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An ultrasound investigation of the lip levator musculature

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SUMMARY The aims of this study were to determine if there were any differences in the thickness of the lip levator musculature in men and women, and whether the height of the smile line in adults was related to the thickness of the lip levator musculature. Thirty Caucasian (13 males, 17 females), and 24 Asian (11 males, 13 females) undergraduate dental students participated in this study. The subjects were placed in high, medium, and low smile-line groups, according to the height of their upper lip while smiling. The thickness of the levator labii superioris and zygomaticus major muscles was measured on ultrasound scans of the relaxed muscles. Gender, right–left side, and ethnic differences in muscle thickness were determined, and the thicknesses of the lip levator musculature in subjects in the high, medium, and low smile-line groups were compared.

There were significantly more women than men with high smile-lines and the zygomaticus major muscle was significantly thicker in the women, as compared with the men. There were, however, no statistically significant differences in muscle thickness in the three smile-line groups. While it appears that women have higher smile-lines and significantly thicker zygomaticus major muscles than men, the height of the smile line is not due to the thickness of either the levator labii superioris or zygomaticus major muscles.

Introduction

A high smile-line has been defined as a smile where the upper lip retracts to display a continuous band of gingivae above the maxillary anterior teeth (Tjan *et al.*, 1984). Some clinicians have expressed the opinion that such a smile is unattractive (Hulsey, 1970; Singer, 1974; Janzen, 1977), but others disagree (Crawford, 1991; Peck *et al.*, 1992a). Women are reported to have higher smile-lines than men (Tjan *et al.*, 1984; Rigsbee *et al.*, 1988; Peck *et al.*, 1992b).

It has been suggested that differences in the height of a smile may be due, in part, to differences in the morphology of the lip levator musculature (Rubin, 1974; Rigsbee *et al.*, 1988) and, in particular, to a greater 'muscular capacity' to raise the upper lip (Peck *et al.*, 1992a). The muscles primarily responsible for elevating the upper lip are the levator labii superioris and the zygomaticus major muscles (Burkitt and Lightoller, 1925, 1927; Lightoller, 1925; Rubin, 1974, 1989; Nairn, 1975; Delaire, 1978). In the past, the morphology of these muscles has been based on studies of cadaver preparations. However, imaging with ultrasound will enable muscle thickness, which has been shown to be related to the tension developed in a muscle during contraction (Ikai and Fukunaga, 1970; Åstrand and Rodahl, 1986), to be determined in live subjects.

The aims of this study were to determine if there were differences in the thickness of the lip levator musculature in men and women, and whether the height of the clinical smile-line in adult subjects is related to the relaxed thickness of the lip levator musculature.

Subjects and methods

Ethical approval for this investigation was obtained from the Southern Regional Health Authority, Dunedin. The subjects in this study were 24 male and 30 female undergraduate dental students attending the School of Dentistry, University of Otago in 1996. The mean age of the males was 21.0 years (range 18–24 years) and for the females 21.2 years (range 19–23 years). There were 30 Caucasian subjects (13 males,

Table 1 Details of the sample.

		Number	Age (years)		Orthodontic intervention	
			Mean	SD	Yes	No
Caucasian	Male	13	21.3	1.3	6	7
	Female	17	21.4	0.9	7	10
Sub-total		30	21.3	1.1	13	17
Asian	Male	11	20.7	1.7	5	6
	Female	13	21.0	1.0	7	6
Sub-total		24	20.9	1.4	12	12
Combined	Male	24	21.0	1.5	11	13
	Female	30	21.2	1.0	14	16
Sub-total		54	21.1	1.2	25	29

17 females) and 24 Asian subjects (11 males, 13 females). Twenty-five subjects gave a history of previous orthodontic treatment. The details of the sample are given in Table 1.

Smile-line assessment

Three standardized frontal facial photographs (35 mm transparencies) were taken of each subject while seated. A millimetre scale, positioned to the right side of the head and in the same plane as the upper lip, was included in all photographs. In the first and last photographs the subjects were smiling to the maximum extent, while in the second photograph the subjects were relaxed with the mandible in the rest position. The subjects rehearsed smiling before the photographs were taken.

