Reliability of a three-dimensional method for measuring facial animation: A case report

Carroll-Ann Trotman, BDS, MA, MS; M. Melissa Gross, PhD; Kelly Moffatt, BS

Facial animation forms the foundation for our instinctive emotional communications.[1,2] Individuals with functional impairment and/or facial disfigurement lose, to varying degrees, this vital, innate form of communication. To date, there have been several attempts to quantify facial function or animation in the form of two-dimensional linear and angular measurements and by studying facial expressions.[2-12] More recently, Frey and co-workers[16-17] conducted a three-dimensional analysis of facial expressions by means of a method similar to the one proposed in this study. The results of their study were promising; however, the reliability of this method was not characterized clearly. Therefore, the present case report was designed to assess the reliability of a three-dimensional method for measuring facial function by means of a set of repeated facial animations.

Materials and methods

Four subjects were enrolled in the study, and a series of facial animations was measured. The material and methods are fully described in the preceeding companion article.[18] The main intent of the study was to assess the reliability of: (1) marker positions between animations within a trial and with the patient at rest, (2) marker positions between sessions (markers removed and replaced) and with the patient at rest, and (3) assessments of facial function (based on landmark amplitude). Additionally, initial assessments of symmetry based on landmark amplitude were made. For all animations, the mean 3-D amplitude for each landmark was calculated according to the formula, $\sqrt{(X^2+Y^2+Z^2)}$, where X, Y, and Z represent change from rest position to maximum displacement of the landmark relative to a reference landmark.

Abstract

Reliable methods of quantifying functional impairment of the craniofacial region are sorely lacking. The purpose of this study was to test the reliability of a three-dimensional method for assessing the functional repertoire of the face. Subjects were instructed to perform repeated sequences of five maximal facial animations. Facial motions were captured by three 60-Hz video cameras, and three-dimensional maximum motion amplitudes were calculated. Student's t-test and Pearson product-moment correlation coefficients were used to test for significant differences between repetitions. The results show moderate to excellent reliability of the amplitude of motion for the landmarks over all animations. For each specific animation, certain landmarks demonstrated excellent reliability of motion.

Key Words

Facial animation • Three-dimensional • Reliability

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Table 1
Mean intratrial and intersession differences (mm) in marker position and correlation (r) of amplitudes (*P<0.05)

	Intratrial comparison						Intersession comparison						Within-session	
Marker	3-D difference in mean amplitude relative to NT			3-D difference in mean amplitude relative to LC			3-D difference in mean amplitude relative to NT			3-D Difference in mean amplitude relative to LC			Correlations	
	Mean	SE	t	Mean	SE	t	Mean	SE	t	Mean	SE	t	r	t
RSO	0.6	1.8	.35	0.1	.9	.11	0.3	2.6	0.13	-0.9	3.1	-.29	0.92 *	2.11
LSO	0.4	2.0	.22	-0.1	1.5	-.09	-0.5	1.8	-0.30	-7.2	9.2	-.78	0.81 *	0.78
RC	-0.1	3.7	-.03	0.1	1.9	.04	-1.5	4.1	-0.37	-4.2	4.5	-.93	-	-
LC	0.1	3.5	.02	0.0	0.0	0.0	-1.0	5.3	-1.89	0.0	0.0	0.0	-	-
RIO	-0.2	1.8	-.11	0.1	1.6	.04	-2.2	2.0	-1.13	-0.6	3.1	-.19	0.89 *	1.35
LIO	0.0	3.2	.00	0.7	1.2	.58	-0.8	3.0	-0.26	-7.8	0.9	-.89	0.64 *	1.77
RA	1.3	1.5	.88	0.6	4.3	.13	-1.7	2.7	-0.61	-5.3	5.4	-.97	0.84 *	1.37
LA	-0.3	2.0	-.14	-0.2	0.2	-.07	-2.7	2.5	-1.08	-5.6	4.1	-1.34	0.66 *	1.42
RCB	-0.5	2.1	-.24	3.8	4.4	.87	1.1	2.1	0.53	-3.3	6.1	-.54	0.82 *	0.45
LCB	0.0	1.4	.03	0.2	3.3	.46	-2.2	2.7	-0.82	-4.6	4.5	-1.03	0.58 *	-1.54
RCO	-0.6	2.9	-.20	0.3	8.2	.03	0.1	2.4	0.03	7.9	5.7	1.39	0.76 *	-0.01
LCO	-0.1	1.5	-.05	1.0	2.4	.41	0.4	1.6	-0.24	-5.0	5.2	-.96	0.86 *	0.51
COL	-5.8	6.0	-.97	2.9	2.5	1.15	-3.1	4.9	-0.62	-5.7	5.5	-1.04	0.97 *	0.78
CH	1.6	2.4	.67	2.1	2.8	.76	1.4	2.5	0.55	-4.7	2.5	-1.88	0.56 *	1.89

