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The effects of PNF training on the facial profile

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Abstract: Although orthodontic treatment improves dentoalveolar problems, the facial profile seldom changes because the perioral muscles do not easily adapt to the new morphological circumstances. We employed proprioceptive neuromuscular facilitation (PNF), which is training with added resisted movement to motions such as lifting the upper lip, lowering the lower lip, and sticking out the tongue, to adapt the perioral muscles to the new morphological circumstances. The subjects were 40 adults with an average age of 29.6 years. A series of PNF exercises was performed three times per day for 1 month. Lateral facial photographs were taken using a digital camera before training (T_0), after training (T_1), and 1 month after the end of training (T_2). The nasolabial (NL), mentolabial (ML), and mentocervical (MC) angles were measured, and linear measurements were taken to verify the change of each measurement point. In the test group, the NL and ML angles significantly increased ($P < 0.05$), and the MC angle significantly decreased after the PNF exercise. From T_1 to T_2, the NL and ML angles decreased significantly, while the MC angle increased significantly. No significant differences were observed in these angles when the values measured at T_0 and T_2 were compared. Although the training appeared to be effective for sharpening the mouth and submandibular region, continued training is necessary to avoid relapse. (J. Oral Sci. 50, 45-51, 2008)

Keywords: proprioceptive neuromuscular facilitation (PNF); profile; perioral musculature; facial aesthetics.

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Introduction

Facial aesthetics are not easily improved after orthodontic treatment in patients with hypotonia of the lips and chin. This problem may be related to the non-adaptation of the soft tissues and perioral muscles, despite improvement in the hard tissues, such as the alveolar bone and dentition (1-4).

Myofunctional therapy (MFT) developed by Rogers (5) or proprioceptive neuromuscular facilitation (PNF) devised by Kabat, Knott, and Voss (6-9) has been reported to permit improvement in the function of the muscles. PNF is a normalized, facilitated training method for muscles that involves stretching, resisted movement, traction (separating the joint surface), and approximation (compressing the joint surface) to ameliorate muscle decline, disharmony, atrophy, and joint movement limitations (10). Recently, PNF has been used in orthopedic diseases of the bone and joints, sports-related trauma, and central nervous system diseases, such as stroke, and its usefulness has been reported in other medical fields (11-13). In orofacial and dental treatment, Nakajima et al. (14) used PNF to improve the aesthetics of facial expression and introduced PNF to Japanese clinicians. We hypothesized that facial aesthetics might be improved by PNF training of the perioral muscles to adapt to the changes in the hard tissues after orthodontic treatment. However, no prior study had examined the effects of PNF on the facial soft tissues. Therefore, we measured the changes in the facial profile in an attempt to verify the effects of PNF on improving facial aesthetics.

Materials and Methods

The subjects were 40 volunteers who had no history of maxillofacial trauma and no marked dento-maxillary deformities. Their Angle's classification was Class I, and the farthest protruding points on their upper and lower lips were within ± 3 mm of the E-line. The test group consisted of ten men and ten women ranging in age from 24 to 34 years (29.3 ± 3.1 years), while the control group consisted of ten men and ten women ranging in age from 26 to 34 years (29.9 ± 2.9 years). This study was approved by the ethics committee of Nihon University School of Dentistry, Tokyo, Japan.

The test group trained for 1 month, and lateral facial photographs were taken before the training (T_0), after the training (T_1), and at 1 month after the end of the training (T_2). PNF training was performed in accordance with Nakajima et al. (14) and Voss et al. (15), with some modifications as shown in Table 1. Each subject was instructed to perform the ten training exercises three times a day, in the morning, at noon, and in the evening, for 1 month. The subjects in the control group did not perform the training.

All of the subjects were instructed to maintain a stable diet throughout the study, and were all weighed at T_0, T_1, and T_2 since a change in weight could affect the profile measurements.

