Journal of Plastic, Reconstructive & Aesthetic Surgery (2018) 000, 1–14

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

# Quantitative dynamic analysis of the nasolabial complex using 3D motion capture: A normative data set

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Received 6 November 2017; accepted 26 May 2018
Available online xxx

**KEYWORDS**
Stereophotogrammetry;
Dynamic;
3D motion capture;
Normal;
4D;
Adult

**Summary**
*Introduction:* Smile reanimation should be considered from a dynamic perspective. Any intervention should restore normality. To date no such normative dynamic data has been published.
*Aim:* To quantitatively analyse maximal smiles between a healthy group of Caucasian male and female adults using 3D motion capture (4D stereophotogrammetry).
*Method:* Using a 3D facial motion capture system 54 males and 54 female volunteers were imaged whilst performing a maximal smile. Eight nasolabial landmarks were digitised and tracked. Differences in displacement and speed of bilateral landmarks between males and females were analysed in each direction (*x, y, z* and Euclidian), from rest ($T_0$), to median smile ($T_1$) and maximal smile ($T_2$), using paired *t*-tests and Wilcoxon-Signed Rank tests.
*Results:* In males and females the displacement and speed of the left and right alar base landmarks were similar in the *x* and *y* directions but less in the *z* direction. For the philtrum, the displacement and speed of the bilateral landmarks were similar in the *y* and *z* directions, but less in the *x* direction. The left alar base and left philtrum moved significantly more in

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https://doi.org/10.1016/j.bjps.2018.05.001


Please cite this article as: C.J. Lowney et al., Quantitative dynamic analysis of the nasolabial complex using 3D motion capture: A normative data set, Journal of Plastic, Reconstructive & Aesthetic Surgery (2018), https://doi.org/10.1016/j.bjps.2018.05.001

males. Left and right cheilion moved a similar amount in the *x* and *y* directions but more in the *z* direction. Labiale superius moved significantly more in the *z* direction, and labiale inferius moved significantly more in the *y* direction in males.
In conclusion, this study has presented a novel normative data set of dynamic nasolabial complex movement for males and females during maximum smile. The data, as well as providing magnitudes of displacements of the nasolabial complex, also provides the speeds of movement.


## Introduction

The human face is a complex and dynamic three-dimensional structure which is involved in verbal and non-verbal communication, identification, perception, creativity and sexuality.[1] Numerous facial muscles are responsible for the myriad of expressions that can be made including: joy, shock, fear and sadness. Diminished facial expression or facial paralysis has been shown to have a negative effect on an individual's psychological wellbeing and quality of life.[2]

Various surgical procedures are undertaken to restore function and re-establish facial dynamics. These include nerve repair and grafting,[3,4] cross-face nerve graft,[5] hypoglossal-nerve transfer,[6] masseter or temporalis muscle transposition[7] and free muscle flaps.[8] The outcome of the intervention is often assessed using subjective measures based on comparison with the patient's unaffected side. Two of these include House–Brackman facial grading system (HB FGS) [9] and the Sunnybrook Scale (SB FGS).[10] While many of the subjective grading systems are easy to use and inexpensive, the HB FGS is prone to inter-observer variability and may not be sensitive enough to detect clinically important changes over time or with treatment.[11] When assessed by 28 Doctors the HB FGS was found to have fair to good intra-rater reliability but poor to fair inter-rater agreement scores, whilst the SB FGS showed good to excellent intra-rater reliability and moderate to excellent inter-rater agreement scores. Voluntary movement was the most agreed on score for the SB FGS and the resting symmetry component the least agreed on between raters and within raters.[12] The same author, following a large scale study, concluded "the need for a more accurate facial grading system both in everyday clinical settings and for research purposes" is required.[13]

Reproducibility of a specific facial animation is a fundamental prerequisite to be able to assess whether an intervention has had a clinically significant effect. Recent studies have shown maximal smile to be the most reproducible facial expression in static[14] and dynamic function.[15] Even though reproducible, work by Rubin has shown that not all smiles are the same between individuals.[16] It has been suggested there should be co-ordinated contraction of the perioral muscles for a smile to be considered "normal".

Previous studies have quantitatively analysed normal smiles using 3D stereophotogrammetry to help in facial reanimation surgery.[17] All studies to date have assessed the magnitude of change in landmark positions at two discrete time points – rest position and maximum expression. 3D motion capture (4D stereophotogrammetry), unlike static 3D imaging is able to capture the rate of change of the smile, or the characteristics of the smile between rest and maximal expression.

Technological advances in the games and entertainment industry have recently been used to assess facial motion in a clinical environment. The technology has been used to assess changes in facial animation following orthognathic surgery, cleft lip and palate repair[18] and oncology access procedures.[19] The studies to date have assessed the result of the intervention, i.e. has the surgery improved (in cleft patients) or at least maintained (in oncology access patients) the pre-treatment situation with respect to facial dynamics. None have assessed whether the patients facial animation has returned to "normal". A previous study reporting 3D dynamic normative data was based on a small sample size and reported inter-landmark Euclidian distances rather than the *x*, *y* and *z* distances.[20] In addition another study used pre-placed large 4 mm retro-reflective markers to assess landmark displacement and a facebow protruding through the lips for head movement registration.[21] The large markers would make precise landmark identification difficult and the facebow may interfere with labial soft tissue movement. Both studies also only reported displacement of landmarks from rest to maximum expression; one could argue this could be carried out using two 3D images. The dynamic movement between these two time points, even though recorded was not analysed.

Therefore, the aim of this study is to quantitatively analyse dynamic smiles, from a spatial-temporal perspective, between a healthy group of Caucasian male and female adults, using 3D motion capture (4D stereophotogrammetry). This provides the potential to allow diagnosis, aid facial reanimation procedures and assess outcome. The null hypothesis is that there is no statistical difference in nasolabial movement between males and females both at maximum expression, and half way through the expression.

## Materials and methods

Ethical approval was granted by the Dental Research Ethics Committee (DREC) at the University of Leeds, U.K. (DREC reference 240915/BK/179).

### Sample size calculation

A clinically significant difference in landmark position between males and females was set at 2 mm.[22] The ex-

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