Cinefluorographic Study of Velarpharyngeal Function Before and After Removal of Tonsils and Adenoids

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Introduction

Obstruction of the nasal and nasopharyngeal passages has long been considered to be an important etiological factor of mouth breathing. It has been suggested that the so-called "adenoidal facies" type is the product of mouth breathing caused by enlarged adenoids.[1-2] Most authorities agree that enlarged adenoids can cause mouth breathing although they disagree on the percentage of cases so caused. The effects of both enlarged tonsils and adenoids upon the functions of the oronasopharyngeal areas would seem to require further intensive and objective study.

The purpose of the present investigation was to determine, from standardized cinefluorographic records, the resting posture and the patterns of movement of the oropharyngeal structures in children before and after surgical removal of both tonsils and adenoids. Deglutition and speech were chosen for the present investigation which centers, objectively, upon the position and patterns of movement of the velarpharyngeal structures, tongue, lips, mandible, and hyoid bone, with the hope of providing further information regarding the "form and function" relationship of these structures.

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Materials and Methods

The sample consisted of twenty-eight Caucasian children including seventeen boys and eleven girls. Their ages ranged from five to fourteen years with an average of eight and one-half years. These children attended the E.N.T. Clinic of the out-patient department of the Winnipeg Children's Hospital with a history of recurrent upper respiratory tract infection and were judged to require surgical removal of both tonsils and adenoids as soon as all the acute signs and symptoms of the upper respiratory tract infection had subsided. Those patients with accompanying middle ear infection were not included in the present investigation.

All cinefluorographic records were obtained by a lateral plane projection at the time when the child was admitted for surgery. The movements of the oronasopharyngeal structures during deglutition and speech were recorded on the cine films using a standardized sequence. Patients were instructed to stand relaxed and watch a small object placed at eye level approximately five feet away during the cinefluorographic sequence. Radiopaque paste was painted on the midline of the tongue and lips to help identify these structures. About 5 cc. of water was given to the patient and the patient directed to swallow upon the request of the operator. This was followed by a short pause after which the patient recited, "Peter looks silly swimming." The sequence often ended by the patient performing a saliva clearance swallow. The complete sequence

