Three-dimensional face morphometry

Márcio de Menezes*, Chiarella Sforza**

Facial anthropometry plays a key role in clinical assessments, providing an accurate diagnosis for different syndromes. Clinicians working with the head and face (maxillo-facial, plastic and aesthetic surgeons; orthodontists and prosthodontists) are the mostly interested in this three-dimensional information, being able to estimate the normal and abnormal growth, planning and evaluating surgical or orthodontic treatment, plastic surgeries and anthropometric studies.[1,6]

Currently, classic direct anthropometry is being replaced with various three-dimensional image (3D) analyzers, and the knowledge and application of this technology is essential for clinicians to analyze the information for planning and evaluating medical procedures and treatments.

Facial landmarks (previously marked on the face of the subject) represent the link between conventional and digital anthropometry[7]: conventional anthropometry identifies soft-tissue landmarks, and places some instrument (calipers, protractors) over them. Fundamentally, digital anthropometry collects a set of digital landmarks from the soft-tissue surface, and uses their spatial x, y, z coordinates as end-points for calculations based on Euclidean geometry: linear distances and angles. Together with these classic measurements, mathematics and geometrics allow the assessment of more complex characteristics from the same set of landmarks used by conventional anthropometry: estimations of volumes and surfaces, analyses of symmetry, and detailed assessments of shape.[2-5,8]

THREE-DIMENSIONAL MORPHOMETRY METHODS

Two main groups of instruments can be used for soft-tissue three-dimensional facial anthropometry: contact instruments (electromagnetic and electromechanical digitizers, ultrasound probes) and optical/non contact instruments (laser scanners, optoelectronic instruments, stereophotogrammetry, Moiré topography). All these instruments are not invasive and do not provoke pain or discomfort to the subjects. But both

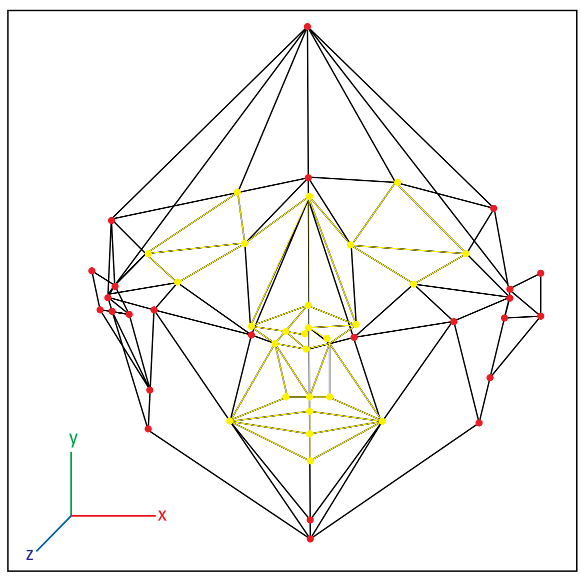

FIGURE 1 - Landmarks digitized by the electromagnetic three-dimensional tablet.

* Postgraduate student, Department of Human Morphology, University of Milan, Milano, Italy.
** Professor, Department of Human Morphology, University of Milan, Milano, Italy.

categories of instruments have advantages and limitations, which should be considered according to the investigated problem and the human resources.

An ideal method for the quantitative evaluation of the patients should combine:

- non-invasive;
- low-cost;
- a fast (simple data collection technique that provides three-dimensional digital data of the facial morphology);
- possibility to create a digital database;
- possibility to use computerized techniques for visualization, simulation and quantitative assessment of the treatment.

