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A comparison study of different facial soft tissue analysis methods

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ABSTRACT

Objectives: The purpose of this study was to evaluate several different facial soft tissue measurement methods.
Materials and methods: After marking 15 landmarks in the facial area of 12 mannequin heads of different sizes and shapes, facial soft tissue measurements were performed by the following 5 methods: Direct anthropometry, Digitizer, 3D CT, 3D scanner, and DI3D system. With these measurement methods, 10 measurement values representing the facial width, height, and depth were determined twice with a one week interval by one examiner. These data were analyzed with the SPSS program.
Results: The position created based on multi-dimensional scaling showed that direct anthropometry, 3D CT, digitizer, 3D scanner demonstrated relatively similar values, while the DI3D system showed slightly different values. All 5 methods demonstrated good accuracy and had a high coefficient of reliability (>0.92) and a low technical error (<0.9 mm). The measured value of the distance between the right and left medial canthus obtained by using the DI3D system was statistically significantly different from that obtained by using the digital caliper, digitizer and laser scanner ($p < 0.05$), but the other measured values were not significantly different. On evaluating the reproducibility of measurement methods, two measurement values (Ls–Li, G–Pg) obtained by using direct anthropometry, one measurement value (N′–Prn) obtained by using the digitizer, and four measurement values (En_{Rt}–En_{Lt}, Ala_{Rt}–Ala_{Lt}, Ch_{Rt}–Ch_{Lt}, Sn–Pg) obtained by using the DI3D system, were statistically significantly different. However, the mean measurement error in every measurement method was low (<0.7 mm). All measurement values obtained by using the 3D CT and 3D scanner did not show any statistically significant difference.
Conclusion: The results of this study show that all 3D facial soft tissue analysis methods demonstrate favorable accuracy and reproducibility, and hence they can be used in clinical practice and research studies.

1. Introduction

Facial soft tissue analysis is very useful and mandatory for presurgical planning, post-surgical evaluation, or for the evaluation and description of maxillofacial growth. Generally, cephalic radiographs have been used to analyze maxillofacial soft tissues (Lines et al., 1978; Ayoub et al., 1996), but these two-dimensional (2D) cephalic radiographs usually focus on the analysis of hard tissues thereby resulting in limitations in the analysis of soft tissues. There are difficulties in reconstructing the three-dimensional (3D) maxillofacial form and performing 3D maxillofacial analysis based on a 2D image. In addition, surgeons wish to demonstrate the facial changes and patients also desire to see the facial changes via 3D images before and after orthognathic surgery. The 2D analysis methods that are currently being used widely such as cephalometric analysis do not fulfill these requirements.

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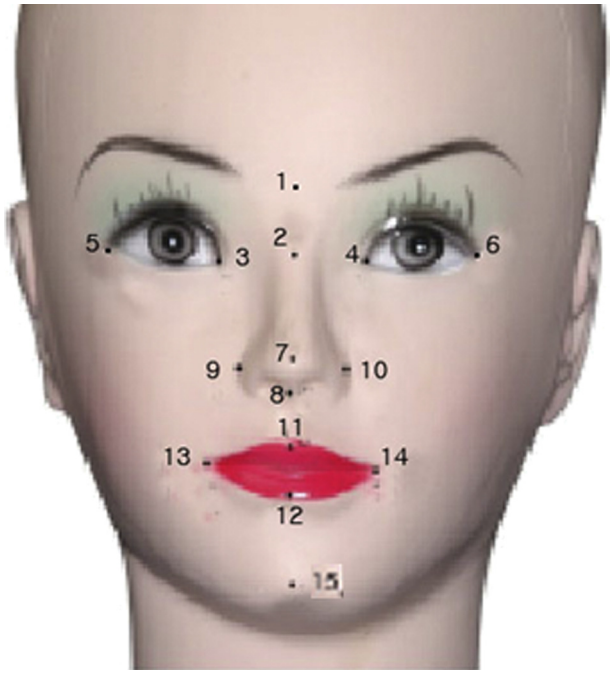

Fig. 1. The landmarks used in this study; 1. G, glabella; 2. N′, soft tissue nasion; 3. En_{Rt}, right endocanthion; 4. En_{Lt}, left endocanthion; 5. Ex_{Rt}, right exocanthion; 6. Ex_{Lt}, left exocanthion; 7. Prn, pronasale; 8. Sn, subnasale; 9. Ala_{Rt}, right alare; 10. Ala_{Lt}, left alare; 11. Ls, labrale superius; 12. Li, labrale inferius; 13. Ch_{Rt}, right cheilion; 14. Ch_{Lt}, left cheilion; 15. Pg′, soft tissue pogonion.

In order to address these shortcomings many studies and clinical applications regarding 3D analysis of the craniomaxillofacial field are currently being conducted (Swennen et al., 2006).