Photographs of profiles of all subjects were taken at each time point using a digital camera (Camedia C-5060; Olympus, Tokyo, Japan) with a shutter speed of 1/10, aperture of F3.2, and focal distance of 22.9 mm. The distance between the top of the lens and the center of the ear-rods was fixed at 900 mm. In preliminary tests, when some of the subjects stood with their head in its natural position, the line from the corner of the eye to the superior-most point of the base of the ear was approximately parallel to the floor. For reproducibility, this line was then defined as the horizontal reference line (HRL) in this study, and we took photographs of all subjects under the same conditions by referring to the HRL (Fig.1). Subjects who were wearing eyeglasses removed them when photographed, and all measurement points were defined clearly.

The measurement points were the glabella (G; the anterior-most point of the midline of the forehead), columella (Cm; the inferior- and anterior-most point of the nose), subnasal (Sn; the point where the upper lip joins the columella), labial superior (Ls; the most protrusive point of the upper lip), labial inferior (Li; the most protrusive point of the lower lip), supramental (Sm; the deepest point of the inferior sublabial concavity), pogonion (Pog; the anterior-most point of the chin), menton (Me; the inferior-most point of the inferior edge of the chin), and cervical (C; the innermost point between the submental area and the neck, located at the intersection of tangents drawn to the neck and submental areas). The nasolabial (NL; Cm-Sn-Ls), mentolabial (ML; Li-Sm-Pog), and mentocervical (MC; G-Pog-Me-C) angles were measured (Fig. 1), and linear measurements were taken to verify the change of each measurement point (Fig. 2). In the linear measurements, the horizontal reference plane was defined as the *x*-axis and a line perpendicular to the *x*-axis passing through point G was defined as the *y*-axis. The weight of each subject at T_0, T_1, and T_2 was compared, and subjects with a change of more than 2% were excluded from the analysis.

Statistical analysis was performed using repeated measures analysis of variance (ANOVA). When a significant difference was observed, a multiple comparison was made using the Wilcoxon *t*-test with the Bonferroni correction (paired *t*-test, $P < 0.05$). One examiner (the first author) made all of the measurements to eliminate inter-examiner error. All measurements were performed twice with an interval of at least 1 month, and the absence of any significant differences between the two measurements was confirmed ($P < 0.05$) (16,17).

Table 1 PNF training procedure

1.	Smile without opening the mouth, then use your fingers to resist the movement for 5 seconds.
2.	Purse the lips, as in whistling, and then apply resistance using the fingers for 5 seconds.
3.	Lift the angle of the mouth, and then apply resistance using the fingers for 5 seconds.
4.	Lower the lower lip, and then apply resistance for 5 seconds.
5.	Strain the chin with the mouth closed, and then apply resistance for 5 seconds.
6.	With the head upright, open the mouth wide, and then apply resistance for 5 seconds.
7.	After exercise 6, release the resisted movement and then stick out the tongue and hold for 5 seconds.
8.	Stick the tongue upward to try to touch the tip to the nose and hold for 5 seconds.
9.	Stick the tongue downward to try to touch the tip to the chin and hold for 5 seconds.
10.	Stick the tongue to the right and then to the left. When sticking the tongue to the right (left), lower the left (right) shoulder, and hold each for 5 seconds.

Each subject was instructed to perform the ten training exercises three times a day, in the morning, at noon, and in the evening for 1 month.

