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Research paper

Three-dimensional analysis of lower lip movement during articulation in subjects with mandibular prognathism

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ABSTRACT

Objective: The aim of this study was to investigate lower lip movement during articulatory tasks using a three-dimensional video-based system in subjects with mandibular prognathism.

Materials and methods: Ten subjects with mandibular prognathism (mean age: 25.4 years) and 20 volunteers (mean age: 27.8 years) participated in the study. The target sounds used were five vowels (/a/, /i/, /u/, /e/ and /o/). The motion of black foam balls placed on four canthal points and four lip points was tracked using two video cameras with a three-dimensional analysis system for animated images. After three-dimensional coordinates were established using the canthal points to correct head motion, lip movement was measured with reference to the coordinates. The standardized trajectory for each point was computed. By comparing the standardized trajectories, differences in lower lip movement between subjects and controls were examined. The Mann–Whitney *U*-test was used to determine the differences in the maximum displacement of movement between the groups.

Results: The results showed that (1) the trajectory of lower lip movement in subjects differed to some extent in all vowels and (2) there were significant differences in the amount of lower lip movement between subjects and controls.

Conclusions: These results suggest that (1) lower lip movement during articulation was affected in subjects with mandibular prognathism and (2) the present method is feasible for the clinical three-dimensional analysis of lower lip movement.

1. Introduction

Impaired oral function such as misarticulation has a major impact in subjects with mandibular prognathism besides malocclusion and facial disharmony [1]. Consequently, orthodontists are concerned with both facial balance and oral function in these subjects in the course of orthodontic treatment combined with orthognathic surgery. The facial disharmony in subjects with mandibular prognathism has been analyzed with reference to the lip position using facial photographs [2] and to the oronasal position using photographic cephalometric radiographs [3–6].

Impaired oral function may result from morphological (e.g., malocclusion, maxillomandibular discrepancy) and motor (e.g., tongue [7,8], lips, mandible [9,10]) problems. Lip movement is associated with facial expression and articulation.

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With regard to facial expression, movements of several landmarks during emotional expressions (e.g., smile, lip-pursing, grimace, eye closure, cheek-puff) [11–21] in subjects with cleft lip and palate (CLP), and those with neuroparalysis have been reported. Facial expression is associated with soft-tissue movement that accompanies emotion. Moreover, fine and rapid changes in various facial muscles are integrated to produce facial expression. For these reasons, it is difficult to exactly repeat a given facial expression and to accurately evaluate such expression in an artificial setting. On the other hand, there have been many studies on lip movement during articulation. Muraoka et al. analyzed the changes among midpoints of the upper and lower lips and bilateral commissural points in healthy adults [22]. They found that several perioral muscles were active during articulation [22]. On the other hand, Rutjens et al. reported angular changes in the lips in subjects with CLP [23]. Thus, a task related to articulation is easier to repeat identically and accurately than a task accompanied by facial expression. However, no previous studies have evaluated lip movement during articulation in subjects with mandibular prognathism.

In our previous study [24], we introduced a newly developed three-dimensional system for analyzing lip movement using a video-based tracking technique. The purpose of this study was to investigate lower lip movement in association with vowels using this system in subjects with mandibular prognathism. Thus, we compared the trajectories and maximum displacements of several landmarks between subjects with and without mandibular prognathism.

2. Materials and methods

2.1. Subjects

The patient group (PG) consisted of 10 adults with mandibular prognathism (9 males and 1 female, mean age: 25.4 years, range: 19–28 years), who visited the Orthodontic Clinic at Tokyo Medical and Dental University Dental Hospital. They had been diagnosed to undergo orthognathic surgery. The inclusion criteria for the PG were (1) no history of congenital facial and/or oral malformation (e.g. craniofacial anomalies, syndromes or clefting), (2) no facial asymmetry, and (3) no previous trauma in the face. Cephalometric variables in our sample are shown in Table 1. The control group (CG) consisted of 20 healthy adults (11 males and 9 females, mean age: 27.8 years, range: 24–31 years), who were recruited from staff members of Maxillofacial Orthognathics, Graduate School, Tokyo Medical and Dental University. The inclusion criteria for the CG were (1) no morphological and functional problems, (2) normal occlusion, and (3) no skeletal deformities. This study was in accordance with the Declaration of Helsinki.

2.2. Analyzing system

A video-based tracking system [24] was used to record facial movements of subjects in both the PG and CG. This system tracks black foam polystyrene markers (diameter: 10 mm) attached to eight specific landmarks on the face with a point contact (Fig. 1). Four immobile landmarks on the canthus (bilateral mesial and distal canthal points) were used to correct for head movement. Four landmarks on the lips (bilateral commissural points and midpoints of the upper and lower lips) were used to track lip movement. The hardware consisted of two digital video cameras (DEJIMO VCC-277, Osaka, Japan) and a three-dimensional analysis system for animated images (DEJIMO D4202-01-T, Osaka, Japan). Two video cameras were symmetrically located 70 cm from the subject and at a 45° angle from the midline of the subject (Fig. 2).

Table 1 – Cephalometric variables of the patient group

	Males ($n = 9$)		
	Pre-surgery	Japanese standard [25]	
	Mean	Mean	S.D.
SNA (°)	71.25	81.82	3.09
SNB (°)	83.54	78.61	3.14
A–B plane angle (°)	3.89	−5.10	3.28
Mandibular plane angle (°)	31.04	26.25	6.34
U1 to FH plane (°)	112.91	108.94	5.62
L1 to Mandibular plane angle (°)	85.51	94.67	7.21
Females ($n = 1$)			
SNA (°)	78.98	82.32	3.45
SNB (°)	78.75	78.90	3.45
A-B plane angle (°)	0.84	−4.81	3.50
Mandibular plane angle (°)	40.61	28.81	5.23
U1 to FH plane (°)	106.43	111.3	5.54
L1 to Mandibular plane angle (°)	83.3	96.33	5.78

S.D.: standard deviation.

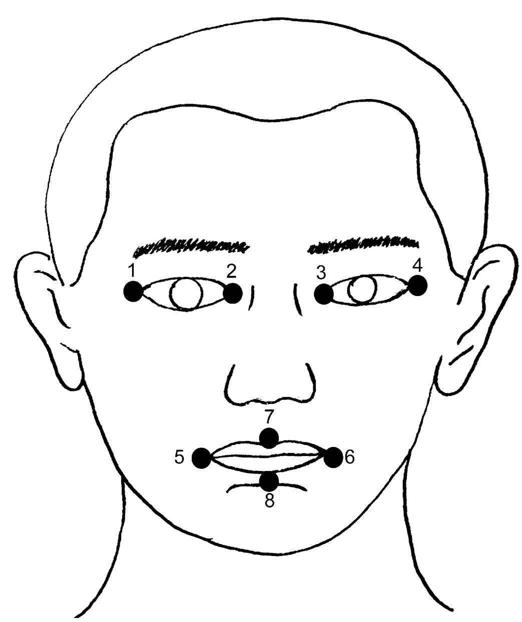

Fig. 1 – Facial landmarks: 1, right distal canthal point; 2, right medial canthal point; 3, left distal canthal point; 4, left medial canthal point; 5, right commissural point; 6, left commissural point; 7, midpoint of the upper lip; 8, midpoint of the lower lip.