ORIGINAL Aichi Gakuin Dent Sci 35 : 1–11, 2022

INVENTION OF THE PALATAL NANCE LINGUAL ARCH AND STABILITY OF THE MAXILLARY ARCH DURING USE OF CLASS III ELASTICS

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SYNOPSIS

In order to reduce the application duration for multi-bracket appliances, we devised a Palatal Nance Lingual Arch (PNLA) as an anchorage appliance, combining a palatal bar, a Nance holding arch and a lingual arch. The PNLA can be used as the source of anchorage for Class III elastics in the maxillary arch to replace maxillary stabilization. We then examined changes with PNLA against the use of Class III elastics. The results showed no significant difference in maxillary dentition and skeletal changes up to 4 months of Class III elastic use. In the 3-, 4- and 5-month groups, the mandibular first and second molars were distally inclined. In the 5-month group, the maxillary first molars were extruded, and in terms of specific skeletal changes, FMA and ANB had increased. The PNLA, when used for an appropriate duration, is an effective anchorage source for Class III elastics.

Key words: Palatal Nance Lingual Arch (PNLA), Class Ⅲ elastics, anchorage

INTRODUCTION

The Level Anchorage System (LAS) is an orthodontic treatment system established by Dr. Root in 1981[1,2]. This system is based on the concept of the treatment mechanics of the Tweed technique and the concept of Steiner's analysis[3-5], and it enables accurate prediction of treatment outcomes by quantifying the degree of treatment difficulty and treatment operations for each clinical case and standardizing treatment procedures and orthodontic appliances. Another feature of this system is the quantification of "anchorage", something which could not be achieved by conventional methods.

The LAS is divided into seven steps (Table 1A), and has the advantage of ensuring reliable treatment outcomes if the treatment is performed according to the set goals to be achieved at the end of each step[6]. However, based on the concept of anchorage preparation, the maxilla and mandible alternately assume the roles of working and stabilizing sides, and therefore treatment on both the maxillary and mandibular sides rarely proceeds simultaneously[7]. For example, after maxillary leveling and stabilization are completed and the maxillary anchorage is established in step 1, anchorage preparation of the mandibular molars, including the use of Class III elastics, is performed in step 2. In this case, the mandibular treatment cannot be started until the step 1 treatment is completed, resulting in some waiting period. Thus, this method also has the possible disadvantage of a prolonged treatment period.

To eliminate the waiting period for mandibular treatment during step 1 in the LAS, we devised the Palatal Nance Lingual Arch (PNLA), an anchorage appliance combining a palatal bar, a Nance holding arch, and a lingual arch (Fig. 1), as a source of anchorage for Class III elastics to replace maxillary stabilization in step 1. We hypothesized that the use of the PNLA as a functional anchorage source in the maxillary arch would reduce the treatment period. The objective of this study

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Received for publication December 9, 2021
Accepted for publication February 2, 2022

was to determine whether the PNLA could be an anchorage source equivalent to maxillary stabilization in step 1.

Materials and Methods

Patients and materials

This study targeted patients diagnosed with maxillary protrusion or bimaxillary protrusion or crowding and involved patients for whom LAS was indicated for multi-bracket treatment in the Department of Orthodontics at our university hospital who underwent mandibular treatment in step 2 using the PNLA attached to the maxilla as an anchorage source (Table 1B). Among them, 15 patients were selected who used Class III elastics with the PNLA for 2, 3, 4, and 5 months (2 males and 13 females, mean age at start of treatment: 18.00 ± 5.40 years, 3-5 patients for each period of Class III elastic use). The duration of Class III elastic use was limited up to 5 months because it is recommended that Class III elastics be used for no more than 6 months in LAS step 2[8]. All patients treated with the PNLA and Class III elastics had their bilateral mandibular first premolars extracted before the start of LAS step 2, according to the usual procedure.

The PNLA consisted of a palatal bar, a Nance holding arch, and a lingual arch, which were soldered to bands attached to four teeth: the bilateral maxillary first premolars and first molars. The loop of the palatal bar was bent distally and soldered to the bands to connect the bilateral maxillary first molars while being separated 2-3 mm from the palate. The wire of the Nance holding arch was soldered to the bands to connect the bilateral maxillary first premolars while being separated 2-3 mm from the palate, with a palatal resin placed against the palatal mucosa. The lingual arch was designed to contact the palatal surface of teeth from the maxillary right first molar to the left first molar as closely as possible. All the components of the appliance were made of cobalt-chromium alloy wire of 0.9 mm in diameter (Fig. 1A). The PNLA was placed intramaxillary with bands cemented to these four teeth, namely, the bilateral maxillary first premolars and first molars (Fig. 1B).

In LAS step 2, brackets are placed on the bilateral mandibular canines and second premolars, bands are placed on the bilateral mandibular first and second molars, and a wire is passed through these parts to begin leveling. The Class III elastics used in this step were engaged between a hook attached to the wire at the mesial surface of the mandibular canine and another hook welded to the band of the maxillary first molar on each side. Patients were instructed to wear the elastics for 12h a day from the start of step 2 (Fig. 2). The Class III elastics (3M Company, Maplewood, USA) were 7.9 mm in diameter with a force of 3.5 oz (99.2 g).

This clinical study was carried out with approval by the Research Ethics Committee of our institution (Approval No.613). All patients provided informed consent for inclusion in the study.