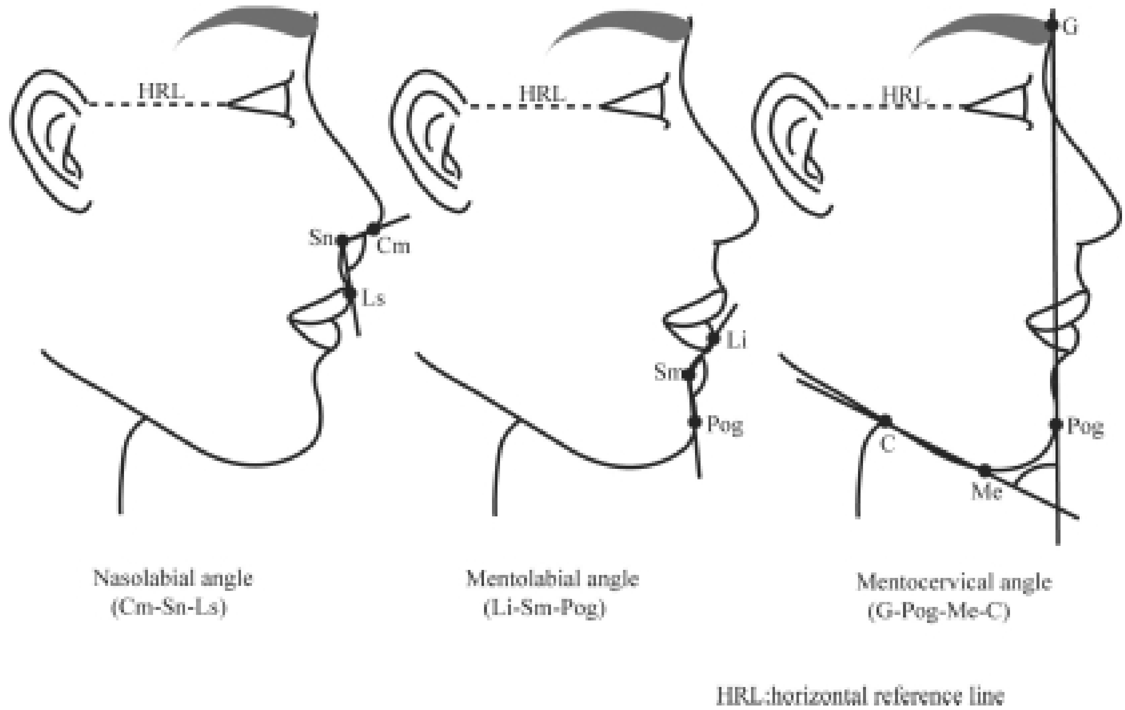

Fig. 1 Measurements. HRL: the line from the corner of the eye to the superior-most point of the base of the ear; Cm: the inferior- and anterior-most point of the nose; Sn: the point where the upper lip joins the columella; Ls: the most protrusive point of the upper lip; Li: the most protrusive point of the lower lip; Sm: the deepest point of the inferior sublabial concavity; Pog: the anterior-most point of the chin; G: the anterior-most point of the midline of the forehead; Me: the inferior-most point of the inferior edge of the chin; C: the innermost point between the submental area and the neck located at the intersection tangents drawn to the neck and submental areas.

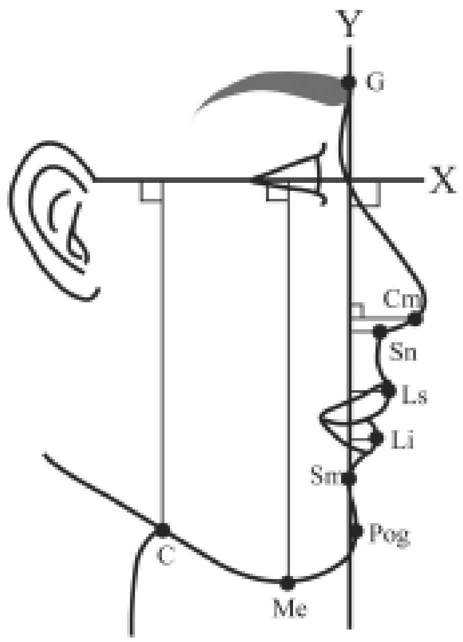

Fig. 2 Linear measurements. The horizontal reference line (HRL) was defined as the x-axis, and a line perpendicular to the x-axis passing through point G was defined as the y-axis. For points C and Me, distance was determined from the x-axis; for the other points, distance was determined from the y-axis.

Fig. 3 Typical silhouette of a study subject. The profile in shadow is the subject's before PNF training. The solid line is the subject's profile after PNF training. The broken line shows the profile 1 month after discontinuing the training. (This silhouette was created using profiles of the subject's photographs superimposed by the HRL at the corner of the eye.)

