formula.

Table 2. Reliability Levels assessed by Cronbach's α

Cronbach's α	Reliability level
0.00–0.20	Less reliable
0.21–0.40	Rather reliable
0.41–0.60	Quite reliable
0.61–0.80	Reliable
0.81–1.00	Very reliable

Table 3. Multiple comparisons of precision and accuracy for lower teeth exposure, smile index and buccal corridor ratio

	Group I	Group II	MAD (precision)
Lower teeth exposure			
Subgroup A	0.210±0.060	0.216±0.077	0.0031
Subgroup B	0.290±0.090	0.184±0.0672	0.0531
Subgroup C	0.2171±0.069	0.210±0.075	0.0038
Cronbach's α (Accuracy)	0.423	0.784	
Smile index			
Subgroup A	3.024±0.684	2.956±1.0058	0.0340
Subgroup B	3.610±1.180	2.980±0.790	0.3150
Subgroup C	2.895±0.520	2.370±0.573	0.2623
Cronbach's α (accuracy)	0.131	0.137	
Buccal corridor ratio			
Subgroup A	1.333±0.240	1.360±0.277	0.0132
Subgroup B	1.495±0.349	1.370±0.450	0.0625
Subgroup C	1.472±0.340	1.390±0.370	0.0408
Cronbach's α (accuracy)	0.023	0.270	

All data are expressed as mean±SD.

MAD, mean absolute deviation.

However, for the smile index ratio, Cronbach's α test for group I and group II between the different used smile analysis techniques revealed that it was 0.131 in group I, being less reliable (less accurate), and 0.137 in group II, being less reliable (less accurate), as listed in the Table 3.

For the buccal corridor ratio, Cronbach's α test was calculated for group I and group II between the different used smile analysis techniques, revealing that it was 0.023 in group I, being less reliable (less accurate), and 0.270 in group II, being rather reliable (rather accurate), as listed in the Table 3.

Discussion

In complete dentures, the dentist normally designs the smile, which is created by the technician, and then the patients are allowed to try them on in a mirror during the try-in stage. Patients are becoming more esthetically demanding, seeking near-ideal tooth arrangement and color, in contrast to the dentist, who suggests teeth arrangement that follows anatomical averages or any accessible pre-extraction record, and selection of tooth color that harmonizes with the hair and skin [20].

Following DSD, facial analysis based only on an image may yield inaccurate and/or incomplete results. A study with video recording assessed static photographs of a posed smile and found that 11% of patients with a posed smile had a high smile, compared with 21% of patients with anterior high smile research with video recording [21]. The smile on video was also investigated and found that the average duration of a spontaneous smile was 500 ms, highlighting the difficulty of photographing this moment [22]. These findings have helped to clarify the findings of previous studies, which found that 42% of patients evaluated on video had more anterior teeth exposed and a gingival strip, indicating a high posterior smile. This excessive exposure of teeth, as well as the number of teeth visible in the smile, tends to fade with age, as evidenced by photographic and dynamic evaluations. However, many more esthetic qualities that have been specified in photographs have not yet been determined in videos [23].

In the present study, the presence of parallelism between planes and the reference lines follows the principles presented by other authors, who indicated that the parallelism between these structures affords generalized symmetry and is of esthetic value in the context of an esthetic smile. According to these

investigations, there is a link between the pupils and the incisal edge of the maxillary central incisors. All of these investigations aid the prosthodontist in determining a patient's esthetics; they serve as essential principles but not strict guidelines [24,25].

The posed smile can be constantly repeatable. A smile mesh, or grid, on a computer screen, uses horizontal and vertical lines to measure the features of a smile. As a result, the photo analysis method of an unstrained posed smile was proposed as a standard dental record, and it was used as a method of standardization of photographs in this study with Digimizer image analysis software, which allows accurate manual measurement results as well as fully automated object detection with measurements of object features [26].

Teeth length influences facial contouring and should therefore be considered during a patient's cosmetic makeover. The amount of visible gingiva also affects how attractive a smile is (gingival display via lower teeth exposure). Thus, in the current investigation, the gingiva visibility between the zenith of the gingiva of the maxillary central incisors and the inferior border of the maxillary lip was evaluated using the Digimizer program [27].

Regarding the lower teeth exposure, in this study, in the control group, smiling ranged from 0.21 to 0.29. These results were harmonized with a previous study which reported that the lower teeth exposure in the maximum smile was in the same values [28].

Authors of multiple research studies compared photographs of smiles with various buccal corridor widths. Some altered the same smile by adding or removing teeth, altering the width of teeth beginning with the first maxillary premolars, and altering the number and transverse width of posterior teeth. Others compared the smiles of people who had no similarity in their lateral dark area, either by extracting premolars or otherwise. This is because canines play an important part in forming the dental arch, as evidenced by mounting teeth in a complete denture [29].

Today, posed smile photographs are commonly used for diagnosis and treatment planning, but dynamic (video) smiles have been proposed and tested as an alternative. Videography and photography were compared in analyzing the patient's smile to see if a posed smile is a repeatable strategy [30].

The smile esthetic index strength is its ability to statistically assess the esthetics of a smile and use it to compare the preoperative and postoperative esthetical status of a treated clinical case, and hence the esthetical quality of a treatment outcome. Furthermore, the current study was able to show through a validation session that the proposed method may produce reliable and repeatable results with a high percentage of agreement [31].

Conclusion

With the respect to limitations for this study regarding individualized anatomical variations and standardization liability of the image, it was concluded that nanohybrid resin composite denture teeth had less deviation (higher precision) than the conventional acrylic resin denture teeth regarding different smile parameters ratio with facial proportions. In addition, the DSD and photo analysis method revealed lower accuracy than the direct hand caliper method regarding lower Cronbach's α , a reliability test.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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