The data used were lateral cephalograms taken in the maximal intercuspal position before the start of treatment (T_0) and at the end of the use of Class III elastics (T_1). No other orthodontic appliances were used before or during the use of the PNLA, and patients with congenital disease or jaw deformity were excluded.

Variables and analysis methods

Cephalometric measurement was performed using reference points and lines (Table 2, Fig. 3A) on the tracings of lateral cephalograms taken before the start of treatment (T_0) and at the end of the use of Class III

Table 1. Flow of conventional LAS treatment and PNLA-based treatment

A. Flow of conventional LAS treatment ～Step by Step～

	Upper		Lower	
Step 1	Leveling & stabilizing			
		Step 2	Curve of Spee leveling (using Class III elastics)	
		Step 3	3┬3 retraction	
		Step 4	21┬12 uprighting	
		Step 5	Stabilization	
Step 6	Retraction			
Step 7	Detailing	Step 7	Detailing	
	Finish			

B. Flow of PNLA-based LAS treatment

	Upper		Lower	
	PNLA	Step 2	Curve of Spee leveling (using Class III elastics)	
Step 1	Leveling & stabilizing	Step 3	3┬3 retraction	
		Step 4	21┬12 uprighting	
		Step 5	Stabilization	
Step 6	Retraction			
Step 7	Detailing	Step 7	Detailing	
	Finish			

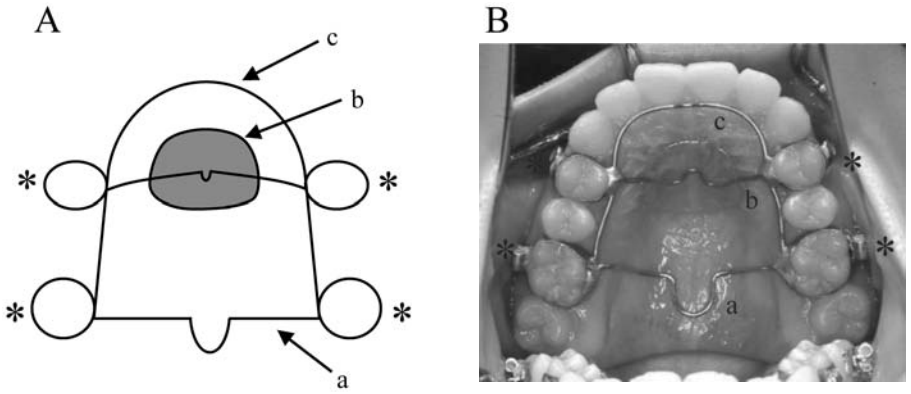

Fig. 1. Palatal Nance Lingual Arch (PNLA)
A: Design of the Palatal Nance Lingual Arch (PNLA), B: Intraoral photograph of the PNLA
The PNLA is an anchorage appliance used in the maxillary arch in combination with a palatal bar (a), a Nance holding arch (b), and a lingual arch (c). Bands (*) were attached to the bilateral maxillary first premolars and first molars so as to integrate the maxillary arch. The palatal bar was soldered to the bands to connect the bilateral maxillary first molars while being separated from the palate, the Nance holding arch was placed along the palatal mucosa, and the lingual arch was designed to contact the palatal tooth surface as closely as possible.

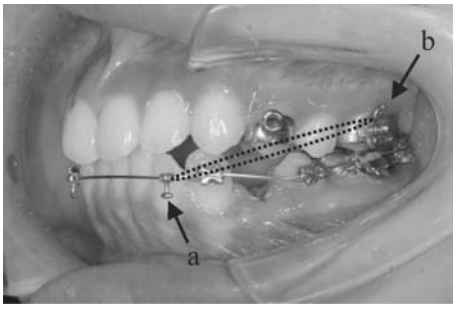

Fig. 2. LAS step 2
The dotted line indicates the application position of a Class III elastic used in LAS step 2. In LAS step 2, brackets are placed on the bilateral mandibular canines and second premolars, bands are placed on the bilateral mandibular first and second molars, and a wire is passed through these parts to begin leveling. The Class III elastics were engaged between a hook attached to the wire at the mesial surface of the mandibular canine (a) and a hook of the maxillary first molar (b) on each side. Patients were instructed to wear the elastics from the start of step 2.

elastics (T_1).

The variables measured were SNA, SNB, ANB, U-1 to NA (distance/angle), L-1 to NB (distance/angle), and FMA for LAS analysis, and A'-Ptm', Ptm'-Mo, and A'-Mo for evaluation of the mesiodistal position of the maxillary first molars in the maxilla. Also measured were the mesiodistal positions of the maxillary and mandibular first molars and central incisors seen from OLp (Ms-OLp, Mi-OLp, Is-OLp, Ii-OLp; Fig. 3B), the vertical positions of the maxillary first and second molars (M6s-NL, M7s-NL), and the vertical positions of the mandibular first molars (M6i-ML; Fig. 3C), as reported by Pancherz.[9,10]; and the axial inclination angles of the mandibular first and second molars (L6 inclination, L7 inclination; Fig. 3D), as reported by Davidovitch et al.[11], for a total of 20 variables (Table 2).

Measurements were taken before the start of treatment (T_0) and at the end of Class III elastic use (T_1) for each group according to duration of Class III elastic use (2, 3, 4, and 5 months). Then, measurements obtained at T_0 were compared between the groups, measurements obtained at T_0 were compared with those obtained at T_1, and the difference between measurements at T_1 and those at T_0 (T_1-T_0) was calculated to determine how the duration of Class III elastic use affected each measurement.