For each subject the transparency showing the highest smile-line was selected. The selected transparencies were arranged in a random order, projected under standardized conditions, and the height of the smile-line assessed according to the following criteria adapted from Tjan *et al.* (1984):

1. *High smile-line*: when a continuous band of gingival tissue above the maxillary anterior teeth was visible on at least one side of the mouth.
2. *Medium smile-line*: when 75–100 per cent of the maxillary anterior teeth and the interproximal gingivae only were visible on at least one side of the mouth.
3. *Low smile-line*: when less than 75 per cent of the maxillary anterior teeth were visible on at least one side of the mouth.

The transparencies were assessed on successive days by one author (RWM) and there were nine disagreements. The disagreements were assessed for a third time and the majority decision was used.

Ultrasound procedures

The ultrasound scanner used in this study was a real-time B-Mode scanner (General Electric RT 2800, Milwaukee, Wisconsin) with a 7.5 MHz linear array probe with a footprint of 27 × 82 mm. Hard copies were made at the time of examination on thermal paper using a FT 1210 printer (Fuji, Tokyo, Japan). A stand-off device was used to obtain optimal imaging in the region of interest. The position lines for imaging both muscles were established after inspection of cadaver preparations and from published anatomical descriptions. Each levator labii superioris muscle was imaged by placing the probe along a line starting beside the alar cartilage of the nose and running up to the pupil of the eye on the side being examined. To image each zygomaticus major muscle the zygomatic buttress was located by palpation and the probe orientated along the line running from the commissure of the mouth to the zygomatic buttress (Figure 1). All subjects were supine during scanning.

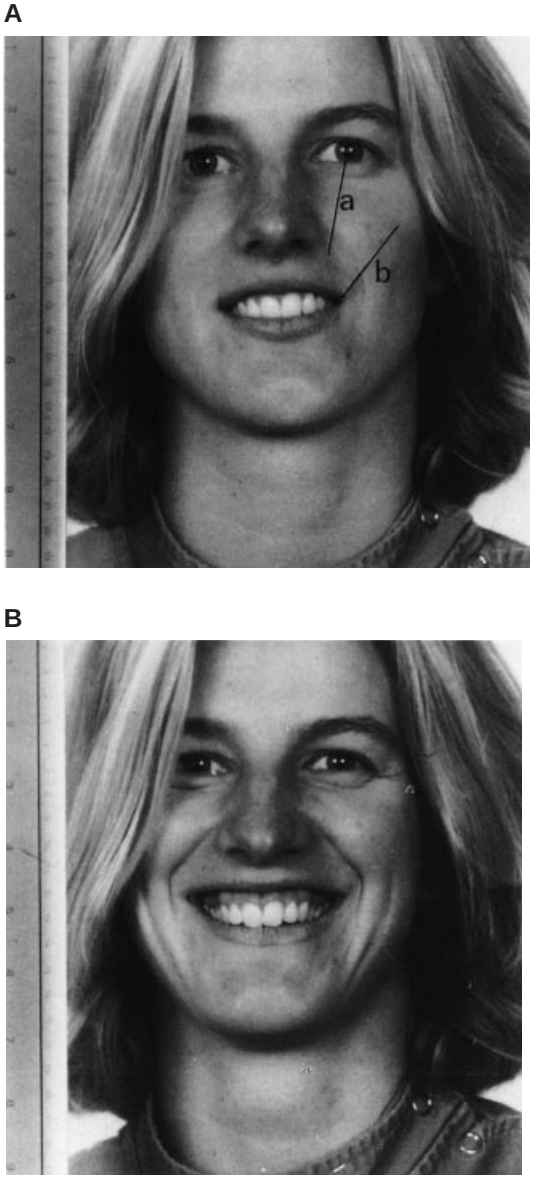

Figure 1 Standardized photographs of a subject. (A) The position lines are marked for scanning of (a) levator labii superioris muscle, and (b) zygomaticus major muscle. (B) A subject with a 'high' smile-line.

A water-based gel was applied to the probe, and to a 7 mm thick flexible stand-off medium, to enable acoustic coupling. The stand-off medium was used to bring the scanner focus up to the level of the levator musculature. During each examination the transducer was held perpendicular to the surface of the skin along each position line. In each subject the relaxed right and left levator labii superioris muscles, and the relaxed right and left zygomaticus major muscles were scanned. The resulting images are cross-sections of the soft tissues between the skin and the underlying bone (Figures 2 and 3).

