Original Article

Introduction of Aesthetic Analyzer Software: Computer-aided Linear and Angular Analysis of Facial Profile Photographs

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ABSTRACT

Statement of Problem: Evaluation of diagnostic records as a supplement to direct examination has an important role in treatment planning of orthodontic patients with aesthetic needs. Photogrammetry as a quantitative tool has recently attracted the attention of researchers again.

Purpose: The purpose of this study was to design computer software to analyze orthodontic patients' facial profile photographic images and to estimate reliability and validity of its measurement.

Materials and Method: Profile photographic images of 20 volunteered students were taken in the natural head position with standard technique. Manual linear and angular measurements were used as a gold standard and compared with the results obtained from Aesthetic analyzer Software (designed for that purpose). Dahlberg's method error and Intraclass Correlation Coefficient (ICC) was used to estimate validity, reliability and inter-examiner errors.

Results: Almost all the measurements showed a high correlation between the manual and computerized method (ICC>0.75). The maximum method errors computed from Dahlberg's formula were 1.345 mm in linear and 3.294 degrees in angular measurements. At the highest levels, inter-examiner errors were 1.684 mm and 3.741 degrees in linear and angular measurements, respectively.

Conclusion: Although a low budget has been allocated for the design of Aesthetic Analyzer software, its features are comparable with commercially available products. The software's capabilities can be increased. The results of the current study indicated that the software is accurate and repeatable in photographic analysis of orthodontic patients.

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Introduction

The perception of an attractive face is clearly influenced by the balance and harmony of facial features. In order to achieve facial harmony, these features must be interrelated with each other in a balanced way. Varying the length of the nose, lip protrusion, and chin projection can change the existing harmony and create a new face, leading to a different aesthetic perception.

Facial features can be changed through several medical specialists (in orthognathic and plastic surgery, orthodontics or dental prosthesis). Hence, there is a need for clinicians working in the maxilla-facial area to know the aesthetic standards of face which help in achieving the aesthetic soft tissue treatment goals in their patients.

In orthodontics, pre-treatment soft tissue analysis, as an important tool for clinicians, has always been used to determine facial aesthetics and treatment goals. Soft-tissue analysis is primarily done through clinical examinations but indirect measurements on diagnostic records usually used to supplement the clinical data. Interestingly, facial features are usually studied in profile. For that purpose radiographic and photographic images of facial features are frequently obtained and analyzed prior to treatment of orthodontic patients [1]. Qualitative observational analysis (anthropology) combined with quantitative anthropometric methods, such as cephalometrics [2-3] and photogrammetry [4-5], are used in the evaluation of facial balance and aesthetic ratios. Of these methods, radiographic analysis was the focus of attention for many years. The cephalometric analysis popularity among clinicians made facial photography a passive record for several years. The emphasis was on the objective assessment of cephalometric radiographs even in evaluation of soft tissue features, leaving only a subjective role for lateral photographs [6]. This may emerged from the diagnostic paradigm in those days which used hard-tissue relationships as the core of diagnosis [7]. However, cephalometrics are not the best method for evaluating facial soft tissues [8]. In addition to concerns about radiation exposure, the soft-tissue structures are recorded only in profile and are limited to the anterior-most outline in cephalograms. Furthermore, patients are not accustomed to viewing and interpreting cephalograms or their tracings [9]. Photographs, on the other hand, can provide a more conventional documentation of the soft tissues of the face. The diagnostic paradigm shift in recent years [7] and the new approach to soft tissue relationships in diagnosis has made researchers rediscover photographic measurements.

Gavan was the first who proposed that accurate anthropometric measurements can be made from standard photographic images [10]. From then on, various methods of measuring photographs have been proposed by researchers such as Stoner [11], Neger [12] and Arnett [5]. Farkas standardized the photographic technique and the taking of records in natural head position (NHP) [13]. Tanner [14] and Diasia [15] evaluated the advantages and shortcomings of photogrammetric method and defined the possible sources of error in the technique. Using photogram-metry, Bishara et al. evaluated the changes in the soft tissue profiles of Class II patients after orthodontic treatment and confirmed the accuracy and reliability of measurements [9]. The use of photogrammetric methods in forensic medicine and identification of a suspect has been discussed [16]. Recently, several studies have been published regarding the normal values of soft tissue measurements in different societies. In this new approach to photogrammetry, authors such as Bearn [17], Fariabi [18], Malcok [19], Milosevic [20] and Riverio [21-22] approved the scientific validity and accuracy of the method in their studies.