The ideal measurement method for facial morphological analysis should have the following characteristics: ability to record facial soft tissue data, good accuracy and precision, ability to produce 3D images, and reproducibility (Thomson, 1985). It should also have a low technique sensitivity and be safe for the patients and the operator, noninvasive, quick and easy to perform, and not be too expensive (Miller et al., 2007). The methods of 3D facial soft tissue analysis that are currently being widely used in clinical practice include direct anthropometry (Allanson et al., 1993), 3D laser scans (Moss et al., 1994; Bush and Antonyshyn, 1996), stereoscopic camera (Ayoub et al., 1998; de Menezes et al., 2009), digitizers (de Menezes et al., 2009) and 3D computerized tomography (CT) (Moerenhout et al., 2009). CT laser scan, and stereoscopic photography are used for providing 3D images and 3D facial measurement values. The other two methods such as direct anthropometry and digitizer scan measure the 3D facial values, but they cannot produce 3D images. Therefore, it needs to determine whether the former three methods provide accurate and reproducible measurement values compared to the latter two methods and to clarify whether 3D image reconstruction can be used as a diagnostic tool or should only be used as a patient consultation tool.

Most previous studies have compared the accuracy or reproducibility of measurement methods, or compared 2D photographs with 3D facial soft tissue analysis methods. There are few studies that compare the accuracy and reproducibility of different 3D facial soft tissue analysis methods, so, there is a need to evaluate the accuracy and reproducibility of 3D measurement values that are obtained through different 3D facial soft tissue analysis methods.

The purpose of this study was to compare the different 3D facial soft tissue analysis methods.

2. Materials and methods

2.1. Materials

Twelve mannequin heads of different sizes and shapes with color and form corresponding to the human head, able to maintain a certain position without any movement or change in shape, were used for this study.

2.2. Methods

2.2.1. Marking facial landmarks

Fifteen facial landmarks suggested by Toma et al. (2009) were used. Black ink was used to mark the following 15 points on the facial area of each mannequin: the glabella, between the left and right eyes (soft tissue nasion, N′), the inner corner of the left and right eyes (endocanthion, En), the outer corner of the left and right eyes (exocanthion, Ex), the tip of the nose (pronasale, Prn), underneath the nose (subnasale, Sn), the most lateral points on the ala of the nose (alare, Ala), the area above the upper lip (labrale superius, Ls), the area under the lower lip (labrale inferius, Li), the area outside the left and right corners of the mouth (cheilion, Ch), the lower chin area (soft tissue pogonion area, Pg′) (Fig. 1). The points were not larger than 0.5 mm in size.

2.2.2. 3D facial soft tissues measurement

Five 3D facial soft tissue analysis methods – 3D stereoscopic camera, 3D CT, laser scan, contact measurement using a caliper – were used by one operator to measure 10 values representing the facial width, height and depth twice at an interval of one week (Fig. 2), and each value was measured twice at once instance. Then the average of the measurement values was calculated.

2.2.2.1. 3D stereoscopic camera. Following the directions of the manufacturer, the head of the mannequin was placed at a position where it was at the same distance and angle from both sides of the

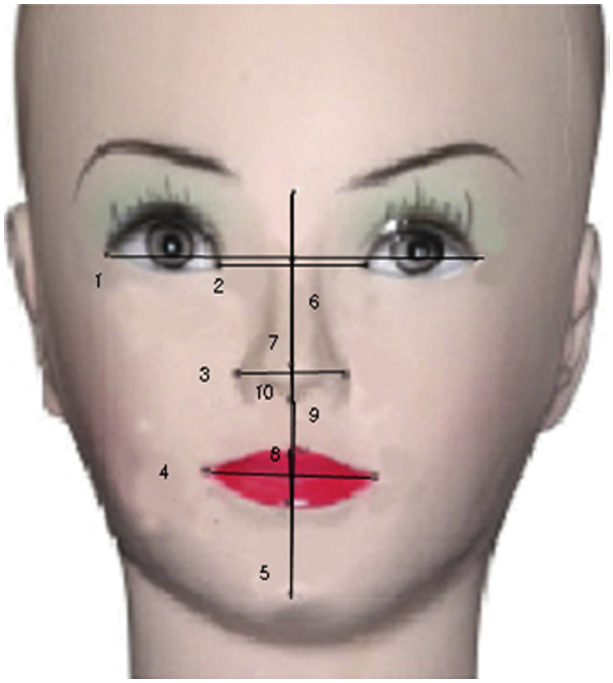

Fig. 2. Linear measurements used in this study; 1. Ex_{Rt}–Ex_{Lt}; 2. En_{Rt}–En_{Lt}; 3. Ala_{Rt}–Ala_{Lt}; 4. Ch_{Rt}–Ch_{Lt}; 5. G–Pg′; 6. N′–Prn; 7. G–Sn; 8. Ls–Li; 9. Sn–Pg′; 10. Ala_{Rt}–Prn.