The thickness of each muscle was measured directly on the hard copies by marking the superficial and deep aspects of the muscle concerned with transparent sheets scribed with fine crossed lines. Each landmark was digitized three times with a reflex metrograph (Scott, 1981), after lifting and replacing the mylar sheets over the landmarks. The mean of the three digitizations was used to calculate the thickness of each muscle in millimetres. The levator labii superioris muscle (LLS) was measured above the canine fossa, while the zygomaticus major muscle (ZM) was measured at its maximum thickness. Both muscles were measured perpendicular to the underlying bone. All images were reduced to 73.5 per cent of the true size by the imager, and the measurements given were corrected to true values.

Statistical analysis

A χ^2 test was used to determine if there were statistically significant differences in the distributions of the smile-lines in the men and women, and in those subjects who had received orthodontic treatment and those who had not received treatment. The thickness of the muscles on the right and left sides was compared with paired *t*-tests, and unpaired *t*-tests were used to test for gender differences in muscle thickness. An analysis of variance and unpaired *t*-tests were used to determine if statistically significant differences in muscle thickness existed between the groups with high, medium, and low smile-lines. The combined errors in imaging and measurement were investigated by scanning a female subject 10 times and repeating the scans 45 minutes later. Short breaks were taken between each scan. The error in the method of measurement was investigated by redigitizing the ultrasound scans of 20 randomly selected subjects. Dahlberg's (1940) formula was used to calculate the errors between the repeated scans of the same

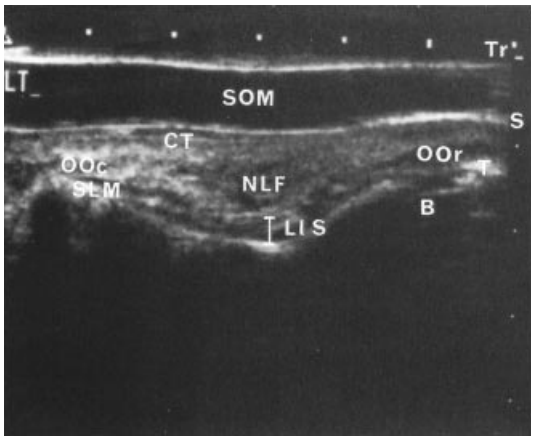

Figure 2 An ultrasound image of the left lip levator musculature with the transducer positioned along line (a) in Figure 1. Tr: transducer; SOM: stand-off medium; S: skin; CT: connective tissue superficial to the muscle; NLF: nasolabial fold; OOc: orbicularis oculi muscle; SLM: superficial levator musculature; LLS: levator labii superioris; OOr: orbicularis oris muscle; T: teeth; B: bone. The superficial musculature consists of the zygomaticus minor and levator labii superioris alaeque nasi muscles.

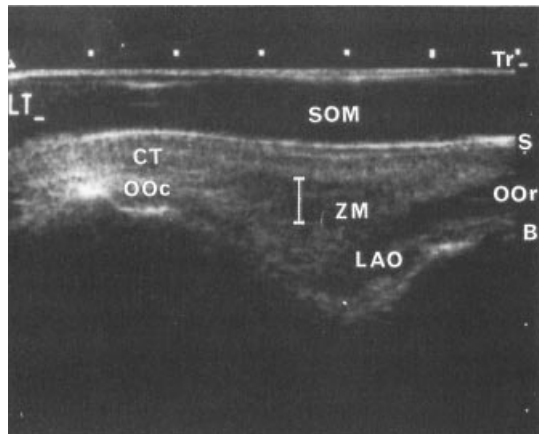

Figure 3 An ultrasound image of the left lip levator musculature with the transducer positioned along line (b) in Figure 1. Tr: transducer; SOM: stand-off medium; S: skin; CT: connective tissue superficial to the muscle; ZM: zygomaticus major muscle; OOc: orbicularis oculi muscle; LAO: levator anguli oris muscle; OOr: orbicularis oris muscle; B: bone.

subject, and the initial and repeat measurements for the 20 subjects.