According to the paradigm shift, dentists are expected to order and evaluate photographs of facial soft tissue. Although standardized photographic analysis methods are available to the clinicians, photographs are still being evaluated as a subjective record. Manual quantitative analysis attracts low attention in clinical settings because it is time consuming and less accurate in nature. Since the computer software products have gained popularity in dental practice management, patient education and even in diagnosis and treatment planning (Dolphin Imaging ™ and Geodigm ™ for example), manual photogrammetric analysis can be incorporated into such software. In this way, the technique becomes more appealing to the dentists who want to carry out quantitative photographic analysis for their patients.

The purpose of the current study was to design a computerized method for analysis and measurement of profile photographic images and to estimate the validity and reliability of its measurements.

Materials and Method

The participants of this study were dental students of Shiraz University, School of Dentistry. Twenty subjects were selected through convenience sampling from volunteered students. Written and verbal information was given to all the participants and written consent was obtained prior to taking standard profile photographic images. The approval of Local Ethics Committee was obtained. Due to the objectives of the study, no occlusal or facial characteristic was considered during selection of the participants.

Photographic set up

The photographic set up was consisted of a tripod which held a single lens reflex (SLR) camera (Canon Eos 400D, Japan) and a primary flash. The camera set up in the right height and according to the participant' body height with tripod. This ensured the correct horizontal position and stability of the lens optical axis (Macro, Sigma, Japan). A 70 mm focal lens was selected in order to maintain the natural proportions. To avoid the 'red-eye effect' on the photographs, a primary flash was attached to the tripod by a lateral arm at a distance of 27 cm from the optical axis of the camera and 75 degrees from the upper right angle. Two auxiliary flashes which were synchronized with the main flash were also used to illuminate the participant's face and to reduce the unwanted shadows. A secondary flash, as another element of the set up, was placed behind the participants to light the background and to eliminate undesirable shadows from the contours of the facial profile. A slave cell allowed synchronization with the main flash. A vertical mirror (20 x 35cm) was used in a distance of 150 cm in front of the participants to help orientation during photography (Figure 1).

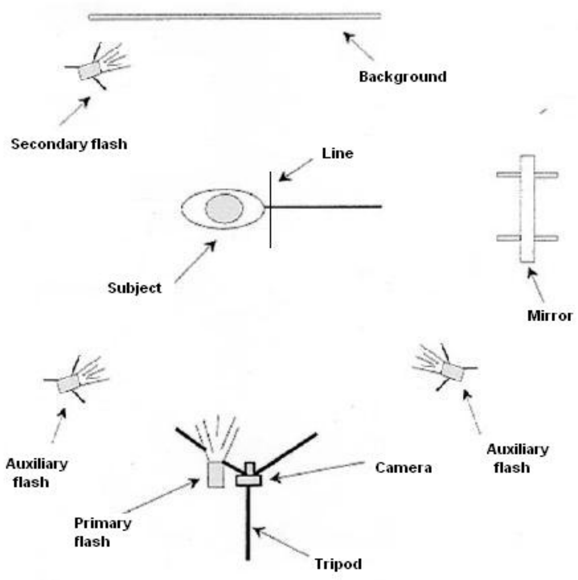

Figure 1 Photographic setup

Taking records

The camera was put in manual mode; the shutter speed was 1/125 sec and the opening of the diaphragm was f/11. The records were taken in NHP. Each participant was shown the right place to stand and was asked to relax. The participants were also asked to remove their glasses, walk a few steps, stand at rest behind the line which was marked on the floor facing the mirror, and look into their own eyes in the mirror while holding their arms at their sides. The vertical mirror was outside the frame, approximately 150 cm from the participants. The lips had to be relaxed, adopting the position they normally show during the day. The operator ensured that the patient's forehead, neck, and ears were clearly visible during the recording process. The digital photos were stored after being recorded on an external hard disk.