Statistical analysis

Statistical evaluation was performed using GraphPad Prism 7 (GraphPad Software, CA, USA). Parametric tests were used for all data after confirming the normality of their distributions. One-way analysis of variance (ANOVA) followed by multiple comparisons with Tukey's test was used to compare age at the start of treatment, cephalometric measurements before the start of treatment (i.e., comparisons at T_0), and changes in

Table 2. Reference points, lines and variables for lateral cephalometric measurement

Reference points and lines	Description
A	Deepest point on the maxillary contour between the anterior nasal spine and the alveolar process between the maxillary central incisors.
B	Deepest point on the mandibular contour between the alveolar process between the mandibular central incisors and the pogonion.
N	Frontmost point of the nasofrontal suture
S	Center of the pot-shaped shadow of the sella turcica of the sphenoid bone
ANS	Apex of the anterior nasal spine
PNS	Apex of the posterior nasal spine
Ptm	Lowermost point of the pterygopalatine fossa
Po	Uppermost point of the upper margin of the external auditory canal
Or	Lowermost point of the orbital bone margin
Me	Lowermost point of the mandibular mental region on a median cross-sectional image
Go(L)	Corner of the lower mandibular margin
Mo	Position of the midpoint of the maxillary first molar when projected onto the palatal plane
A'	Position of point A when projected onto the palatal plane
Ptm'	Position of point Ptm when projected onto the palatal plane
M6sc	Midpoint of the occlusal surface of the maxillary first molars
M7sc	Midpoint of the occlusal surface of the maxillary second molars
M6ic	Midpoint of the occlusal surface of the mandibular first molars
Is (incison superius)	Maxillary central incisal edge
Ii (incison inferius)	Mandibular central incisal edge
Ms (molar superius)	Contact point between the tangent parallel to OLp and the mesial surface of the maxillary first molar
Mi (molar inferius)	Contact point between the tangent parallel to OLp and the mesial surface of the mandibular first molar
Pg (pogonion)	Most anterior portion of the mandibular mental region determined by the tangent parallel to OLp
OLp	Line perpendicular to the occlusal plane (OLs) passing through point S
OLs	Maxillary occlusal plane
FH	Frankfurt plane
SN	SN plane
NL	Palatal plane
ML	Mandibular plane

Variables	Description
SNA (°)	Angle between the SN plane and the NA line
SNB (°)	Angle between the SN plane and the NB line
ANB (°)	Angle between the NA line and the NB line
FMA (°)	Angle between the FH plane and the mandibular plane
U1 to NA (mm)	Distance from the maxillary central incisor to the NA line
U1 to NA (°)	Axial inclination angle of the maxillary central incisor to the NA line
L1 to NB (mm)	Distance from the mandibular central incisor to the NB line
L1 to NB (°)	Axial inclination angle of the mandibular central incisor to the NB line
A'-Ptm' (mm)	Linear distance between A' and Ptm'
Ptm'-Mo (mm)	Linear distance between Ptm' and Mo
A'-Mo (mm)	Linear distance between A' and Mo
Ms-OLp (mm)	Mesiodistal position of the maxillary first molar: the perpendicular distance from OLp to the mesial surface of the maxillary first molar
Mi-OLp (mm)	Mesiodistal position of the mandibular first molar: the perpendicular distance from OLp to the mesial surface of the mandibular first molar
Is-OLp (mm)	Mesiodistal position of the maxillary central incisor: the perpendicular distance from OLp to the most prominent portion of the maxillary central incisal edge
Ii-OLp (mm)	Mesiodistal position of the mandibular central incisor: the perpendicular distance from OLp to the most prominent portion of the mandibular central incisal edge
M6sc-N (mm)	Height of the maxillary first molar: the perpendicular distance from the palatal plane to the maxillary first molar
M7sc-NL (mm)	Height of the maxillary second molar: the perpendicular distance from the palatal plane to the maxillary second molar
M6ic-ML (mm)	Height of the mandibular first molar: the perpendicular distance from the mandibular plane to the mandibular first molar
L6 inclination (°)	Axial inclination angle of the mandibular first molar: the angle between the line perpendicular to the line connecting the functional cusps of the mandibular first molar and the mandibular plane.
L7 inclination (°)	Axial inclination angle of the mandibular second molar: the angle between the line perpendicular to the line connecting the functional cusps of the mandibular second molar and the mandibular plane.