Results

Examination of the images on the scanner and the hard copies showed that although images of the muscles were of variable quality, each muscle had a consistent relationship to adjacent muscles, the underlying bone and teeth, and the overlying skin. On the hard copies the superficial aspect of the levator labii superioris muscle was identified by the difference in density between the muscle and fascia, and on its deep aspect by differences in density between the muscle and bone. Dense structures appeared as white, often broken, lines and the connective tissue between the muscles and the skin had a speckled appearance.

The levator labii superioris muscle lay immediately superficial to the bone, and appeared as a clear image of approximately even thickness along its entire length. It was generally streaked by a variable number of broken lines of differing opacity and thickness. Superficial to the levator labii superioris, the zygomaticus minor, and levator labii superioris alaeque nasi muscles appeared as distinct fibre groups of varying thickness. The nasolabial fold, which is continuous with the orbicularis oris muscle, appeared as an oval image between the levator muscles and the skin. Teeth appeared as irregular opaque objects deep to the orbicularis oris muscle (Figure 2).

The borders of the zygomaticus major muscles were identified by differences in density between muscle and the surrounding connective tissue. The zygomaticus major muscle was roughly oval in shape, and located approximately mid-way between the skin and underlying bone. The levator anguli oris, which appeared as a sinusoidal-shaped image continuous with the orbicularis oris muscle, lay immediately superficial to the canine fossa, and below the zygomaticus major muscle. The orbicularis oculi muscle, which appeared as a thin crescent-shaped image, lay superficial to the zygomatic buttress (Figure 3).

The measurement errors in the 20 scans measured twice were 0.42 mm for the levator labii superioris, and 0.55 mm for the zygomaticus major muscle. The combined errors in the repeated scans of the same subject were 0.42 and

Table 2 Comparison of the smile-line in the treated and non-treated groups.

	Smile-line	Orthodontic intervention		
		Yes	No	*P*
Men	High	1	2	0.426
	Medium	7	10	
	Low	3	1	
Women	High	5	8	0.431
	Medium	9	8	
	Low	0	0	

0.44 mm for the levator labii superioris and zygomaticus major muscles, respectively. Because there were no significant right–left side differences in the thickness of either muscle, it was possible to enhance the accuracy of the method by using the means of the two sides in all calculations. The mean differences between right and left sides expressed as percentages of the means of both sides were 4.6 per cent for the levator labii superioris, and 1.1 per cent for the zygomaticus major muscle. These method errors compare favourably with the those reported by Kiliaridis and Kalebo (1991) and Raadsheer *et al*. (1994) for masseter muscle thickness.

There were no statistically significant differences in the distributions of smile-lines in the men and women who had received orthodontic treatment and those who had not (Table 2). There were, however, significantly more women than men in the combined group with high smile-lines ($\chi^2 = 10.25$, $P < 0.01$). There were no statistically significant male–female differences in the thickness of the levator labii superioris muscle in either of the ethnic groups (Table 3) or the smile-line groups (Table 4). The zygomaticus major muscle was, however, significantly thicker in the women, as compared with the men (Tables 3 and 4). There were no significant differences in the thickness of either muscle in the high, medium, or low smile-line groups.

Discussion

In the present study, no attempt was made to combine the men and the women into a larger sample because women have been reported to have higher smile-lines than men (Tjan *et al.*, 1984; Rigsbee *et al.*, 1988; Peck *et al.*, 1992b). This sexual dimorphism in the height of the upper lip during a full smile is supported by the present study; 43 per cent of the women had high smile-lines, whereas only 12.5 per cent of the men were considered to have high smile-lines. In contrast, other studies (Peck *et al.*, 1992b; Peck and Peck, 1993) have reported that the proportion of females with high smile-lines was twice that found in males. It was also found that a large number of subjects had asymmetric smiles and, as a result, the definitions given by Tjan *et al*. (1984) were modified to deal with this.

A high smile-line may be due to factors such as age, gender, a short upper lip, short maxillary

Table 3 Comparison of muscle thickness, by gender and ethnic group.