Designing the software and picture registration

Some of the available commercial software (Dolphin Imaging ™, Viewbox™) were evaluated and the required capabilities of the software to be designed were determined according to objectives of the current study. The algorithms for each part of the software were written separately and connected together by data flowchart. The Visual Basic™ compiler was used to program the flowchart using Access™ database for Microsoft™ Windows XP. After primary calibration and debugging, the installation package was developed for Windows XP operating system.

To make the pictures ready for measurement, they should first be selected through the software graphic interface. After picture selection and enlargement correction, the operator directed to the point registration interface (Figure 2). The points should be identified manually and registered by the mouse pointer, but the operator could use overall and localized zoom, vertical and horizontal lines, and automatic point locator during the point digitization. The position of each point could change at any time by the operator. After completing registration of all points, the picture should be calibrated with a specially designed ruler to scale the measurements up to real size. The measurements done by the software were presented into a table along the graphic tracing of the profile (Figure 3). The table and tracing could be printed.

Landmarks and measurements

Through using Aesthetic analyzer Software, customized with the landmarks, 18 landmarks were identified and registered on each profile picture. The landmarks used in this study were selected according to the previous studies and based on the following criteria: being easily assessable, reproducible and applicable in available analyses. These landmarks could be minimally altered by wearing makeup. The following landmarks are shown in figure 4: Trichion (Tri), the

Figure 2 Graphic interface of Aesthetic Analyzer software for landmark points registration.

sagittal midpoint of the forehead that borders the hairline, Glabella (G), the most anterior point of the middle line of the forehead, Nasion (N), the point in the middle line located at the nasal root, Pronasal (Prn), the most prominent point of the tip of the nose, Midnasal (Mn), the middle point on the outer contour of the nose between Pronasal and Nasion, Columella (Cm), the most inferior and anterior point of the nose, Subnasal (Sn), the point where the upper lip joins the columella, Labial superior (Ls), the point that indicates the mucocutaneous limit of the upper Lip, Stomion superior (Sts), the most inferior point of the upper lip, Stomion inferior (Sti), the most superior point of the lower lip, Labial inferior (Li), the point that indicates the mucocutaneous limit of the lower Lip, Supramental (Sm), the deepest point of the inferior sublabial concavity, Pogonion (Pg), the most anterior point of the chin, Menton (Me), the most inferior point of the inferior edge of the chin, Cervical (C), the point joining the neck and chin contours, Tragus (Trg), the most posterior point of the auricular tragus, Alar (Al), the most lateral point of the alar contour of the nose, Ort, the point joining the true vertical (TV) and the true horizontal (TH) lines. The following reference lines were used (Figure 4a): TV (sTV-iTV), inferior and superior points automatically generated on monitor display, TH, perpendicular to TV, TV in N (N-Ort), parallel to TV through N, TH, Trg-Ort, perpendicular to TV through Trg, Canut line (Juanita Line), Sn-Sm.

The following vertical linear measurements (parallel to TV) were used (Figure 5): Superior facial third (Tri-G), Middle facial third (G-Sn), Inferior facial third (Sn-Me), Nasal length (N-Sn), Length of upper lip (Sn-Sts), Interlabial gap (Sts-Sti), Length of lower lip (Sti-Sm),Vermilion of upper lip (Ls-Sts), Vermilion of