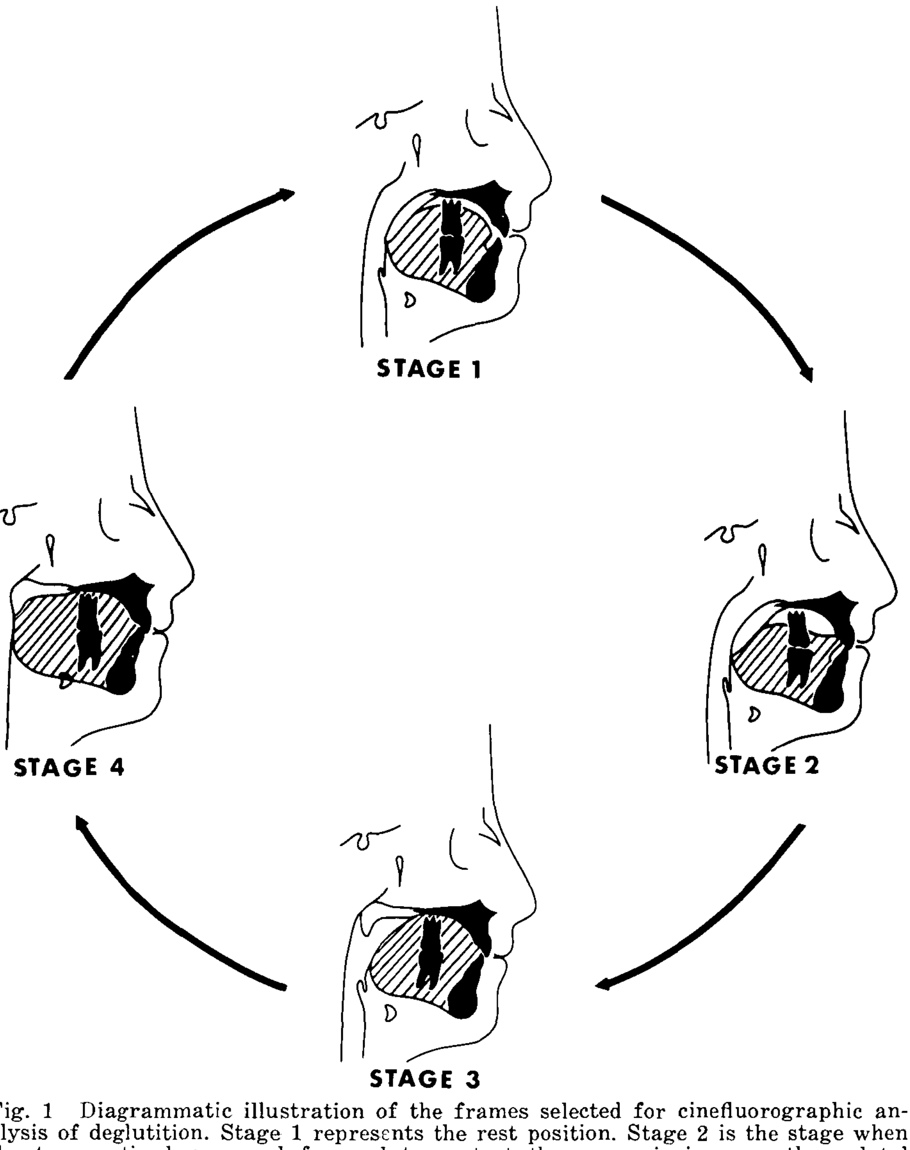

Fig. 1 Diagrammatic illustration of the frames selected for cinefluorographic analysis of deglutition. Stage 1 represents the rest position. Stage 2 is the stage when the tongue tip has moved forward to contact the upper incisors or the palatal mucosa. Stage 3 is the stage when the dorsum of the tongue has reached the junction of the hard and soft palates. Stage 4 is the stage when the hyoid bone has reached its higher and most forward position.

was carried out in an unhurried manner and lasted less than forty seconds. A similar sequence was obtained from each patient six weeks after surgery when normal function had been restored.

The cinefluorographic equipment consisted of an x-ray source, a space to position the patient, an image intensifier, and a 16 mm cine camera to record the attenuated x-ray beam.[4,7] The 16 mm cine camera was synchronized with the x-ray tube and set to run at a speed of thirty frames per second.

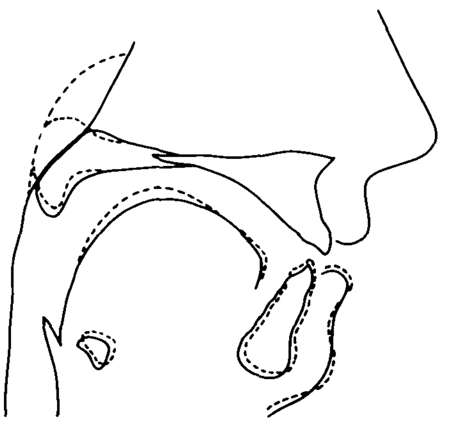

Fig. 2 A composite diagram showing the production of "E" sound before (solid) and after (dash) operation.

Suitable frames for the study of resting postures, swallowing and speech were selected using a Tagarno editing projector. Five frames per sequence were analyzed, four frames in swallowing and one frame in the "E" sound. Figure 1 shows the four stages of swallowing chosen for the present study. Following Stage 4, the swallowing sequence was completed by the return of the structures to the resting posture. This final stage was designated Stage 5 but was not analyzed due to the fact that it was similar to Stage 1. Figure 2 shows the frame selected for the analysis of the "E" sound on pronouncing the first part of the word "Peter." In choosing a swallowing cycle, a non-demanded saliva swallow was preferred.

