Cephalometric Analysis of the Velopharyngeal Muscular Triangle as a Possible Prognostic Factor for Velopharyngeal Closure in Submucous Cleft Palate

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Abstract

Objective: To elucidate the anatomical characteristics of submucous cleft palate (SMCP), we analyzed the velopharyngeal (VP) structures focusing on the relationship between the position of posterior pharyngeal wall (PPW) in the VP muscles and VP closure acquisition in SMCP patients.

Methods: Cranial landmarks for cephalomatric analysis were identified in a study of two cadavers, and the area of the velopharyngeal muscular triangle (VPM-triangle), which was bordered by the origin of the levator veli palatini muscle, the origin of the palatopharyngeal muscle, and the insertion of both muscles, was defined. We then cephalometrically measured the VP structures of 14 SMCP patients (SMCP group) and the position of the PPW within the VPM-triangle. As a comparison group, 20 healthy Japanese childreqwMph]of 14 healents (SRMwthe4 (etini patmfoftmern

pharyngeal wall (PPW). These motions, especially the backward and upward movements of the soft palate, are mainly controlled by the coordinating mechanism of the levator veli palatini and palatopharyngeal muscles [14,15]. Podvinec [16] explained the function of the soft palate by demonstrating the synthesized motion vectors of the levator veli palatini and palatopharyngeal muscles, and suggested that a discrepancy in craniopharyngeal growth might cause tonic contraction of the soft palate in an abnormal direction. The authors previously examined the craniopharyngeal morphology of cleft palate (CP) patients with persistent VPI and reported that anatomical discrepancies of the upper pharynx, such as a wide base and counterclockwise rotation of the pharyngeal triangle, which included the cranial base, cervical vertebrae, and posterior maxilla, were related to persistent VPI after palatal repair [17]. From the above findings, it can be hypothesized that a positional discrepancy of the synthesized motion of the levator veli palatini and palatopharyngeal muscles and PPW due to congenital craniopharyngeal growth abnormalities might make it difficult to achieve VP closure in SMCP patients.

The purpose of this study was to elucidate the reasons why it is difficult to achieve VP closure in SMCP patients. We analyzed the VP structures of SMCP patients focusing on the positional relationship between PPW and the velopharyngeal muscles. Then, we examined the relationship between these factors and VP closure acquisition in order to discuss possible prognostic factors associated with VP closure in SMCP patients.

Methods

Subjects

Fourteen patients with submucous cleft palate (SMCP), who were diagnosed and treated at the Department of Oral and Maxillofacial Surgery, Kagoshima University Medical and Dental Hospital (Kagoshima University Hospital), were enrolled and subjected to cephalometric analyses of their VP structures (SMCP group). The patients included 6 males and 8 females, and their age at the time of the cephalometric assessment ranged from 3 years and 2 months to 11 years and 8 months (mean: 6 years and 7 months) (Table 1). A diagnosis of SMCP was made when a patient exhibited Calnan's triad: bifid uvula, translucency of the midline of the soft palate, and a V-shaped defect of the posterior edge of the hard palate [3]. Before the operation, a nasopharyngeal fiberscopic examination was performed in all patients to ensure midline defect of the nasal surface of the soft palate representing the incomplete union of palatal muscles. All of the patients were Japanese and belonged to a consecutive series of patients that visited our outpatient department between 2006 and 2013. Patients whose clinical symptoms were suggestive of 22q11.2 deletion syndrome were excluded. In addition, other syndromic patients and those with mental retardation were also excluded. A mental development test based on a questionnaire examining exercise, social skills, and language was performed, and the patients that presented with significant delays (more than one year) were considered to be mentally retarded.

	SMCP	Control	Postop CP
No of Subjects	14	20	20
Sex distibution			
Male	6	10	9
Female	8	10	11
Age (mean) at Cephalometric assessment	3 yrs 2 months-11 yrs 8 months	4 yrs 6 months-6 yrs 2 months	4 yrs 0 months-6yrs 9 months

T is study was approved by the clinical research ethical review board of Kagoshima University Graduate School of Medical and Dental Sciences (#93).

Comparison of cephalometric measurements of VP structures

Lateral cephalometric radiographs that were obtained in a resting position were used for the analyses of craniopharyngeal morphology. T e lateral cephalometric radiographs of the subjects in the SMCP group were taken before the palatoplasty was performed. T e dimensions of the craniopharynx were measured by a single examiner (M.T.) to eliminate interoperator error and any operator-based bias. T e skeletal landmarks and measurements were derived from tracings of the lateral cephalograms by drawing the S-N plane to create the X-axis, and projecting a line that ran perpendicular to this plane through point S to create the Y-axis. T e reference baseline and cephalometric landmarks are illustrated in Figure 1.

