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Reliability and validity of measurements of facial swelling with a stereophotogrammetry optical three-dimensional scanner

Wicher J. van der Meer [a,*], Pieter U. Dijkstra [b], Anita Visser [c], Arjan Vissink [d], Yijin Ren [e]

[a] *Assistant professor, Department of Orthodontics, University of Groningen, University Medical Center Groningen, Groningen, the Netherlands*
[b] *Professor, University of Groningen, University Medical Center Groningen, Department of Oral and Maxillofacial Surgery and Department of Rehabilitation, Center for Rehabilitation, Groningen, the Netherlands*
[c] *Assistant professor, University of Groningen, University Medical Center Groningen, Department of Oral and Maxillofacial Surgery, Groningen, the Netherlands*
[d] *Professor, University of Groningen, University Medical Center Groningen, Department of Oral and Maxillofacial Surgery, Groningen, the Netherlands*
[e] *Professor and chair, University of Groningen, University Medical Center Groningen, Department of Orthodontics, Groningen, the Netherlands*

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Abstract

Volume changes in facial morphology can be assessed using the 3dMD DSP400® stereo-optical 3-dimensional scanner, which uses visible light and has a short scanning time. Its reliability and validity have not to our knowledge been investigated for the assessment of facial swelling. Our aim therefore was to assess them for measuring changes in facial contour, in vivo and in vitro. Twenty-four healthy volunteers with and without an artificial swelling of the cheek were scanned, twice in the morning and twice in the afternoon (in vivo measurements). A mannequin head was scanned 4 times with and without various externally applied artificial swellings (in vitro measurements). The changes in facial contour caused by the artificial swelling were measured as the change in volume of the cheek (with and without artificial swelling in place) using 3dMD Vultus® software. In vivo and in vitro reliability expressed in intraclass correlations were 0.89 and 0.99, respectively. In vivo and in vitro repeatability coefficients were 5.9 and 1.3 ml, respectively. The scanner underestimated the volume by 1.2 ml (95% CI -0.9 to 3.4) in vivo and 0.2 ml (95% CI 0.02 to 0.4) in vitro.

The 3dMD stereophotogrammetry scanner is a valid and reliable tool to measure volumetric changes in facial contour of more than 5.9 ml and for the assessment of facial swelling.

Keywords: 3dMD DSP400® stereo-optical 3D scanner; 3D stereophotogrammetry; swelling; measurement; reliability

Introduction

Changes in facial contour may occur as a result of craniofacial surgery, orthognathic surgery, inflammation, trauma, or ablative surgery, for example. Several methods have been used during the past 60 years to measure the various types of facial deformity, mainly contact methods.[1] Later, non-contact technology increasingly replaced them, although these newer methods often required complicated equipment for measurement to allow for standard orientation of the head for photography and radiography.[2] Mathematical methods were then applied to describe the changes in facial morphology.[3] Others used early (non-digital) stereophotogrammetry to make linear measurements on landmark-based points.[4,5]

* Corresponding author. Department of Orthodontics, University Medical Center Groningen, PO Box 30.001, NL-9700 RB Groningen, The Netherlands, Tel.: +31-50-3613840; fax: +31-50-3611136.
E-mail address: w.j.van.der.meer@umcg.nl (W.J. van der Meer).

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With the availability of 3-dimensional scanning technology, these scanners have evolved to become the first choice in research on measurements of volume and their comparison. Among other things, these scanners have been used to assess volumetric changes in acute oedema of burns,[6] breast symmetry,[7] and postoperative facial swelling.[8–11] The most commonly used optical 3-dimensional scanners are the laser scanner, the structured light scanner, and the stereophoto scanner.