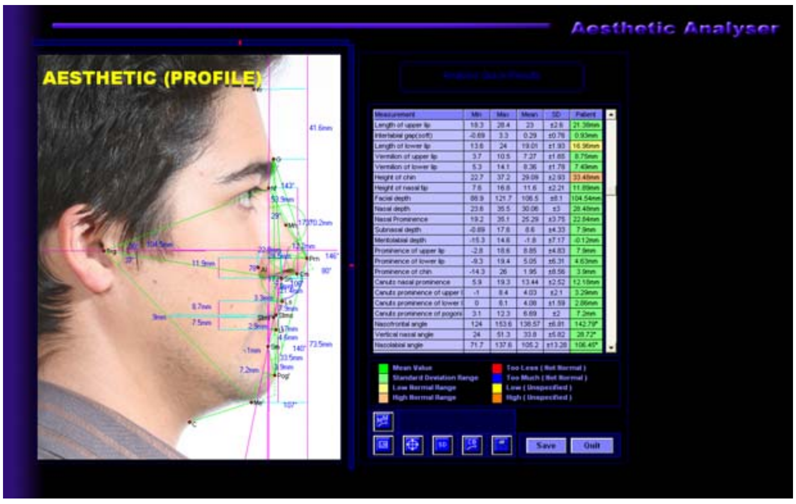

Figure 3 Tracing of the participant's profile and linear and angular measurements tables.

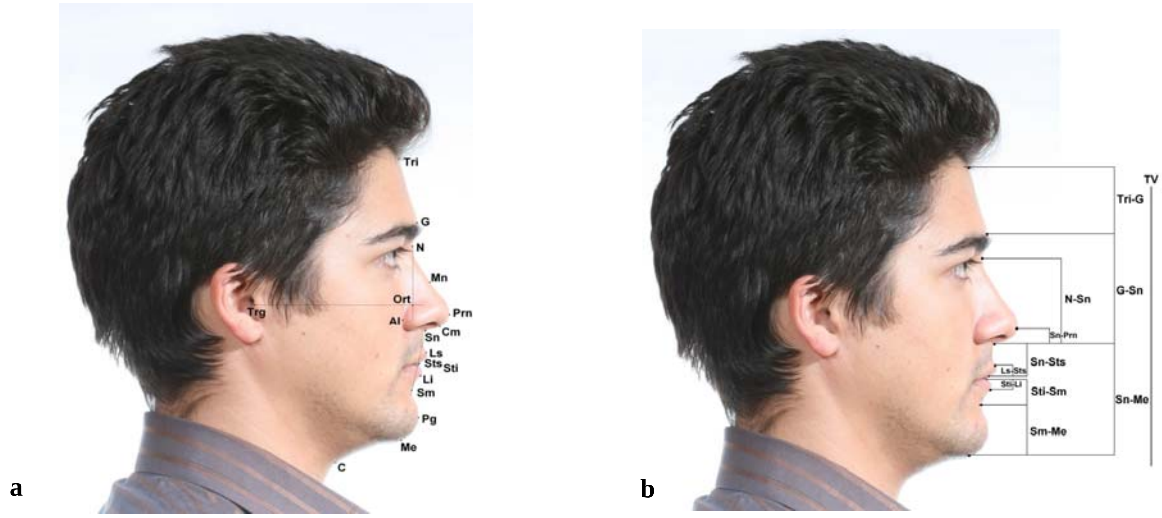

Figure 4a Landmarks and reference lines used in the Analysis. **b** Vertical measurements (measured parallel to TV line).

lower lip (Li-Sti), Height of chin (Sm-Me), Height of nasal tip (Sn-Prn). The following linear horizontal measurements (parallel to TH) were used (figure 4b): Facial depth (Trg-Sn), Nasal depth (Al-Prn), Nasal prominence (Prn to N-Ort line), Subnasal depth, (Sn to N-Ort line), Mentolabial depth (Sm to N-Ort line), Prominence of upper lip (Ls to N-Ort line), Prominence of lower lip (Li to N-Ort line), Prominence of chin (Pg to N-Ort line).

Angular measurements of the analysis (clockwise) were: N–G–Prn, nasofrontal angle; N–Prn/N–Ort, vertical nasal angle; Cm–Sn–Ls, nasolabial angle; Li–Sm–Pg, mentolabial angle; Sn–Cm/N–Prn, nasal angle; N–Mn–Prn, angle of the nasal dorsum; G–Pg/C–Me, cervicomental angle; N–Trg–Sn, angle of the middle facial third; Sn–Trg–Me, angle of the inferior facial third; Trg–Ort/Sn–Sm, angle of the head position (Figure 5a).

