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# Gender differences in posed smiles using principal component analysis

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ABSTRACT

*Objectives:* The purpose of this study was to clarify gender differences in posed smiles using principal component analysis (PCA).
*Materials and methods:* Fourteen adult volunteers, 7 males and 7 females, were enrolled. Using the motion analyzing system we developed, range images and 5 × 5 virtual grids were produced across the whole sequence while the volunteers were asked to smile. Two sets of all intersections of the virtual grids captured while the subject was smiling were regarded as PCA variables. Discriminate analysis was then applied to compare the males and females.
*Results:* The first and second principal component scores (PCSs) were plotted on the x-axis and y-axis, respectively. The center of gravity of the PCSs is shown by the plus on the x-axis and minus on the y-axis for the males and by the minus on the x-axis and the plus on the y-axis for the females. Discriminate analyses of the PCSs revealed a correct gender classification rate of 74.4% for posed smiles.
*Conclusions:* While the sample size is too small to extrapolate from these results, we can conclude that PCA can be used to identify gender differences while smiling.


## 1. Introduction

A nice smile is extremely important to people. Therefore, improving the smile is an important goal of orthodontic treatment (Meyer et al., 2014) and an important outcome of maxillofacial surgery (Popat et al., 2012a). To analyze smiles, both qualitative and quantitative methods are indispensable. If we can determine parameters to analyze that reflect the characteristics of a good smile, quantitative approaches would become more dominant. In other words, if characteristics associated with a balanced smile or healthy smile, or if characteristics that would allow gender differentiation could be identified, significant progress could be made in the study of facial expressions. Several recent articles have discussed the use of principal component analysis (PCA) for this purpose (Valentin et al., 1997; Popat et al., 2010).

On the other hand, there have been reports that both spontaneous smiles (Van der Geld et al., 2007) and posed smiles (Ackerman et al., 1998) could be measured reproducibly. In our previous article, both the three-dimensional intra-rater reliability and the inter-rater reliability of measurements taken for a posed smile were considered to be relatively high, and sufficient reliability could be expected by calculating the average of values measured twice (Mishima et al., 2014).

Therefore, in the present study, PCA was applied to two sets of data for a posed smile, and gender differences were analyzed.

## 2. Materials and methods

### 2.1. Subjects

Fourteen adult volunteers (7 males aged 24–34 and 7 females aged 24–29 years) who had no medical history related to lip movement were enrolled. The subjects were seated with no fixation of their heads. First they were asked to speak five Japanese vowels and to open their mouth wide. Then, they were asked to smile, and their lip motion was measured twice while smiling.

This research was approved by the Institutional Review Board of Yamaguchi University Hospital.

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### 2.2. Production of range images

Motion images obtained by three infrared digital video cameras (IR camera, Sony XC-E150, Tokyo) and one color digital video camera (Sony DXC-390, Tokyo), controlled by a synchronizing signal generator (Imagenics SG-701, Tokyo), were recorded with an infrared pattern projected onto the face at a sampling rate of 30 frames per second. These image sequences were captured directly on a personal computer via IEEE1394. Each frame was digitized at a horizontal and vertical resolution of 720 × 480 pixels.

The computer programs described below were based on 3D Video™ software developed by OGIS Research Institute Co. Ltd. (Osaka), but were improved for the needs of this specific application. The image processing has been described in detail in a previous article (Mishima et al., 2006) and is explained briefly here. The intrinsic and extrinsic parameters for the four cameras, 1 color and 3 IR, were obtained using a known object, which was a cube in which a checkerboard was printed. An infrared pattern was projected and the images were recorded through three IR cameras. To find a match, two different techniques, a multiple-baseline stereo technique (Okutomi and Kanade, 1991) and a template-matching technique (Tamura, 2002), were applied. After stereo-matching, the disparity was then calculated, and a range image was produced across the whole image sequences.

The subjects' heads were not fixed in order not to disturb spontaneous movements of the face. The movement of the head during recording was canceled using a sun visor on which a checkerboard pattern was printed, and which was worn on the head. The intersections of the checkerboard pattern were automatically tracked across image sequences by applying the Lucas-Kanade algorithm (Lucas and Kanade, 1981). The head position was compensated for as follows: the distances between designated immobile points from one frame to the next would be minimized using a least-squares method within the constraints of the orthogonal matrix.