Figure 1: Cephalometric landmarks and velopharyngeal measurements. S=sella: the midpoint of the sella turcica; N=nasion: the most anterior point of the nasofrontal suture; ANS=anterior nasal spine: the tip of the anterior nasal spine; PNS = posterior nasal spine: the tip of the posterior nasal spine; PPW=posterior pharyngeal wall: the margin of the posterior pharyngeal wall at the junction of the palatal plane; S'=the top of the upper pharyngeal space: the point at the junction of the line running perpendicular to the S-N plane and the posterior pharyngeal wall; S"=the bottom of the upper pharyngeal space: the point at the junction of the line running perpendicular to S-S' and the palatal plane. Velar length (PNS-U), pharyngeal depth (PPW-PNS), and pharyngeal height (S'-S") were measured.

T e measurements included velar length (PNS-U), pharyngeal depth (PNS-PPW), and pharyngeal height (S'-S"), and the ratio of velar length to pharyngeal depth (PNS-U/PNS-PPW × 100) was also calculated. As the age and sex distribution (and hence, craniofacial size) of the subjects in the CP and control groups was uneven, all craniopharyngeal dimensions were standardized relative to the length of the anterior cranial base (S-N), which was given a value of 100 (S-N revised).

Identi f cation of anatomical landmarks relating to the motion vectors of the palatopharyngeal muscles

Prior to the analysis of the cephalometric analysis of VP structure, we identiŽed landmarks that corresponded to the origin (L) and insertion (M) of the levator veli palatini muscle and the origin (P) and insertion (M) of the palatopharyngeal muscle using two cadavers (Figure 2a).

Figure 2 (a): Analysis of the position of the PPW within the VPMT. T e identiŽcation of anatomical landmarks corresponding to the origins and insertions of the velopharyngeal muscles using cadavers (a) and the equivalent cephalometric landmarks used to delineate the VPMT.

T e corresponding lateral cephalogram landmarks for the VPM-triangle were deŽned as follows (Figure 2b):

L: T e junction of the bottom of the sphenoid bone and the anterior border of the mandibular condyle

P: T e center of the anterior border of the 4th cervical vertebra

M: T e anterior 1/3rd of the so f palate

V: T e junction of the virtually synthesized motion vector M-L, the motion vector M-P, and the posterior border of the VPM-triangle (L-P).

To analyze the anteroposterior position of the PPW within the VPM-triangle (the PPW to VPM-triangle ratio), the anteroposterior position of the point PPW', which was the located at the junction of an extended version of L-PPW and the virtually synthesized vector M-V, was calculated using the following formula:

Anteroposterior position of PPW=M-PPW'/M-V × 100

T e PPW to VPM-triangle ratio was compared among the SMCP, CP, and control groups.

T e skulls of two so f embalmed cadavers were dissected at the midline. T rough the sagittal plane of each hemi-face section, the origins and insertions of the levator veli palatine and palatopharyngeal muscles were identiŽed. We then chose cephalometric landmarks that corresponded to these origins and insertions. T e triangle produced by l t ie o ie ʾ itvtt ieief -

face section was named the velopharyngeal muscular triangle (VPM-triangle).

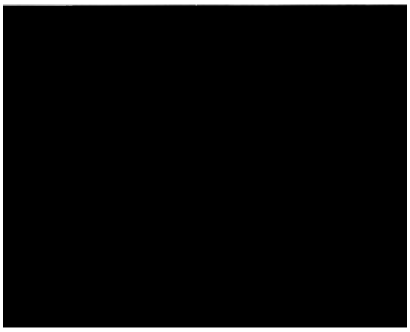

Figure 2 (b): Analysis of the position of the PPW within the VPMT. T e identiŽcation of anatomical landmarks corresponding to the origins and insertions of the velopharyngeal muscles using cadavers. (b) L=origin of the levator veli palatini muscle (cadaver)/the junction of the bottom of the sphenoid bone and the anterior border of the mandibular condyle (cephalogram); M=insertion of the levator veli palatini and palatopharyngeal muscles (cadaver)/ the anterior 1/3rd of the so f palate (cephalogram); P=origin of the palatopharyngeal muscle (cadaver)/the center of the anterior border of the 4th cervical vertebra (cephalogram); V=the point at the junction of the virtually synthesized vector M-L, the vector M-P, and the posterior border of the VPM-Triangle; PPW'=the junction between an extended version of L-PPW and the virtually synthesized vector M-V. T e anteroposterior position of the PPW within the VPM-Triangle=M-PPW'/M-V x 100.