Validity and reliability of computerized photogrammetric method

The degree of validity, reproducibility and the accuracy of linear and angular measurements, made by computer, were assessed through comparing them with their corresponding measurements obtained manually as the gold standard. Manual measurements were done on printed photographs of the participants. HP LaserJet 2010 was used to print the profile photo of each participant on A4 paper through using the scale-to-fit option. Linear and angular measurements were done manually by one person with orthodontic protractor (Ortho organizer). The corresponding measurements were done by computer and the same person

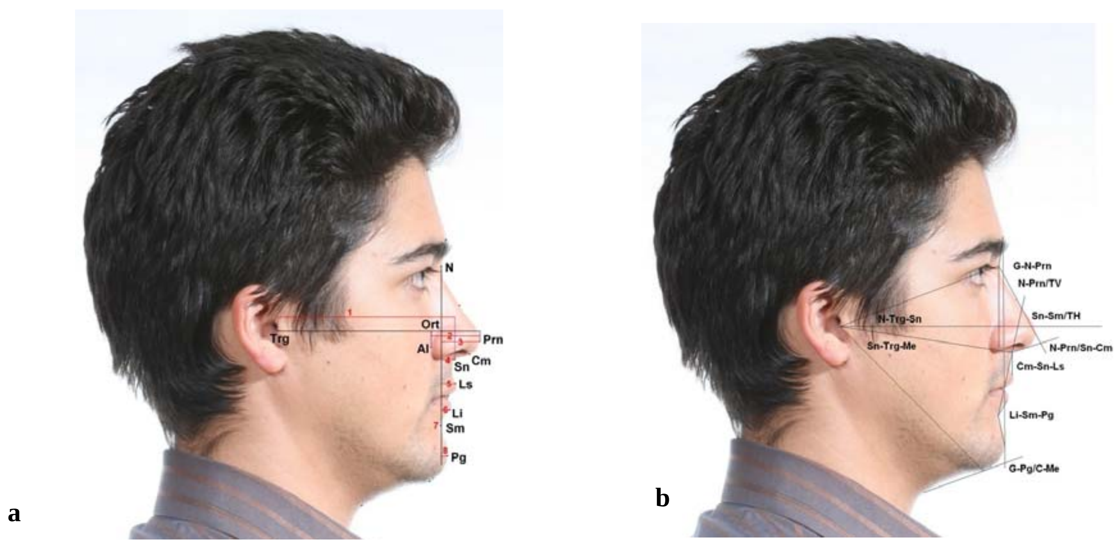

Figure 5a Horizontal measurements (measured parallel to TH line). **5b** Angular measurements of the analysis (clockwise)

digitized the landmarks on each picture through using Aesthetic analyzer software. The manually measured distance between Nasion and Menton on each printed photograph was used for life real sized calibration of computerized measurements which were done on that photograph. In this way, the measurements made by two methods were comparable. Because the same person identified the landmarks in both methods, there was minimum error in landmark identification. For determining the inter-examiner error in point digitization, a second operator digitized the participants' photographs separately. The two operators had agreement on location of the landmarks.

The amount of time which was required to complete manual and computerized measurements on three of the participants' photographs was estimated for the purpose of comparison. The average time required to make manual measurement from the beginning of landmark identification on printed photographs to the end of measurements was 30 minutes for one operator. The same operator did computerized measurements in about 5 minutes on average.

Statistical analysis

The reliability of the method was assessed using ICC (Intraclass Correlation Coefficient) and Dahlberg's formula[24] which is used to assess the method error, (ME = $\sqrt{\Sigma(x1-x2)^2/2n}$), in which x1, x2, and n represent the first measurement, the second measurement, and the number of repeated records, respectively). About 2 weeks after the first set of tracings 20 photographs were retraced and digitized again by the same operator to calculate the method error. Validity of the measurements was assessed through linear regression analysis. Manual measurement was used as the independent method, whereas digital photography was the dependent photogrammetric method in the linear regression model. Inter-examiner error was assessed through comparing the values from the two operators using ICC and Dahlberg's formula.

Results

Tables 1 and 2 depict the method error according to Dahlberg's formula in 30 linear and angular measurements on the 20 subject's photographs, with Aesthetic Analyzer software. All the values were statistically significant (p <0.05). The minimum and maximum method errors in linear measurements were 0.307mm, in nasal prominence, and 1.345 mm, in facial depth respectively.