Results

The NL and ML angles increased significantly from T_0 to T_1, while the MC angle decreased. From T_1 to T_2, the NL and ML angles decreased, while the MC angle increased significantly. Comparing T_0 and T_2, no significant differences were detected in the NL, ML, and MC angles (Table 2). Regarding the control group, no significant differences in any angle were detected between time points (Table 3). The difference of the angles measured at T_0 and T_1 was 4.2, 5.7, and 6.7° for the NL, ML, and MC angles, respectively, and that between T_1 and T_2 was -2.9, -5.6, and 5.1°, respectively (Table 4).

For the horizontal changes, points Cm, Sn, and Sm did not differ significantly, while points Ls, Li, and Pog retracted significantly between T_0 and T_1 and protracted significantly between T_1 and T_2. For the vertical changes, point Me did not differ significantly among T_0, T_1, and T_2, while point C moved upward significantly between T_0 and T_1 and moved downward significantly between T_1 and T_2 (Table 5). No significant difference was observed among all the measurements in the control group (Table 6).

Discussion

Regarding standardized photography of the facial profile, Claman et al. (18) stated that an identical lens focal distance, constant distance from the camera to the object, and a camera fixed to a stand are needed. Additionally the

Table 2 Comparison of the measurements between time points

	Nasolabial angle (deg.)						Mentolabial angle (deg.)						Mentocervical angle (deg.)					
Time points	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*
Before training (T_0)	96.6	9.5	98.5	111.0	78.5	-	127.0	12.4	125.5	148.0	99.5	-	99.7	9.1	96.8	121.0	88.5	-
After training (T_1)	100.8	9.1	102.5	113.0	82.0	*	132.7	12.5	130.0	152.0	105.0	*	93.6	10.7	90.0	118.0	72.0	*
One month after the end of training (T_2)	97.9	9.2	100.3	111.0	80.0	-	127.1	12.4	124.8	150.0	101.5	-	98.7	10.3	95.0	120.0	77.0	-

SD: Standard deviation
W test: Wilcoxon *t*-test with Bonferroni correction
*: Significant differences ($P < 0.05$) against T_0 and T_2

Table 3 Comparison of the measurements between time points in control group

	Nasolabial angle (deg.)						Mentolabial angle (deg.)						Mentocervical angle (deg.)					
Time points	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*
Before training (T_0)	94.7	8.3	94.2	110.8	78.5	-	134.8	9.8	135.0	150.0	119.0	-	98.0	8.9	95.0	115.0	84.1	-
After training (T_1)	94.9	8.2	94.5	110.6	79.0	-	134.4	9.7	135.4	150.1	119.6	-	98.3	9.0	94.9	116.5	85.5	-
One month after the end of training (T_2)	94.7	8.2	94.8	110.0	78.7	-	134.6	9.4	135.2	151.3	120.3	-	98.3	9.0	95.6	116.2	83.6	-

SD: Standard deviation
W test: Wilcoxon *t*-test with Bonferroni correction
There are no significant differences among all time points.

Table 4 The measurement change by PNF training (T_0 - T_1) and relapse after PNF training (T_1 - T_2)

		Nasolabial angle (deg.)		Mentolabial angle (deg.)		Mentocervical angle (deg.)	
	Group	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
$T_0 - T_1$	PNF training	4.2	2.2	5.7	3.3	-6.1	3.9
$T_1 - T_2$	PNF training	-2.9	2.5	-5.6	4.0	5.1	2.0
$T_0 - T_1$	Control	-0.2	0.6	0.4	1.5	-0.3	0.9
$T_1 - T_2$	Control	0.2	0.6	-0.2	1.4	0.0	1.0