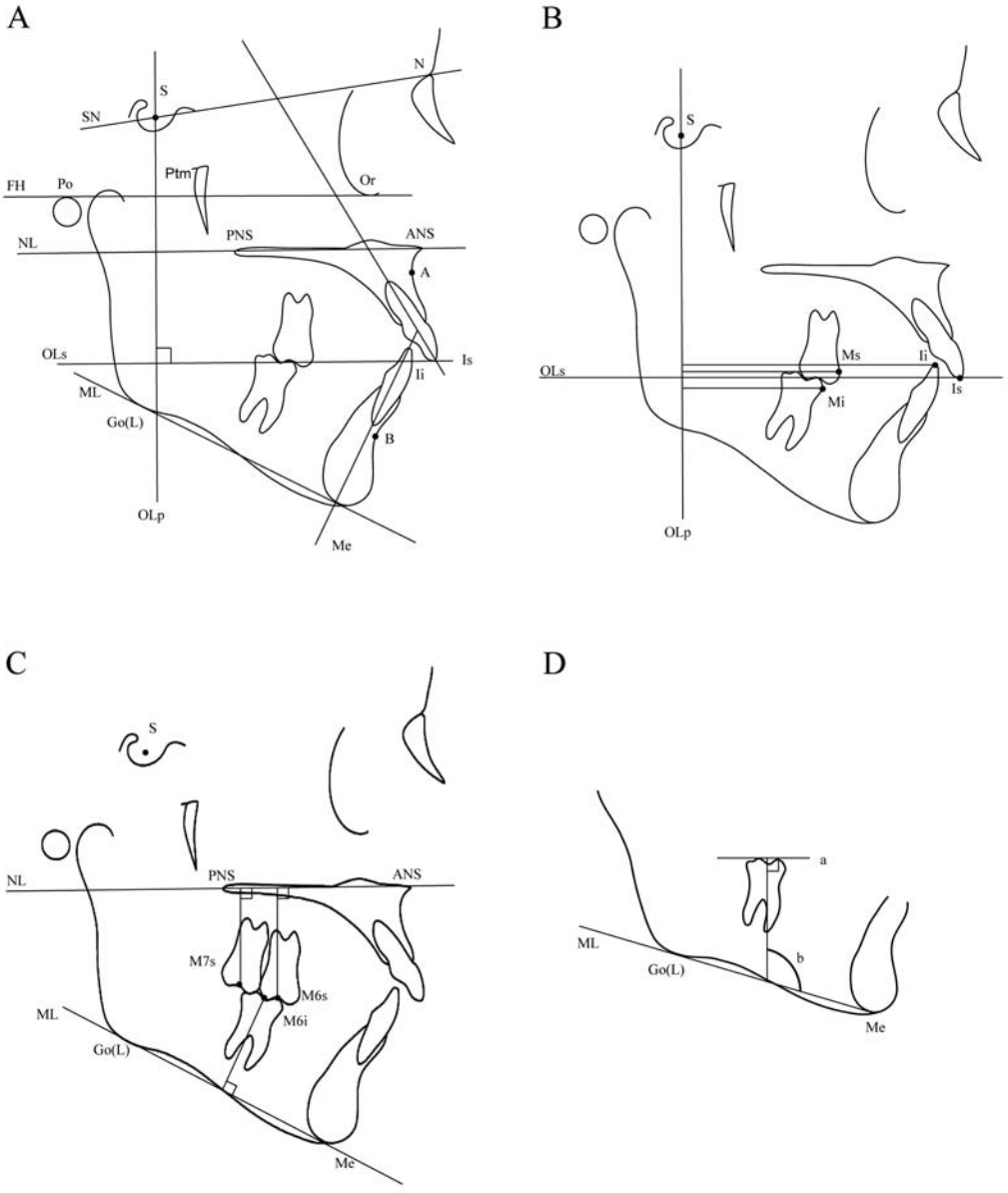

Fig. 3. Cephalometric points and lines

A: Reference points and lines used for distance and angle measurements. B: Reference points and lines used for measuring the mesiodistal position of the maxillary and mandibular first molars and central incisors (Ms-OLp, Mi-OLp, Is-OLp, and Ii-OLp). The line perpendicular to the occlusal plane (OLs) passing through point S (OLp) was used as the reference for measuring the distance to the mesial surface of the maxillary first molar (Ms), the mesial surface of the mandibular first molar (Mi), the maxillary central incisal edge (Is), and the mandibular central incisal edge (Ii). C: Reference points and lines used to measure the vertical positions of the maxillary first and second molars (M6s-NL, M7s-NL) and those of the mandibular first molars (M6i-ML). For the vertical positions of the maxillary first and second molars, the palatal plane (NF) was used as the reference for measuring the distance to the midpoints of the occlusal surfaces of the maxillary first and second molars (M6s and M7s) (M6s-NL and M7s-NL). For the vertical positions of the mandibular first molars, the mandibular plane (ML) was used as the reference for measuring the distance to the midpoint of the occlusal surface of the mandibular first molar (M6i) (M6i-ML). D: Reference points and lines used for measuring the axial inclination angle of the mandibular first and second molars (L6 inclination, L7 inclination). The angle was measured between (b) the line perpendicular to the line connecting the functional cusps of a mandibular molar tooth (a) and the mandibular plane.

cephalometric measurements before and after the use of Class III elastics (i.e., comparisons of T_1-T_0) among four groups of patients using Class III elastics for 2, 3, 4, and 5 months. For comparison of cephalometric measurements before the start of treatment (T_0) and at the end of Class III elastic use (T_1) (i.e., comparison between T_0 and T_1), Student's t-test was used to assess statistical significance. All data are presented as mean ± standard deviation, and $P < 0.05$ was considered statistically significant.

Results

Demographic information of the patients

The number of patients, male to female ratio, and age at the start of treatment in the 2-, 3-, 4-, and 5-month Class III elastic use groups are shown in Table 3. There was no significant difference in age at the start of treatment among groups.

Baseline (T_0) jaw morphology by group

To compare the pre-treatment jaw morphology of the patients in the 2-, 3-, 4- and 5-month groups, the cephalometric measurements at baseline (T_0) were compared between the groups (Table 4). There was a significant difference in U-1 to NA (angle) between the groups, and subsequent multiple comparison showed a significant lingual inclination of the maxillary anterior teeth in the 3-month group compared with the 2-month group. No significant differences were observed for other measurements. Thus, except for a significant difference in U-1 to NA (angle) between the 2- and 3-month groups, the pre-treatment jaw morphology was comparable among groups.