Table 1 Method error in linear measurements according to Dalhberg's Formula

Parameter	Method error (mm)
Tri-G *	1.059
G-Sn*	0.385
Sn-Me*	1.341
N-Sn*	0.915
Sn-sts*	0.575
sts-sti*	0.575
sti-Sm*	0.705
Ls-sts*	0.911
Sti-Li*	0.705
Sm-Me*	0.882
Sn-Prn*	0.780
trg-Sn*	1.345
Al-Prn*	0.654
Prn/N-ort line*	0.307
Sn/N-ort line*	0.576
Sm/N-ort line*	0.461
Ls/N-ort line*	0.508
Li/N-ort line*	1.151
Pg/N-ort line *	0.383

* Statistically significant differences

Table 2 Method error in angular measurements according to Dalhberg's Formula

Parameter	Method error (degree)
G–N–Prn *	1.582
N–Prn/TV(N) *	0.479
Cm–Sn–Ls *	3.294
Li–Sm–Pg *	2.883
Cm–Sn/N–Prn *	1.920
N–Mn–Prn *	1.285
C–Me/G–Pg*	1.240
N–Trg–Sn *	0.426
Sn–Trg–Me *	1.749
Sn–Sm/TH *	0.496

*Statistically significant differences.

Also, the minimum error method in angular measurements was 0.426 in angle of the middle facial third and the maximum error method was 3.294° and in nasolabial angle. The ICC values for manual and computer-aided methods were calculated in 30 angular and linear measurements in the 20 participants. The values, statistically significant (p <0.05), have been displayed in table 3.

In one linear (upper lip vermilion) and one angular (lower third facial angle) measurements, the ICC was below the ideal threshold (ICC<0.75). However, in the other 28 measurements, the ICC value was larger than 0.75. This revealed the high correlation

Table 3 Intraclass Correlation Coefficient values for manual and computer-aided methods of measurements

Parameter	ICC
Tri-G *	0.982
G-Sn*	0.977
Sn-Me*	0.926
N-Sn*	0.966
Sn-sts*	0.957
sts-sti*	0.895
sti-Sm*	0.880
Ls-sts*	0.706
Sti-Li*	0.794
Sm-Me*	0.947
Sn-Prn*	0.889
trg-Sn*	0.980
Al-Prn*	0.942
Prn/N-ort line*	0.894
Sn/N-ort line*	0.962
Sm/N-ort line*	0.994
Ls/N-ort line*	0.983
Li/N-ort line*	0.975
Pg/N-ort line *	0.991
G–N–Prn *	0.973
N–Prn/TV(N) *	0.888
Cm–Sn–Ls *	0.953
Li–Sm–Pg *	0.973
Cm–Sn/N–Prn *	0.910
N–Mn–Prn *	0.963
C–Me/G–Pg*	0.984
N–Trg–Sn *	0.955
Sn–Trg–Me *	0.501
Sn–Sm/TH *	0.991

* Statistically significant differences

Table 4 Intraclass Correlation Coefficient and Dahlberg's values for inter-examiner error

Parameter	ICC	Dahlberg (mm or degree)
Tri-G *	0.973	1.329
G-Sn	0.954	1.192
Sn-Me*	0.944	1.425
N-Sn*	0.952	0.991
Sn-sts*	0.941	0.588
sts-sti*	0.543	0.442
sti-Sm*	0.680	1.081
Ls-sts*	0.540	0.969
Sti-Li*	0.715	0.905
Sm-Me*	0.923	1.127
Sn-Prn*	0.837	0.883
trg-Sn*	0.958	1.684
Al-Prn*	0.948	0.713
Prn/N-ort line*	0.965	0.574
Sn/N-ort line*	0.943	0.763
Sm/N-ort line*	0.984	0.620
Ls/N-ort line*	0.964	0.659
Li/N-ort line*	0.858	1.434
Pg/N-ort line *	0.990	0.515
G–N–Prn *	0.909	2.629
N–Prn/TV(N) *	0.898	1.105
Cm–Sn–Ls *	0.923	3.741
Li–Sm–Pg *	0.919	3.422
Cm–Sn/N–Prn *	0.902	2.239
N–Mn–Prn *	0.938	1.820
C–Me/G–Pg*	0.974	1.299
N–Trg–Sn *	0.949	0.440
Sn–Trg–Me *	0.425	1.966
Sn–Sm/TH *	0.984	0.666