T_0: Before training
T_1: After training
T_2: One month after the end of training
$T_0 - T_1$ indicates change from T_0 to T_1.
$T_1 - T_2$ indicates change from T_1 to T_2.
SD: Standard deviation

line from the center of the lens to the eye of the subject should parallel the horizontal plane. In our study, the camera was fixed to a stand, and the distance between the camera and the center of the ear-rods was fixed at 900 mm. To take a photograph under natural conditions, we used the head position resembling the natural head position (NHP), which was defined as when a human is standing, the visual axis is horizontal and the head is in the natural position (19), and which has been utilized to measure human faces (20-26). Our preliminary test confirmed that when some subjects stood in the NHP, the angle between the line from the corner of the eye to the superior-most point of the base of the ear and the floor was within 5°. This line was then defined as the reference line in this study to take reproducible photographs. While being photographed, the subjects were instructed to fix their mandible in centric occlusion without straining the facial muscles.

We measured the NL, ML, and MC angles. The muscles affecting these measurements were thought to be the risorius, zygomatic major, orbicularis oris, levator labii superior, depressor labii inferior, mentalis, infrahyoid, suprahyoid, internal lingual, genioglossus, and geniohyoid muscles (14). Considering the relationships between the training movements and the muscles, the muscles involved in the various exercises were as follows: 1) the risorius and zygomatic major muscles act in "smiling without opening the mouth"; 2) the orbicularis oris muscle is used in "pursing the lips to whistle"; 3) the levator labii superior muscle "lifts the angle of the mouth"; 4) the depressor labii inferior muscle "lowers the lower lip"; 5) the mentalis muscle "strains the chin with the mouth closed"; 6) the infrahyoid and suprahyoid muscles "keep the mouth wide open in the upright head position"; and 7-10) the internal lingual, genioglossus, and geniohyoid muscles are involved in "sticking out the tongue" (14). Therefore, training the risorius, zygomatic major, orbicularis oris, and levator

Table 5 Comparison of the measured distances between time points

Measured distances		Before training (T_0)						After training (T_1)						One month after the end of training (T_2)					
		Mean	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*
Horizontal	Cm (mm)	10.7	1.6	11.1	13.1	6.6	-	10.7	1.6	11.1	13.1	6.6	-	10.7	1.6	11.1	13.1	6.6	-
	Sn (mm)	1.2	2.0	1.0	4.1	-1.6	-	0.9	1.8	0.4	4.1	-1.6	-	1.2	1.8	1.0	4.1	-1.6	-
	Ls (mm)	4.0	2.1	3.7	8.2	0.5	-	2.9	2.0	3.3	7.4	0.0	*	3.9	1.9	3.3	7.4	0.0	-
	Li (mm)	2.0	2.2	1.6	6.6	-1.6	-	0.9	2.1	0.4	6.6	-2.5	*	1.5	2.3	1.6	6.6	-4.9	-
	Sm (mm)	-3.6	3.1	-3.7	0.8	-9.0	-	-4.3	3.0	-3.9	0.8	-11.5	-	-4.1	2.9	-3.7	0.8	-9.8	-
	Pog (mm)	-3.1	3.8	-3.7	3.3	-9.8	-	-4.0	3.8	-4.1	3.3	-11.5	*	-3.4	3.8	-3.7	3.3	9.8	-
Vertical	Me (mm)	100.7	6.2	101.3	113.3	88.3	-	100.4	6.0	99.8	111.4	86.4	-	100.8	6.1	100.8	113.3	88.3	-
	C (mm)	105.2	7.8	106.6	119.0	90.2	-	102.1	8.4	103.7	117.1	86.3	*	105.0	8.3	105.6	121.0	88.3	-

SD: Standard deviation
W test: Wilcoxon *t*-test with Bonferroni correction
*: Significant differences ($P < 0.05$) against T_0 and T_2

Table 6 Comparison of the measured distances between time points in the control group