Comparison of jaw morphology by duration of Class III elastic use

Measurements of 20 cephalometric variables at baseline (T_0) were compared with those at the end of Class III elastic use (T_1) in PNLA-wearing patients who used Class III elastics for 2, 3, 4, and 5 months (Table 5).

In the 2-month group, there were no significant differences between T_0 and T_1 measurements for any variable.

In the 3- and 4-month groups, L6 and L7 inclination angles at T_1 were significantly increased compared with those at T_0 ($P = 0.002$ and 0.015 for L6 inclination, $P = 0.039$ and 0.012 for L7 inclination, respectively), indicating distal inclination of the mandibular first and second molars. There were no significant differences between T_0 and T_1 measurements for other variables.

In the 5-month group, there were significant increases in L6 and L7 inclination angles at T_1 compared with T_0 ($P = 0.027$ for L6 inclination, $P = 0.009$ for L7 inclination), indicating alveolar changes that caused distal inclination of the mandibular first and second molars. In addition, M6s-NL was significantly increased at T_1 compared with T_0 ($P = 0.009$), indicating extrusion of the maxillary first molars. No significant differences were observed in U-1 to NA (distance/angle), L-1 to NB (distance/angle), A'-Ptm', Ptm'-Mo, A'-Mo, Ms-OLp, Mi-OLp, Is-OLp, or Ii-OLp, indicating no changes in the mesiodistal position of the maxillary and mandibular central incisors and first molars. As for skeletal changes, FMA was significantly increased at T_1 compared with T_0 ($P = 0.014$), indicating an increase in FMA and mandibular backward rotation. SNB was significantly decreased at T_1 compared with T_0 ($P = 0.023$) and ANB was significantly increased at T_1 compared with T_0 ($P = 0.031$), indicating an increase in ANB due to retraction of point B.

Comparison of changes in jaw morphology by duration of Class III elastic use

Changes in measurements of 20 cephalometric variables from baseline (T_0) to the end of Class III elastic use (T_1) were compared among four groups of PNLA-wearing patients who used Class III elastics for 2, 3, 4, or

Table 3. Demographic information of patients

Duration of use of Class III elastics	2 months	3 months	4 months	5 months	*P*-value	Significant difference
No. of subjects (n)	5	4	3	3		
Sex (male/female)	2/3	0/4	0/3	0/3		
Age at start of treatment (years : Mean±S.D.)	15.80±4.21	19.50±4.43	20.67±9.87	17.00±3.61	0.4606	NS

NS : not significant

Table 4. Baseline (T_0) jaw morphology by group

Duration of use of Class III elastics / Variables	2 months		3 months		4 months		5 months		*P*-value	Significant difference
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
SNA (°)	81.90	3.63	84.33	2.44	79.10	0.36	83.57	3.33	0.161	NS
SNB (°)	78.42	4.27	78.40	4.92	75.47	1.33	79.07	4.22	0.703	NS
ANB (°)	3.48	0.91	5.93	2.85	3.63	0.97	4.50	2.42	0.306	NS
FMA (°)	25.24	1.96	30.40	5.84	28.90	4.43	29.33	7.05	0.438	NS
U1 to NA (mm)	9.78	2.34	6.25	2.50	10.43	0.81	8.57	0.32	0.058	NS
U1 to NA (°)	34.98	4.88	21.33	7.83	34.37	6.18	27.43	2.66	0.020	* (※)
L1 to NB (mm)	9.36	0.92	9.85	2.20	10.10	2.75	11.07	2.45	0.720	NS
L1 to NB (°)	37.70	3.21	34.55	4.16	39.43	1.06	34.10	3.27	0.164	NS
A'-Ptm' (mm)	49.54	3.01	51.98	0.41	46.60	1.23	50.97	4.85	0.136	NS
Ptm'-Mo (mm)	18.90	3.46	20.50	4.25	17.43	5.37	20.63	7.44	0.824	NS
A'-Mo (mm)	30.64	1.42	31.48	4.09	29.17	4.14	30.33	2.75	0.813	NS
Ms-OLp (mm)	58.02	4.20	62.75	4.27	55.00	5.00	58.50	2.78	0.159	NS
Mi-OLp (mm)	60.00	4.03	64.38	4.52	60.33	6.66	62.50	1.80	0.501	NS
Is-OLp (mm)	91.66	5.73	95.88	2.84	88.17	1.89	93.07	3.49	0.161	NS
Ii-OLp (mm)	87.16	4.50	90.88	2.95	84.00	5.57	88.90	0.36	0.192	NS
M6sc-NL (mm)	23.52	2.26	24.58	1.89	24.67	3.22	25.07	1.61	0.788	NS
M7sc-NL (mm)	18.96	1.93	21.00	1.89	21.13	5.49	20.90	2.43	0.672	NS
M6ic-ML (mm)	34.96	3.31	36.60	1.49	34.70	4.33	35.03	1.26	0.794	NS
L6 inclination (°)	101.00	4.30	104.75	5.38	103.67	7.09	100.00	2.65	0.562	NS
L7 inclination (°)	98.40	9.07	105.75	5.25	101.17	10.20	100.67	7.57	0.622	NS