* Statistically significant differences.

between the two methods of measurement in the study. Inter-examiner error has been represented in table 4.Dahlberg's formula and ICC were used to compare 30 linear and angular measurements in the 20 studied subjects. The maximum data error was 1.684 mm and 3.741˚ in linear and angular measurements, respectively. The former was in facial depth and the latter was in nasolabial angle. The findings also revealed that in 26 out of 30 measurements, the correlation between the two operators was high (ICC >0.75). All the differences were statistically significant (p <0.05).

Discussion

The accuracy of measurements plays an important role in the integrity of computer software. Therefore, prior to using any software in clinical settings, it is necessary to estimate the validity and reliability of its measurements. Aesthetic Analyzer Software, which was used in the current study, deploys mathematical algorithms to carry out linear and angular measurements. These algorithms are naturally free of error, so the main source of error in the measurements is digitization of landmarks by the operator. The results revealed that Aesthetic Analyzer had a high reliability in photogrammetric measurements. The method error in most instances was below two units of measurements which was clinically favorable [17]. Generally, the method error was greater in angular measurements than in linear ones. Considering the fact that three points should be digitized for each angular measure, the greater amount of error is involved with it in comparison with two point digitization which is required in linear measurements. The nasolabial and mentolabial angles had the greatest variability with the largest method errors associated with them. This is due to the nature of comprising points and the difficulty in their identification in rather dull borders of nose and chin. The degree of error in the current study is comparable to the similar studies on 2D photographs. For instance, Riverio et al. [21-22] reported that the method error in reliability of linear and angular measurements was 0.5-3mm and 0.72-4.5˚, respectively, which is higher than in the present study. In a similar study, Milosevic et al. [20] reported that the error in angular measurements was 0.5 -2.5˚ and Malcok et al. [19] mentioned error of 0.18 to 2.16 ˚ in their measurements. Bister [25] et al. encountered a 1.2 mm error in their study and Beam et al. [17] mentioned that an error of 2˚ in reproducibility was clinically favorable. In their studies on 3D photographs, Kochel [16] and Mall [27] reported that the error in linear measurement was about 0.39 to 1.5 mm, due to landmark digitization error. Their findings were similar to those of 2D studies.

The inter-examiner error in the current study was less than 2 units of measurement, and clinically favorable, in most measurements. The maximum data errors were found in angular measurements, especially in angles like mentolabial and nasolabial whose comprising points were somehow difficult to locate with precision in the rather dull contours. Different clinicians have different perceptions about locations of landmark points on facial photographs and this can lead to unpredictable measurement errors in research. Therefore, in this study, the operators who were involved with the evaluation of inter-examiner error contributed each other and had agreement on the definition of landmark points. In a similar study on 2D photographs, Dimmagio et al. [28] reported an inter-examiner error of 0.792 mm. On 3D models, Mall et al. [27] reported an inter-examiner error of 1mm. The authors mentioned that the error had risen from different protocols for point location and different opinions among researchers.

The validity of the method was evaluated through comparing the measurements made by computer with gold standard measurements. The validity for the measurements was assessed by estimating ICC. This method is preferred to tests used for determining significant differences between the means for repeated measurements, such as Paired Student's t-tests. It is because of the fact that these tests will tend to find no significant difference if the statistical power is low and so improperly consider the method as valid [29]. In most of the measurements, the Correlation Coefficient was clinically ideal, higher than 0.75. The high correlation between the two methods means that they can be used instead of each other and it can also give credentials for the use of computer-aided measurement method. The correlation was less than optimum for angle of the inferior facial third. This is risen from difficulty in locating Menton point precisely (even by the same operator in different intervals).

