Automated Landmark Extraction for Orthodontic Measurement of Faces Using the 3-Camera Photogrammetry Methodology

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**Objectives:** To set up a three-dimensional photogrammetric scanning system for precise landmark measurements, without any physical contact, using a low-cost and noninvasive digital photogrammetric solution, for supporting several necessary tasks in clinical orthodontics and/or surgery diagnosis.

**Materials and Methods:** Thirty coded targets were directly applied onto the subject’s face on the soft tissue landmarks, and then, 3 simultaneous photos were acquired using photogrammetry, at room light conditions. For comparison, a dummy head was digitized both with a photogrammetric technique and with the laser scanner Minolta Vivid 910 (Konica Minolta, Tokyo, Japan).

**Results:** The precise measurement of the landmarks is ranged between 0.017 and 0.029 mm. The system automatically measures spatial position of face landmarks, from which distances and angles can be obtained. The facial measurements were compared with those done using laser scanning and manual caliper. The adopted method gives higher precision than the others (0.022-mm mean value on points and 0.038-mm mean value on linear distances on a dummy head), is simple, and can be used easily as a standard routine.

**Conclusions:** The study demonstrated the validity of photogrammetry for accurate digitization of human face landmarks. This research points out the potential of this low-cost photogrammetry approach for medical digitization.

**Key Words:** Landmarks, facial morphology, photogrammetry, orthodontics


Landmarks are the primary anthropometric parameters for high-accuracy generation of face and head models. In fact, they can be used as input parameters for the interpolation functions to obtain, such as output, the full-face model with the accurate shape description of the face features, according to statistical properties. The aim was to facilitate a clinical diagnosis for orthodontic/surgical purposes based not only on absolute values (linear-angular distances related to a standard range of measurements) but also on relative values (angles, proportions, and changing surfaces) to make a three-dimensional soft tissue template that can be related to an average normal face, which is different for each population.

The landmark high relief points can be obtained in 3 main ways: (1) extraction from a three-dimensional virtual facial model (according to Kovacks et al, 9 Baik et al,4 and Winder et al7), (2) manual digitization onto the face (according to Sforza et al4), and (3) placement of targets on the subject’s face.7 To obtain a three-dimensional landmark face model (1) starting from a three-dimensional full surface face model, it is necessary to follow a specific measurement protocol.

On the three-dimensional faces models, the protocol illustrated in Baik et al4 is used. A consistent coordinate system is obtained starting from the nasion N as 0 point and establishing the axial referenced plane by rotating the Camper plane (right nasal ala– and both tragus points) 7.5 degrees upward on the axis formed by both tragus points. The sagittal reference plane passes through the soft tissue N and the midpoint of both tragus points; it is also perpendicular to the axial referenced plane. Finally, the coronal reference plane passes through N and is perpendicular to both the axial and sagittal reference planes (Fig. 1). Most landmarks used in this study were proposed by Farkas.8 Simply connecting the landmarks and then calibrating the size (height, width, and depth), it is possible to create a simplified three-dimensional facial landmark model; subsequently, it is necessary to carry out superimposition, to compare the landmark face model with the patient’s full surface face model,9 so as to verify the reliability of the information thus obtained.

As regards manual digitization onto the face (2), in a previous study on soft tissue facial shape based on manual digitizations, Ferrario et al4 reported that three-dimensional measurement values were not sensitive to head position. Nevertheless, a natural head position (NHP) is better exploitable: in fact, if the subject changes his position, the soft tissue attached to the bone will be stretched or constricted, and soft tissue draping could also be changed.4 Moreover, the NHP is considered the most reproducible head position, and it is the face’s natural orientation for treatment planning. In the Ferrario-Sforza method described in Sforza et al,4 a three-dimensional computerized electromagnetic contact digitizer (3 Draw, Polhemus, Colchester, VT) is used to collect 50 soft tissue landmarks previously individuated by an expert operator through direct inspection or palpation of the patient’s facial soft tissue.