For each patient, in order to estimate the stability of marker position at rest, the position of each landmark in the first frame of the first animation within a trial was compared with the position of that landmark in the corresponding first frame of the last animation. The reliability of marker placement (with the patient at rest and between sessions) was estimated by comparing the position of each landmark as seen in the first frame of the first animation with the position of that landmark in the corresponding first frame and animation after the markers had been removed and replaced. (We reasoned that the first frames of each animation would represent the position of the various landmarks at rest.) All 3-dimensional position measurements were made relative to the nasal tip (NT) and left canthal (LC) markers.

To assess the reliability of the assessment of facial function, mean amplitudes of the landmark displacement in the second and third trials for each patient were compared within a session. The mean amplitude of each landmark was calculated relative to facial landmarks for which evidence of stability could be inferred from computer generated plots of displacement versus time for all landmarks. Based on these plots and the distances between the left canthal (LC), right canthal (RC), and nasal tip (NT) markers (variation in the distance between LC and RC, mean variation = 0.4 mm, SD = 0.2mm; variation in the distance between RC and NT, mean variation = 0.6 mm, SD = 0.6 mm; and variation in the distance between LC and NT, mean variation = 0.5 mm, SD = 0.3 mm), these three markers were assumed to be reasonably stable over the entire animation sequence.

Statistics

Pearson product-moment correlation coefficients of the within-session amplitudes for each landmark were generated to assess reliability of facial function. Student's *t*-tests were used to test for significant ($P<0.05$) within-trial and between-sessions differences in marker position, and differences in animation amplitude between trials.

Findings and Discussion

The mean intratrial differences (Table 1) in landmark rest-position ranged from -5.8 mm to 1.6 mm when these distances were calculated relative to the nasal tip (NT) marker, and -0.2 mm to 2.9 mm relative to the left canthal (LC) marker. These minimal differences in marker position within a trial sequence suggest the ability of patients to return to rest position after each animation.

The mean intersession (markers removed and replaced) differences (Table 1) in landmark rest position were greater than the intratrial differences. Also, these differences were of a greater magnitude when measured to the left canthal (LC) marker than to the nasal tip (NT) marker (relative to LC, range = -7.8 mm to 7.9 mm; and relative to NT, range = -3.1 to 1.4 mm). Thus differences were much greater when the markers were removed and replaced, suggesting a greater combined error resulting from both repositioning markers and soft tissue hysteresis.

The correlations between test-retest amplitudes of the landmarks (Table 1) were all significantly greater than zero ($r=0.56$, chin marker-CH; $r=0.97$, columella base point-COL). When these correlations were determined for each animation separately, the following results were noted: cheek puff animation, the nasal or alar rim ($r=0.98$), infraorbital ($r=0.92$), and lateral-lip ($r=0.90$) regions were significantly correlated; grimace animation, the columella base point ($r=0.99$), supraorbital ($r=0.93$), and alar rim ($r=0.97$) regions were significantly correlated; eye closure animation, the supraorbital ($r=0.76$) and middle-lip regions ($r=0.96$) were significantly correlated; and for the smile animation, the chin region ($r=0.99$) was significantly correlated. Thus, each animation had specific landmarks that were particularly sensitive to motion. Frey et al.[17] noted a difference of 1 mm for amplitudes between repeated animations, suggesting a very high overall reliability; however, in our sample we were not able to demonstrate this type of generalized reliability. Finally, the correlations of the amplitudes between the right and left paired landmarks were all significantly different from zero, and ranged from $r=0.64$ to 0.96.

In summary, given the small sample size, we are encouraged by the reliability results for this method of quantifying facial function, and because this method is potentially applicable to patients with a wide range of craniofacial functional problems, further studies are warranted.

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Author Address

Dr. Carroll-Ann Trotman
Assistant Professor
Department of Orthodontics and
Pediatric Dentistry
The University of Michigan
1011 North University Ave.
Ann Arbor, MI 48109-1078

C-A. Trotman, assistant professor, Department of Orthodontics and Pediatric Dentistry, University of Michigan, Ann Arbor, Michigan.

M. Gross, assistant professor, Department of Movement Science and Institute of Gerontology, University of Michigan, Ann Arbor, Michigan.

K. Moffatt, engineering student, Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, Michigan.

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