	Muscle	*n*	Male			Female		
			Mean (mm)	SD	*n*	Mean (mm)	SD	*P*
Caucasian	LLS	13	3.13	0.60	17	3.35	0.59	0.473
	ZM	13	4.60	0.68	17	6.31	1.05	**0.001**
Asian	LLS	11	2.90	0.50	13	3.30	0.48	0.145
	ZM	11	4.95	1.05	13	5.79	0.91	0.134
Combined	LLS	24	3.02	0.55	30	3.32	0.53	0.135
	ZM	24	4.76	0.86	30	6.08	0.99	**0.000**

Significant differences at the 5 per cent level are shown in bold.

Table 4 Comparison of muscle thickness in the combined group, by smile line.

	Muscle	*n*	Smile line								
			High			Medium			Low		
			Mean (mm)	SD	*n*	Mean (mm)	SD	*n*	Mean (mm)	SD	*P*
Men	LLS	3	3.11	0.71	17	3.05	0.60	4	2.83	0.27	0.856
	ZM	3	5.02	0.88	17	**4.60**	0.84	4	5.26	1.00	0.558
Women	LLS	13	3.09	0.43	17	3.51	0.58	–	–	–	0.121
	ZM	13	6.55	0.98	17	**5.73**	0.94	–	–	–	0.092

The bar indicates groups, found to be different at the 5 per cent level of significance, $P = 0.011$.

incisors, an upwardly-tilted palate, a high mandibular plane angle, excessive maxillary height, increased lip mobility, anterior maxillary excess, excessive overjet and overbite, and a greater 'muscular capacity' to raise the upper lip (Singer, 1974; Vig and Brundo, 1978; Rigsbee *et al*., 1988; Peck *et al.*, 1992a,b; Peck and Peck, 1993). We assume that the latter refers to tension developed in a muscle during its contraction. Of these factors, muscular capacity or muscle tension has been largely ignored, presumably because of the difficulty in measuring tension in the lip musculature. To determine the muscular capacity of the upper lip, use was made of the relationship between the thickness of a muscle and the tension developed during its contraction (Ikai and Fukunaga, 1970; Åstrand and Rodahl, 1986; Kiliaridis and Kalebo, 1991).

Using ultrasound to image musculature in the living has several advantages. It is non-invasive, relatively quick, and inexpensive. Several methodological problems are, however, likely to be encountered when ultrasound is used to determine the thickness of a muscle. Ultrasound produces an unfamiliar cross-sectional image, and structures may have poorly defined boundaries, making measurement difficult. For this reason a detailed knowledge of the anatomy along the plane of section and experience in identifying structures on an ultrasound scan are essential. A lead-in period before starting an ultrasound study is also necessary to gain experience of the factors that can cause image variability. Muscle thickness may be affected by compression from the probe or by the contractile state of the muscle. The probe should be held perpendicular to the skin as Cady *et al.* (1983) reported that the inclination of the transducer was important to obtain a consistent image of skeletal muscle. Repeated scans may keep the errors to an acceptable level providing they do not affect muscle thickness. This problem was avoided in this investigation by using the mean of the right and left sides. In view of the difficulties experienced in obtaining a reliable scan of a full smile in either standing, seated or supine subjects, ultrasound scans were taken of the relaxed muscles in supine subjects.

The thicknesses of the two principal muscles elevating the upper lip were measured on hard copies of the ultrasound scans taken of living subjects. We were unable to find any difference in the thickness of the levator labii superioris muscle in the three smile-line groups. The thickness of the levator labii superioris muscle was measured opposite the canine fossa, as neighbouring anatomical structures enabled the muscle to be easily identified. Therefore, measurements of this muscle do not include muscle fibres that may have originated from the nasolabial fold, and which may have contributed to lip elevation (Rubin, 1989). The zygomaticus major muscle was significantly thicker in the women than in the men. Although there are gender differences in the thickness of the zygomaticus major muscle, no evidence was found that the height of the

smile-line was related to the relaxed thickness of either muscle.

Conclusions

The relationship between the smile-line and the thickness of the lip levator musculature has been investigated in young men and women.

There were significantly more women than men with high smile-lines and the zygomaticus major muscle was significantly thicker in women as compared with men. There were, however, no statistically significant differences in muscle thickness between the high, medium, and low smile-line groups.

While the findings of this study agree with previous reports that women have higher smile-lines than men, it does not appear that the thickness of either the levator labii superioris or zygomaticus major muscles is responsible for this difference.

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