Measured distances		Before training (T_0)						After training (T_1)						One month after the end of training (T_2)					
		Mean	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*	*Mean*	*SD*	*Median*	*Max*	*Min*	*W test*
Horizontal	Cm (mm)	10.1	2.2	9.8	14.8	6.5	-	10.0	2.3	9.8	14.8	5.7	-	10.2	2.2	9.8	14.8	6.6	-
	Sn (mm)	0.4	2.3	0.0	4.1	-3.3	-	0.5	2.0	0.0	4.1	-2.5	-	0.5	2.0	0.0	4.1	-2.5	-
	Ls (mm)	4.0	2.9	4.9	9.8	0.0	-	3.9	2.7	4.9	9.0	0.0	-	3.9	3.0	4.9	9.8	-1.6	-
	Li (mm)	2.0	2.8	1.6	8.2	-1.6	-	2.0	2.9	1.6	8.2	-1.6	-	2.0	2.9	1.6	8.2	-1.6	-
	Sm (mm)	-3.2	3.2	-3.7	3.3	-8.2	-	-3.1	3.0	-3.7	3.3	-8.2	-	-3.2	3.2	-3.7	3.3	-8.2	-
	Pog (mm)	-2.5	3.3	-3.3	5.0	-9.0	-	-2.5	3.3	-3.3	4.9	-8.2	-	-2.5	3.3	-3.3	5.0	-8.2	-
Vertical	Me (mm)	101.3	6.5	102.7	111.4	88.3	-	101.3	6.5	102.7	111.4	88.3	-	101.4	6.4	102.8	111.4	88.3	-
	C (mm)	104.4	8.4	105.6	117.1	90.2	-	104.4	8.7	106.6	117.1	90.2	-	104.6	8.7	106.6	117.1	90.2	-

SD: Standard deviation
W test: Wilcoxon *t*-test with Bonferroni correction
There are no significant differences among all time points.

labii superior muscles influences the NL angle; training the orbicularis oris, depress or labii inferior, and mentalis muscles affects the ML angle; and training the infrahyoid, suprahyoid, internal lingual, genioglossus, and geniohyoid muscles influences the MC angle.

In the test group, the NL and ML angles increased significantly and the MC angle decreased significantly from T_0 to T_1. The training affected the perioral muscles, and the change in each measurement averaged 4 to 6°. These changes in the angular measurements were caused by retraction of the measurement points on the lips (Ls, Li, Pog) and upward movement of the measurement points on the cervical (C). The change in the NL angle was caused by the movement of the Ls, the ML angle was affected by the Li and Pog, and the MC angle was influenced by the C and Pog. Changes in the orbicularis oris, mentalis, and geniohyoid muscles might affect the retraction of the Ls and Li, the retraction of Pog, and the upward movement of C, respectively. Therefore, the PNF training of these three muscles appears to be useful for aesthetic improvement of the face.

Satomi (27) reported that lip strength increased significantly after 6 months of MFT training and then decreased. We observed significant differences in the NL, ML, and MC angles after 1 month of training, but the three measurements indicated relapse 1 month after the end of the training. PNF differs from MFT in that the training is facilitated by the proprioceptive neuromuscular system; proprioceptors such as muscle and tendon spindles and receptors in the joint capsule, and ligaments are stimulated (28). Using this method, resisted movement stimulates the proprioceptors, facilitating muscle contraction, and may result in short-term changes. The 24 facial muscles act mutually or individually and lack fascia; a facial muscle is a thin cutaneous muscle acting from bone to skin or skin to skin. PNF might affect the cutaneous muscles distributed over a wide area of the human face, which may contribute to the early improvement. Since the facial muscles are thin cutaneous muscles, continuous training might be needed to maintain the strengthened muscles.

We confirmed no changes in weights for all subjects during the experimental period because changes in soft tissue such as subcutaneous fat might be related to the changes in facial profile. Regardless of this prudent consideration, we cannot conclude that PNF training affects the muscle force because we did not perform physiologic measurements of muscle tonus in this study. It would therefore be necessary to carry out a physiologic experiment in the future in order to clarify the effects of PNF training on the muscle force.

In summary, proprioceptive neuromuscular facilitation training appeared to be effective for sharpening the mouth and submandibular region, and might be useful for helping the perioral muscles adapt to alterations in the hard tissues following orthodontic treatment. However, the training must be continued to avoid relapse, which tended to occur within 1 month of discontinuing training.

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