※Tukey's test
2 months vs. 3 months, $P = 0.022$
Other, NS

＊ : $P<0.05$
NS : not significant

Table 5. Comparison of jaw morphology by duration of Class III elastic use

	2 months						3 months						4 months						5 months					
	To		T 1				To		T 1				To		T 1				To		T 1			
Variables	Mean	SD	Mean	SD	*P*-value	Significant difference	Mean	SD	Mean	SD	*P*-value	Significant difference	Mean	SD	Mean	SD	*P*-value	Significant difference	Mean	SD	Mean	SD	*P*-value	Significant difference
SNA (°)	81.90	3.63	82.02	3.57	0.109	NS	84.33	2.44	84.33	2.44	Untestable		79.10	0.36	79.10	0.36	Untestable		83.57	3.33	83.67	3.23	0.225	NS
SNB (°)	78.42	4.27	78.76	4.00	0.124	NS	78.40	4.92	78.38	4.94	0.836	NS	75.47	1.33	74.83	0.74	0.210	NS	79.07	4.22	78.50	4.23	0.023	*
ANB (°)	3.48	0.91	3.26	0.73	0.151	NS	5.93	2.85	5.95	2.87	0.836	NS	3.63	0.97	4.27	0.38	0.210	NS	4.50	2.42	5.17	2.35	0.031	*
FMA (°)	25.24	1.96	25.18	2.06	0.573	NS	30.40	5.84	30.80	6.02	0.278	NS	28.90	4.43	29.80	5.03	0.188	NS	29.33	7.05	30.57	7.25	0.014	*
U1 to NA (mm)	9.78	2.34	10.38	2.40	0.112	NS	6.25	2.50	6.85	3.11	0.232	NS	10.43	0.81	11.30	0.30	0.112	NS	8.57	0.32	9.27	0.31	0.109	NS
U1 to NA (°)	34.98	4.88	36.64	6.09	0.200	NS	21.33	7.83	22.73	10.47	0.386	NS	34.37	6.18	37.63	5.36	0.093	NS	27.43	2.66	30.70	2.63	0.191	NS
L1 to NB (mm)	9.36	0.92	9.00	0.60	0.291	NS	9.85	2.20	9.55	2.61	0.654	NS	10.10	2.75	9.20	2.21	0.560	NS	11.07	2.45	10.37	2.89	0.379	NS
L1 to NB (°)	37.70	3.21	37.72	3.05	0.987	NS	34.55	4.16	33.13	5.73	0.396	NS	39.43	1.06	35.77	7.95	0.500	NS	34.10	3.27	31.80	6.00	0.448	NS
A'-Ptm' (mm)	49.54	3.01	49.54	3.01	Untestable		51.98	0.41	51.98	0.41	Untestable		46.60	1.23	46.70	1.14	0.225	NS	50.97	4.85	51.10	4.70	0.270	NS
Ptm'-Mo (mm)	18.90	3.46	19.22	3.57	0.173	NS	20.50	4.25	20.93	3.94	0.231	NS	17.43	5.37	18.27	5.13	0.054	NS	20.63	7.44	21.10	7.31	0.085	NS
A'-Mo (mm)	30.64	1.42	30.32	1.19	0.173	NS	31.48	4.09	31.05	3.81	0.231	NS	29.17	4.14	28.43	4.01	0.058	NS	30.33	2.75	30.00	2.72	0.109	NS
Ms-OLp (mm)	58.02	4.20	58.10	4.17	0.099	NS	62.75	4.27	63.05	4.24	0.092	NS	55.00	5.00	55.50	4.50	0.225	NS	58.50	2.78	59.30	2.50	0.086	NS
Mi-OLp (mm)	60.00	4.03	60.00	4.23	1.000	NS	64.38	4.52	64.00	4.43	0.215	NS	60.33	6.66	59.90	6.18	0.281	NS	62.50	1.80	62.53	2.20	0.926	NS
Is-OLp (mm)	91.66	5.73	92.10	5.39	0.192	NS	95.88	2.84	96.43	3.10	0.128	NS	88.17	1.89	89.33	2.08	0.118	NS	93.07	3.49	93.73	3.96	0.270	NS
Ii-Olp (mm)	87.16	4.50	87.06	4.19	0.802	NS	90.88	2.95	90.25	3.20	0.504	NS	84.00	5.57	83.50	4.77	0.622	NS	88.90	0.36	87.87	0.65	0.166	NS
M6sc-NL (mm)	23.52	2.26	23.72	2.13	0.103	NS	24.58	1.89	24.83	2.08	0.269	NS	24.67	3.22	25.23	3.54	0.136	NS	25.07	1.61	25.67	1.63	0.009	*
M7sc-NL (mm)	18.96	1.93	19.28	2.10	0.105	NS	21.00	1.89	21.33	2.25	0.262	NS	21.13	5.49	22.07	5.45	0.202	NS	20.90	2.43	21.37	2.15	0.229	NS
M6ic-ML (mm)	34.96	3.31	35.20	3.21	0.109	NS	36.60	1.49	36.95	1.87	0.391	NS	34.70	4.33	35.13	4.08	0.133	NS	35.03	1.26	35.90	0.61	0.169	NS
L6 inclination (°)	101.00	4.30	104.50	2.69	0.057	NS	104.75	5.38	113.25	4.17	0.002	*	103.67	7.09	112.17	8.78	0.015	*	100.00	2.65	110.50	5.27	0.027	*
L7 inclination (°)	98.40	9.07	101.30	7.84	0.068	NS	105.75	5.25	114.50	8.44	0.039	*	101.17	10.20	111.83	11.51	0.012	*	100.67	7.57	113.33	5.69	0.009	*

＊ : $P<0.05$
NS : not significant

5 months.