The reliability and validity of the 3dMD DSP400® system have been assessed in landmark measurements on an animal's skull,[12] a phantom head,[13,14] a human face,[15,16] the human torso,[17] and the breast.[18] They have proved to be more than sufficient for clinical needs and better than direct anthropometry or 2-dimensional photography.[13] It is often hard to compare studies, as only a few authors actually define the properties that they have assessed.[12,13,15,19,20]

The 3dMD DSP400® stereo-optical 3-dimensional scanner (Atlanta, GA 30339, USA) has not to our knowledge been used to measure postoperative swelling, but could be an alternative to laser scanners, as stereo-optical 3-dimensional scanners are usually less expensive, easy to use, and have a recording time of milliseconds. The latter is a great aid in the prevention of motion artefacts, which may easily happen in the head and neck region.

The aim of the current study was to assess the reliability and validity of the 3dMD DSP400® stereo-optical 3-dimensional scanner of volumetric changes in facial morphology by making repeated analyses of the volume of the cheeks when an artificial swelling was in place at 4 separate moments during the day, and analysing repeatedly the volume of an artificial swelling attached to the head of a mannequin.

In this study "reliability" was defined as the degree to which the measurement is free from measurement error, and "validity" was defined as the degree to which an instrument truly measures the construct it purports to measure.[21]

Material and methods

Subjects

To assess in vivo reliability we enrolled 24 healthy volunteers (12 women and 12 men), who were coworkers at the department of orthodontics in the University Medical Centre, Groningen. Their mean (range) age was 29 (19–63) years. Informed consent was obtained from each volunteer before the study.

The artificial swelling

For each volunteer an artificial swelling was made by mixing a similar amount of base paste and catalyst paste of an impression material (Provil Novo Putty®, Heraeus Kulzer GmbH, Hanau, Germany), by forming it into a small bolus. The volunteers were asked to keep their teeth gently occluded. The artificial swelling (bolus) was then placed in the molar region of the subject's mouth on the buccal side of the teeth and pressed gently against the teeth, which made small impressions in the artificial swelling. These impressions enabled reinsertion of the artificial swelling in the same position again for further measurements later in the day. After the material had set it was removed. It was disinfected with alcohol, as the impression material is not affected by short term disinfection.[22] Each artificial swelling was stored in a marked bag.

To assess the in vitro reliability and validity of the scanner, 6 artificial swellings were made with the same impression material to cover the full volume range of the artificial swellings that were used in vivo. These artificial swellings were placed on the exterior surface of a Styrofoam mannequin head, which was measured 4 times with the stereo-optical scanner, with and without each artificial swelling in place.

Measurement of the volume of the artificial swelling

Each artificial swelling was weighed on a high-precision scale (Mettles PJ 360, Mettler-Toledo GmbH, Griefensee, Switzerland). The density of the impression material was taken from the Material Safety Data Sheet of the material (Provil Novo Putty®, Material Safety Data Sheet, Heraeus Kulzer GmbH, Hanau, Germany). The volume of each of these constructed swellings was calculated by dividing the weight of the artificial swelling by its density (1.60 g/cm^3).

The scanner

Three-dimensional scans were made with the 3dMD DSP400® stereo-optical 3-dimensional scanner by one observer who was proficient with the scanner. The 3dMD system uses a synchronised digital multicamera configuration, with 3 cameras on each side (1 colour, 2 infrared) that capture photorealistic quality pictures. The system can capture full facial images from ear to ear and under the chin in 2 ms at the highest resolution. The geometrical accuracy of the facial system used in the study as claimed by the manufacturer is < 0.2 mm.

Data capture technique

A custom-built studio was used with standard lighting conditions. The natural head position was used, as it is clinically reproducible.[23] The subjects sat on a self-adjustable chair and were asked to level their eyes horizontally, and the midline of the face was aligned towards the camera. The height of the seat was adjusted to assist the subjects in achieving natural head posture. To create a standard position for the head and jaws the subjects were instructed to swallow and to keep the jaws in a relaxed position while occluding gently during scanning. The total scan time was roughly 2 ms. Scans with and without the artificial swelling were taken on 2 occasions: in the morning and in the afternoon. After the subjects