The gold standard in the current study was manual angular and linear measurements made by orthodontic protractor on printed photographs of facial profile. These measurements were done with the utmost precision. However, the error of 0.3 mm in manual measurements has been accepted in the literature [30] and had to be considered in the current study, too. It is worth mentioning that, in this study, the manual method was regarded as the gold standard, thus the difference between the two measurement methods was considered as the computer-aided method error, even though it could be the gold standard error in reality. Using printed photographs for measurement affected the results adversely at least in one landmark, Ls (Labial superior), since locating that point on the monitor after enlarging the picture was easier. No such limitations were recognized with regard to the other landmarks.

In most of the similar studies, the statistical data on validity of measurements have not been included. In these studies, the researchers have argued that measurements have been made through computer algorithms and thus they were sufficiently accurate. In other words, in these studies, validity has been ensured.

With regard to the validity of computer-aided measurements on photographs, we should consider that the final objectives of these measurements are to use them as an aid for treatment planning, based on the real sized images of the patients' faces. In other words, the accuracy of these measurements can not be higher than the accuracy of photographic anthropometric method itself. Several studies have confirmed that accurate anthropometric measurements can be done on photographs [11-14]. However, a recent study [3], on comparing anthropometric and photographic measurements, showed that only 54% of linear and 44.5% of angular measurements, which were made on photographs, were reliable. Other measurements should be converted (multiplied by a specific constant which should be calculated for each measurement separately) before use in clinical diagnosis. Doing the computations manually and increasing the images to real sized scales are complicated tasks but any programmed software can make them easy and practical. Therefore, computer-aided measurement method is preferred due to these advantages.

The idea of using computers in clinical diagnosis is not a new one. From 90s when it first gained popularity [32] to the present time, profound advances have been made in the 3D models era in the field. Computer-aided computation and measurement is advantageous in that they are faster and more accurate than manual measurements. These advantages can best serve the needs of dentists in analyzing the diagnostic records of orthodontic patients, which is a lengthy and complicated process. In the current study, tracing the photographs by the software needed about 5 minutes on average, however, doing the same tracing manually needed about 30 minutes. This can make a great difference in a crowded clinic.

Aesthetic Analyzer is 2D software. A two dimensional measurement of a three dimensional object (face) in locating some landmarks with great accuracy is not without some major limitations. Some landmarks like Tragus, Menton and Glabella cannot be defined with great reproducibility. The final solution to this problem lies in recent advancements in three-dimensional image-taking and virtual face modeling [26-27]. However, implementation of new technologies is costly and entails additional equipments and infrastructures like CT units and laser scanners, which are not easily available, especially in sub-urban areas. This makes the role of simpler 2D methods more important in some circumstances developing countries. The software products like Aesthetic Analyzer are more available, low budget and practical, and works on the documents already ordered for every orthodontic patient in routine.

Although the definition of every landmark point is provided in the literature, Locating and registering landmark points on digital photographic images on monitor screen can be challenging, especially for the landmarks which are located in the minimum or maximum contours. To overcome this problem and to locate landmark points, the operator can draw the guiding vertical and horizontal lines wherever necessary in Aesthetic Analyzer graphic interface. Also the regional picture enlargement and accessory magnifier can make the process easier. These capabilities are similar to those seen in some commercial software like Dolphin Imaging.

Another important feature in Aesthetic Analyzer Software is its capability for automatic point location. The underlying algorithms can be improved and the software can locate the landmark points used in the measurement analysis automatically through defining maximum and minimum contours and through detection of differences in shade contrasts. This capability can reduce the amount of time required for analysis to a great extent. Anyway photographs must be of good quality and have a high background contrast.

Conclusion

The results of the present study revealed that Aesthetic Analyzer Software has high accuracy and reliability in the analysis of facial profile images. The software is easy to use in clinical settings by dentists and their trained assistants. Although a low budget, provided by domestic experts, has been allocated for the design of Aesthetic Analyzer, its features are comparable with commercially available software. The software's capabilities can be increased based on the needs of dental teams. These needs may range from making diagnosis and treatment plans to research activities, such as evaluation of facial changes in adolescents during growth stages or changes after treatment. Aesthetic Analyzer Software can provide the researchers with a model for more complex 3D software which are to be designed in future.

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