The changes in inclination angles were significantly larger in the 5-month group for L6 inclination ($P = 0.013$) and in the 4- and 5-month groups for L7 inclination ($P = 0.034$ and 0.0094, respectively) compared with the 2-month group, indicating increased distal inclination of the mandibular first and second molars. No significant differences were observed in the changes in U-1 to NA (distance/angle), L-1 to NB (distance/angle), A'-Ptm', Ptm'-Mo, A'-Mo, Ms-OLp, Mi-OLp, Is-OLp, or Ii-OLp, indicating no changes in the mesiodistal position of the maxillary and mandibular central incisors and first molars.

As for skeletal variables, the change in SNB was significantly smaller in the 4- and 5-month groups compared with the 2-month group ($P = 0.020$ and 0.030, respectively). The change in ANB was significantly larger in the 4- and 5-month groups compared with the 2-month group ($P = 0.024$ and 0.019, respectively). The change in FMA was also significantly larger in the 5-month group compared with the 2-month group ($P = 0.019$) (Fig. 4).

Discussion

Invention of the Palatal Nance Lingual Arch (PNLA)

Anchorage refers to resistance to unwanted tooth movement[12]. Ensuring reliable anchorage during lingual movement of the anterior teeth or distal movement of the canines, as well as during the use of intermaxillary elastics, is important for successful treatment.

In this study, we used an intramaxillary anchorage method that is not affected by the cooperation of the patient, and that uses the teeth, alveolar bone, and palate in the same jaw as the sources of anchorage for Class III elastics. Conventional intramaxillary anchorage appliances for the maxilla include the palatal bar, the Nance holding arch, and the lingual arch.

The palatal bar is an anchorage appliance developed by Goshgarian and designed to cross the palate and connect the bilateral molars[13]. It provides a loop in the middle of the palate for expansion of the dental arch and rotation of the molars, and also provides reinforced anchorage during maxillary anterior retraction. It has also been reported that the tongue puts pressure on the palatal arch during chewing, swallowing, and speaking, and that the force applied in the intrusive direction holds the molars vertically[14]. In LAS, the use of a palatal bar is recommended when using Class III elastics to prevent extrusion and mesial movement of the maxillary molars[8].

The Nance holding arch, a fixed orthodontic appliance consisting of bands, a main wire, and an acrylic button, is considered to prevent mesial movement of the molars by connecting the bilateral molars for reinforced anchorage and by providing support from the mucosal surface

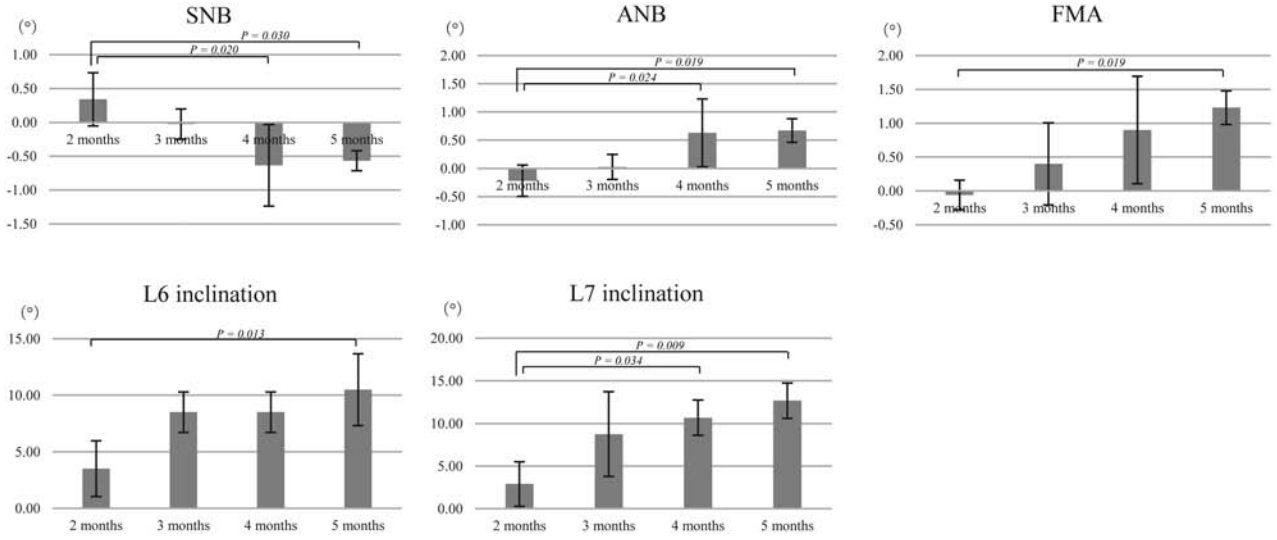

Fig. 4. Comparison of changes in jaw morphology by duration of Class III elastic use (SNB, ANB, FMA, L6 inclination, L7 inclination).

through the resin part[15,16]. During distal movement of the maxillary canines, the amount of mesial movement of the maxillary first molars was reported to be less when anchorage was provided with a palatal bar combined with a Nance holding arch than with a palatal bar alone[17].