### 2.3. Analysis of lip motion

The lips were divided into eight areas, which consisted of four areas in the upper white lip and four areas in the upper and lower vermilions. Each area consisted of 15 straight lines connecting ten landmarks and three Bezier curves. In these eight areas, the following 5 × 5 virtual grids were produced (Fig. 1). A three-dimensional curved line on the range image was divided into several segments. The divided points were projected in two dimensions (XY planes), and intersections between these gridlines were produced. The intersections were projected perspectively onto the curved surfaces of the range images, and the three-dimensional coordinates of these intersections were computed.

Lip motions when making a posed smile were analyzed using PCA. The program was based on Body Shape Browser™ (Ergovision, Osaka) and customized for the needs of this specific application. Before PCA, distances between both mouth corners at rest were normalized for all subjects. Two sets of three-dimensional coordinates of all intersections of the virtual grid were regarded as variables of PCA for all frames from the starting to the end frame while making a posed smile. The first to the 12th principal component scores (PCSs) were then calculated. Lip configurations corresponding to specific PCSs could be observed by adjusting each PCS available in the present program using a sliding scale. The relationship between lip configurations and the PCSs were investigated. It was found that the first and second scores were parameters that almost completely described anterior-posterior movement and superior-inferior movement of the lips, respectively (Fig. 2). Therefore, the first and second scores were plotted (first on the x-axis and second on the y-axis), and discriminate analysis was then applied to compare the difference in the posed smiles of males and females (IBM SPSS ver. 22).

## 3. Results

The PCSs plotted in two dimensions (first PCS on the x-axis and second PCS on the y-axis) are shown in Fig. 3. The center of gravity of the PCSs is shown by the plus sign on the x-axis and by a minus sign on the y-axis for the males, and by a minus sign on the x-axis and a plus sign on the y-axis for the females.

Discriminate analysis of the points (PCSs) plotted in two dimensions for the male and female subjects revealed that Wilk's lambda and significant probability were 0.676 and 0.000, respectively, and that the measurements were able to correctly discriminate males and females for 74.4% of the posed smiles.

## 4. Discussion

In studies on smiles, two types of smiles, a spontaneous smile and a posed smile, are often described. Ackerman et al. (1998) have stated that a posed smile can be repeated reliably. On the other hand, Van der Geld et al. (2007) reported that the reproducibility of a spontaneous smile is also high, and indicated that a spontaneous smile is a person's authentic smile expression. However, until now there have been no reports comparing the reproducibility of a spontaneous smile and a posed smile using the same measurement

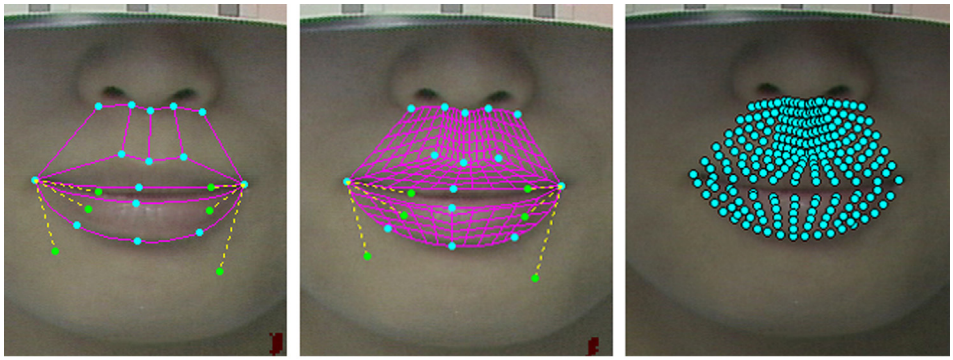


**Fig. 1.** Eight areas and virtual grids applied to the lip. Grids (5 × 5) were applied to eight areas, as determined by ten landmarks and Bezier curved lines (a). Two sets of three-dimensional coordinates of the virtual grid intersections were utilized for PCA (b). Blue dots indicate the intersections of the virtual grid (c).