Analysis of the relationship between the PPW to VPM-triangle ratio and VP closure achievement in the SMCP group

Postoperatively, the SMCP patients were followed-up every 3 months by two speech-language-hearing therapists (SLHT) belonging to the cle f lip and palate (CLP) team. Reliable speech assessments including of hypernasality, nasal emission, and VP closure status were performed by one SLHT (N.M.) to avoid an inter examiner error. In the speech assessment, hypernasality and nasal emission were categorized into four groups: normal, slight, moderate, and severe. Furthermore, according to the results of these assessments, VP closure status was then judged as VP competence (VPC), borderline VPC, borderline VPI, or VPI. During the speech assessments, cephalograms obtained during the phonation of the /i/ syllable, and Nasometer test

Comparison of the anteroposterior position of the PPW within the VPM-triangle among the three groups

Figure 3 schematizes the mean craniopharyngeal structure measurements obtained in the three groups superimposed on the S-N plane (X-axis) and the line perpendicular to it (Y-axis).

T e form of the VPM-triangle and the position of the PPW within the VPM-triangle varied among the three groups. T e VPM-triangle of the SMCP group was anteroposteriorly wider than that of the control group. T e VPM-triangle of the postoperative CP group was anteroposteriorly narrower, vertically longer, and rotated counterclockwise compared with those seen in the other two groups.

Regarding the position of the PPW, the height of the PPW was almost the same in all three groups. T e anteroposterior position of the PPW di ered among the three groups (Figure 3). T e PPW was situated near to the line running perpendicular to S-N in the postoperative CP group, and the PPW was much closer to the motion vector line L-M in the control and postoperative CP groups than in the SMCP group.

	SMCP (n=14)	Control (n=20)	Postop. CP (n=20)
PPW to VPM-triangle ratio	47.87 ± 21.95	39.94 ± 16.82	33.35 ± 12.26

Table 3: Comparison of the PPW to VPM-triangle ratio between the SMCP, control, and postoperative CP groups

Statistical analyses of the mean (and SD) PPW to VPM-triangle ratio revealed that the ratio of the SMCP group (47.87 ± 21.95) was signiŽcantly greater than that of the postoperative CP group (33.35 ± 12.26, $p<0.05$) and tended to be greater than that of the control group (39.94 ±1 6.82) (Table 3). T e above Žndings suggest that the PPW was positioned close to the motion vector of the levator veli palatini muscle in the healthy subjects and CP patients who had already acquired favorable VP closure, while it was situated more posteriorly within the VPM-triangle and further away from the synthesized motion vector of the levator veli palatini and palatopharyngeal muscles in the SMCP patients.

Figure 3:

(61.5%) in this series was markedly lower than those for patients with other cleft types, when we compare these findings with the postoperative acquisition rates of VP closure after palatoplasty at our department between 2006 and 2012 [18]. This investigation was an attempt to characterize the velopharyngeal structures that may influence VP closure acquisition in SMCP patients, focusing on the coordinating mechanism of the levator veli palatini and palatopharyngeal muscles and the location of the posterior pharyngeal wall. If possible, we also hoped to identify craniopharyngeal morphological markers that could be used as possible indicators of speech outcomes following palatal repair for SMCP.

Several conclusions are thought to be warranted from our data. The first major conclusion is that the craniopharyngeal structures of SMCP patients are characterized by a short velum and a deep and high sample size of the present study. T erefore, further studies are necessary to develop clinically useful prognostic factors for SMCP.

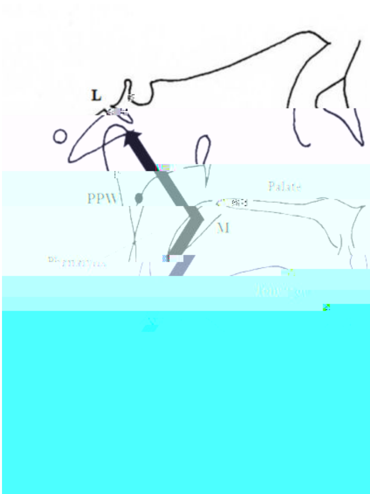

Figure 4(b): Schematic illustration of the craniopharyngeal structures of the VPMT of control and postoperaticve CP group SMCP groups (Figure 4b). T e craniopharyngeal structures of the SMCP patients were characterized by a: 1) a short velum, 2) a wide pharynx, 3) a wide-based VPM-Triangle, and 4) a posteriorly located PPW within the VPM-Triangel. Greater strength and ẑexibility in the so f palate might be required to achieve contact between the so f palate and pharyngeal wall in SMCP patients.

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