The lingual arch, invented by Mershon in 1918[18], provides bands attached to molars that serve as the main sources of anchorage, and it is widely used in clinical practice as it provides reinforced anchorage and enables tooth movement using main and auxiliary wires. The use of a lingual arch has been shown to be effective in preserving coronal arch length and width and preventing the extrusion of the teeth[19-21]. Renfroe[22] stated that as many available teeth as possible should be used for reinforcement of the anchorage source.

Thus, in this study, we devised the PNLA by combining a palatal bar, a Nance holding arch, and a lingual arch, so as to make the entire maxilla the source of anchorage for Class III elastics, and investigated whether the PNLA, when placed immediately after the start of treatment, could be substituted as the anchorage source for Class III elastics in the maxillary arch at the end of LAS step 1.

Uprighting of mandibular molars

The effects of typical Class III elastics include the promotion of mesiodistal tooth movements, including lingual movement of anterior teeth and distal movement of molars in the mandible and mesial movement of molars and labial movement of anterior teeth in the maxilla, and vertical tooth movements including extrusion of both anterior teeth and molars[23,24]. In LAS step 2, Class III elastics are used to upright the molars while leveling the mandibular arch for anchorage preparation as proposed by Tweed. This prevents the mesial movement and extrusion of the mandibular molars that may occur as a counteraction to the Class II elastics used during the lingual movement of the maxillary anterior teeth in step 6, and also enables lingual movement of the mandibular anterior teeth to the treatment goal.

Gebeck et al.[25] stated that in patients treated with Tweed's technique, insufficient anchorage preparation causes labial inclination of the mandibular anterior teeth, mesial movement and extrusion of the mandibular molars, and mandibular backward rotation when using Class II elastics, suggesting that anchorage preparation is crucial for good treatment outcomes.

In a clinical study comparing cephalometric measurements before and after treatment[26], the use of Class III elastics resulted in mandibular backward rotation, maxillary forward rotation, extrusion of the maxillary molars and lingual inclination of the mandibular anterior teeth. Meanwhile, no study has investigated changes in jaw morphology in detail after different durations of use of Class III elastics.

In this study, there was no significant difference in the distal inclination angle of the mandibular first and second molars before and after the use of Class III elastics in the 2-month elastic use group, whereas distal inclination of the mandibular first and second molars was observed in the 3-, 4-, and 5-month groups. The amount of change in the distal inclination angle of the mandibular first and second molars tended to increase as the duration of Class III elastic use increased from 2 months to 4 or 5 months, indicating increased uprighting of the mandibular molars. Thus, these results suggest that the use of Class III elastics for more than 3 months is effective to ensure sufficient uprighting of the mandibular molars for anchorage preparation.

Changes in maxillary molars and mandibular position

The results of this study revealed that the use of Class III elastics with the PNLA for 5 months showed maxillary first molar extrusion and increased FMA, but for 2, 3, and 4 months did not affect the maxillary dentition or skeletal jaw morphology, except for uprighting of the mandibular first and second molars. Specifically, the PNLA did not cause any extrusion of the maxillary first molars up to 4 months of Class III elastic use and was considered to be an effective anchorage source for Class III elastics.

Regarding the effect of Class III elastics on the maxillary first molars, Kameda[26]. treated mandibular prognathism with Begg's technique using round wires and Class III elastics and noted an average of 1.83 mm extrusion and 2.13 mm mesial movement of the maxillary first molars. Nakamura et al.[27] reported that the use of Class III elastics with the edgewise technique using a multi-bracket appliance (0.018 × 0.025-inch slots) resulted in an average of 1.1 mm extrusion of the maxillary first molars. In this study using the PNLA as

the source of anchorage for Class III elastics, extrusion of the maxillary first molars was noted in patients who used Class III elastics for 5 months, but the amount of extrusion, 0.60 mm on average, was smaller than the aforementioned reports, suggesting that the PNLA was able to reduce extrusion of the maxillary first molars, which is a counteraction to Class III elastic use.

Moreover, no mesial movement of the maxillary first molars was observed in this study. This was probably because the bilateral maxillary first premolars, in addition to the maxillary first molars, served as anchorage teeth for the PNLA bands, and also because the addition of a Nance holding arch and a lingual arch also reinforced anchorage at the anterior portion of the maxillary arch, thus preventing the mesial movement of the maxillary arch that would otherwise be caused by Class III elastics.

These results suggest that the duration of Class III elastic use should be limited to 4 months to avoid the risk of further mandibular backward rotation and resulting increased complexity of treatment, especially in patients with a large FMA angle at the beginning of treatment. Moreover, when Class III elastics are to be used for 5 months or longer, attention should be paid to any changes in the maxillary first molars and mandibular position.

The limitation of this study include a small sample size, and a lack of data on patients who performed LAS step 1 of the conventional method (Table 1A) and used Class III elastics. For future studies, it is necessary to compare conventional LAS and PNLA usage to confirm the effectiveness of PNLA.

Conclusion

In this study, in order to reduce the duration of application of a multi-bracket appliance in the maxilla in LAS, we devised the PNLA as an anchorage appliance by combining a palatal bar, a Nance holding arch and a lingual arch, and used it as the source of anchorage for Class III elastics in the maxillary arch to replace maxillary stabilization in LAS step 1.

The results showed no significant difference in maxillary dentition or skeletal changes up to 4 months of Class III elastic use, suggesting that the PNLA is an effective anchorage source for Class III elastics. These results indicate that the PNLA with Class III elastics, when used for an appropriate duration, can shorten the treatment period without compromising the treatment outcome.

The authors have no financial conflict of interest to disclose concerning the paper.

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