CONTACT INSTRUMENTS

Ultrasound probes, electromagnetic and electromechanic digitizers are among the most used contact instruments. The ultrasound method is widely used for prenatal, intrauterine imaging and diagnosis, and three-dimensional reconstructions of fetal face are becoming a current clinical practice. However its application for postnatal facial morphometry is limited and it's being used just to evaluate the facial soft tissue thickness. Electromagnetic and electromechanic digitizers provide the three-dimensional coordinates of landmarks that are previously marked on the face of the subject, which directly correspond to anatomical and anthropometric structures. The facial landmarks are digitized one by one using a stylus connected to the digitizer.[2,4,7]

Ultrasound probes use acoustic waves in the Megahertz frequency domain, while electromagnetic and electromechanic digitizers are based on electromagnetic waves. The main limitations of the instruments are the reduction of information obtained, and the data acquisition time, which is extremely long when compared to optical methods. Indeed, movements of facial muscles (in particular around mouth and eyes), as well as global head movements, may occur during digitization producing errors. The acquisition of only single, selected landmarks impedes to produce life-like facial models (Fig 1).

OPTICAL INSTRUMENTS

The optical instruments need no physical contact with the skin, thus eliminating the risk of cutaneous compression, and of potential injuries during measurements.

The instruments of this category are laser scanners and stereophotogrammetric systems. Laser scanners illuminate the face with a laser light source, and digital cameras capture the reflected light; the depth information is obtained by triangulation geometry.

Stereophotogrammetry uses a light source (either patterned or conventional) to illuminate the face, and two or more synchronized cameras record images from different points of view. A previous calibration, made with objects with known geometric characteristics, supplies the mathematical information to obtain a stereoscopic reconstruction of the face. The system can record also facial texture, and combines the three-dimensional information with an accurate reproduction of all facial characteristics (Fig 2, A and B).

Some methods using photogrammetric practices are also available for facial measurement as the Photomodeler system (Eos Systems Inc. Vancouver, British Columbia). This system uses similar techniques from stereoscopic images. Conventional pictures obtained from different angles are analyzed by a dedicated software, and the information is employed to work out the 3D measurements and geometric reconstructions of the face (Fig 3). In a recent study,[1] this system showed able to assess the coordinates of facial landmarks with satisfactory precision and can be used to obtain reliable facial measurements, identifying the major anthropometric landmarks. The method is relatively fast and inexpensive equipment is needed; thus it is simple for those in private practice, researchers, or other practitioners to use[1].

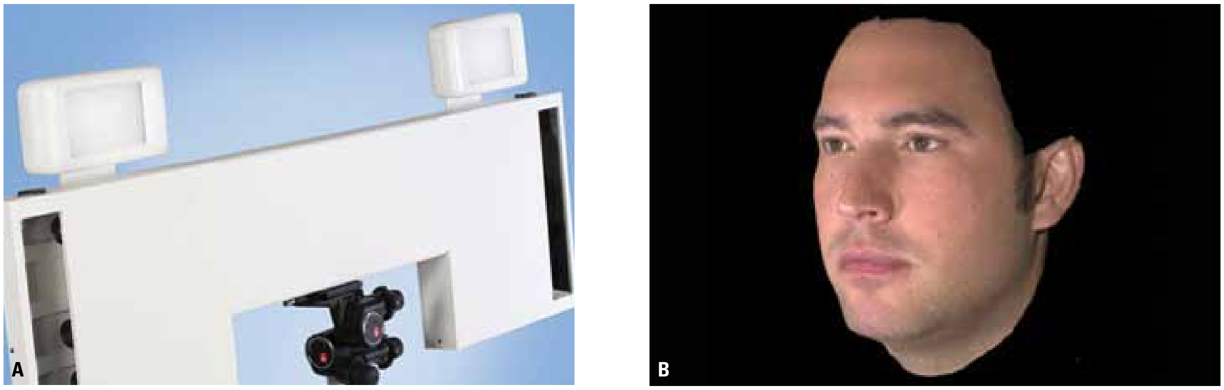

FIGURE 2 - **A**) Vectra-3D system, CanfieldScientific, Inc., Fairfield, NJ, USA. **B**) Facial image obtained with stereophotogrammetry system.

FIGURE 3 - Photogrammetry system (Photomodeler).

Different methods for 3D analysis are being developed and studied, but in general the elevate costs restrict the use in clinical practice.

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Contact address
Márcio de Menezes
Praça Cônego Joaquim Alves 79
CEP: 14.300-000 – Batatais / SP
E-mail: marcio.demenezes@unimi.it