A Quantitative Assessment of Lip Movements in Different Facial Expressions Through 3-Dimensional on 3-Dimensional Superimposition: A Cross-Sectional Study

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Purpose: The quantitative assessment of facial modifications from mimicry is of relevant interest for the rehabilitation of patients who can no longer produce facial expressions. This study investigated a novel application of 3-dimensional on 3-dimensional superimposition for facial mimicry.

Materials and Methods: This cross-sectional study was based on 10 men 30 to 40 years old who underwent stereophotogrammetry for neutral, happy, sad, and angry expressions. Registration of facial expressions on the neutral expression was performed. Root mean square (RMS) point-to-point distance in the labial area was calculated between each facial expression and the neutral one and was considered the main parameter for assessing facial modifications. In addition, effect size (Cohen *d*) was calculated to assess the effects of labial movements in relation to facial modifications.

Results: All participants were free from possible facial deformities, pathologies, or trauma that could affect facial mimicry. RMS values of facial areas differed significantly among facial expressions ($P = .0004$ by Friedman test). The widest modifications of the lips were observed in happy expressions (RMS, 4.06 mm; standard deviation [SD], 1.14 mm), with a statistically relevant difference compared with the sad (RMS, 1.42 mm; SD, 1.15 mm) and angry (RMS, 0.76 mm; SD, 0.45 mm) expressions. The effect size of labial versus total face movements was limited for happy and sad expressions and large for the angry expression.

Conclusion: This study found that a happy expression provides wider modifications of the lips than the other facial expressions and suggests a novel procedure for assessing regional changes from mimicry.

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Mimicry is a crucial function of interpersonal communication and with time has acquired increased importance in anatomic studies. Indeed, metric and morphologic assessment of faces showing different facial expressions has several applications in clinical medicine, such as the rehabilitation of patients affected by facial paralysis or traumatic lesions that might decrease or even cancel facial movements.[1,2] In addition, the assessment of facial mimicry is of interest in cases of parotidectomy in which sacrifice of the facial nerve hinders the production of facial expressions.[3,4] In all these cases, the standardization of parameters describing normal movements is important to assess the residual function in patients affected by limitations in facial mimicry and to evaluate the outcome of rehabilitation.

Within the face, mouth movements are of special interest, not only because most facial expressions (ie, smiling) use the lips and perioral region but also because possible alterations of this portion have esthetic consequences with clear difficulties in interpersonal relationships. For this reason, lip movements have been analyzed by the existing literature in depth: Rubin[5] first analyzed smiling movements and classified different anatomic smiles into 3 categories (corner-of-the-mouth or "Mona Lisa smile," canine smile, and full-denture smile). In addition, he observed that each type of smile occurs with an orderly and coordinated contraction of muscles of the lips and nasolabial folds.

Metric assessment of lip movements started from linear measurement, although often differences in experimental protocols prevented a complete comparison of results; for example, some researchers obtained measurements of facial images using rulers.[6,7] This approach has the disadvantage of considering facial movements in only 2 dimensions, whereas facial motion is reported by the literature as more extended in 3-dimensional (3D) than in 2-dimensional (2D) space. The mere analysis of 2D facial movements proved to underestimate 3D measurements by as much as 43%.[8]

An improvement in assessment was published by Linstrom et al[9] who applied a computer interactive system based on acquisition through a video camera, with the opportunity of measuring not only the linear displacement of landmarks but also the velocity of movement; however, full 3D visualization of facial movements could not be achieved because the system considered only movements on the *x*- and *y*-axes.[10] Attempts at considering 3D facial movements were performed by Frey et al[11] who applied a digital video camera with mirrors, which achieved a high accuracy in recording displacement of facial landmarks in 3 dimensions.

An important improvement to this research derived from the introduction of modern 3D image acquisition systems, such as stereophotogrammetry, that could acquire a 3D model of the face. Sawyer et al[10] analyzed smiling movements using stereophotogrammetry with a focus on the displacement of landmarks in 3 dimensions. However, the potential of stereophotogrammetry is not limited to classic studies of landmarks but allows researchers to perform more complex analyses of faces. An example is the possibility of superimposing models of the same individual to assess variations expressed as point-to-point distances.[12] This type of approach does not consider parceled movements divided into displacement of single landmarks, but rather analyzes the variations of the entire surface in comparison with a reference model, such as the 3D model of the face in a neutral position. This technique can provide additional data to the assessment of facial movements and could be an innovative method for assessing possible amelioration of mimicry performances in cases of facial reanimation, for example, by comparing the current model with a reference model from the beginning of the therapy. A first attempt focusing on the entire face was performed by the authors who verified relevant differences between smiling and open-mouth surprised expressions compared with sad and angry expressions.[12] However, a precise evaluation of labial movements in the smiling expression has not been performed.

This article continues the previous publication concerning the superimposition of facial expressions on the entire face and focuses on the labial movements to extract modifications of different expressions compared with the neutral expression. The authors hypothesized that labial modifications from facial mimicry could differ from changes affecting the entire face. The specific aims were to apply an innovative procedure for the registration and superimposition of 3D surfaces and to measure a metric parameter (root mean square [RMS]; point-to-point distance between 3D surfaces) as a possible marker for assessing facial movements. This could add information useful for a full comparison of this type of movement and the elaboration of methods for assessing ameliorations in patients affected by mimicry limitations.

Materials and Methods

STUDY DESIGN AND SAMPLE

To address the research purpose, the authors designed and implemented a cross-sectional study. To be included in the study sample, participants had to be adults and to have undergone facial stereophotogrammetry from 2014 through 2016. Exclusion criteria were possible facial deformities, pathologies, or signs of previous surgery or trauma that could affect facial mimicry. The chosen subjects represent the group analyzed in a previous publication focusing on the entire face.[12] This study followed the Declaration of Helsinki on medical protocol and ethics and local