The cinefluorographic analysis of the individual frames was carried out on a Vanguard Motion Analyzer. A standardized set of angular and linear measurements was used for the analysis of each individual frame using the palatal plane as the plane of reference. Registration on this plane was made at either a point perpendicular to the pterygomaxillary fissure (R) or a point perpendicular to point A (R′), (Figs. 3, 4 and 5).

Angular Measurements

Angles formed with the palatal plane at R: Angle A is the angle formed with the mandibular central incisor. Angle B is the angle formed with the tip of the tongue. Angle C is the angle formed with menton. Angle D is the angle formed with the hyoid bone. Angle E is the angle formed with the tip of soft palate.

Angles formed with the palatal plane at R′: Angle G is the angle formed with the mandibular central incisor. Angle H is the angle formed with pogonion. Angle I is the angle formed with the tip of the tongue.

Linear Measurements

Vertical Measurements: Length a is the velar height. Length b is the distance between the palatal plane and tip of soft palate. Length c is the distance between the palatal plane and the hyoid bone. Length d is the distance between the palatal plane and menton. Length e is the distance between the palatal plane and tongue tip. Length h is the distance between the upper and lower lips. Length i is the interincisal distance. Length k is the intermolar distance.

Horizontal Measurements

Length l is the distance between the vertical projection of PTM and the posterior pharyngeal wall at the level of the palatal plane. Length m is the distance between the vertical projection of PTM and the posterior pharyngeal wall at the level of point A. Length n is the distance between the vertical projection of PTM and the posterior pharyngeal wall at the level of the maxillary central incisor. Length p is the distance between the tongue tip and the maxillary central incisor. Length q is the distance between the tongue tip and the mandibular central incisor. Length r is the separation between the tip of the soft palate and the posterior part of the tongue.

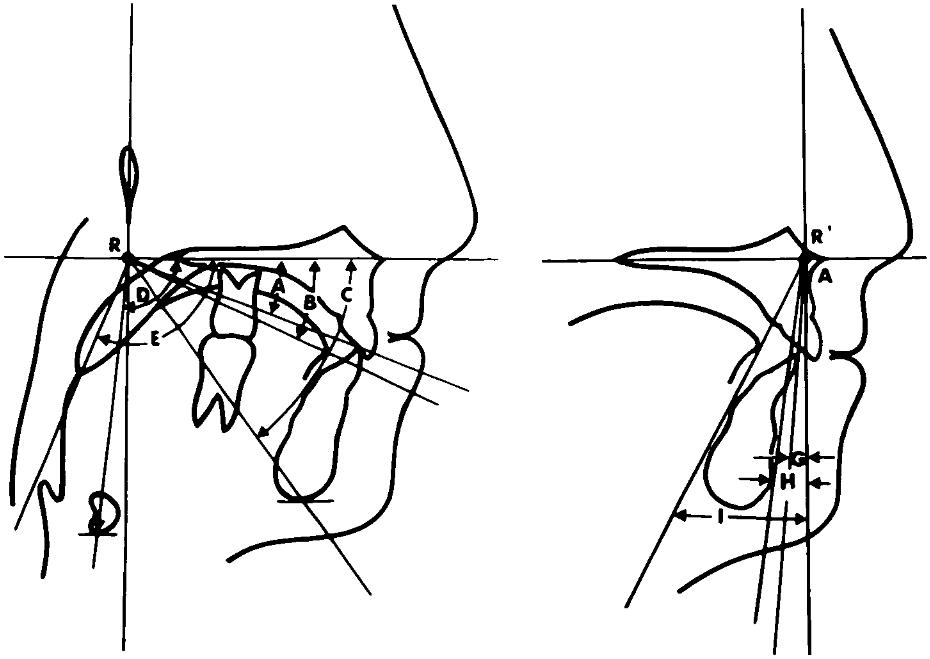

Fig. 3 Diagrams showing the angular measurements registered at R and R'.

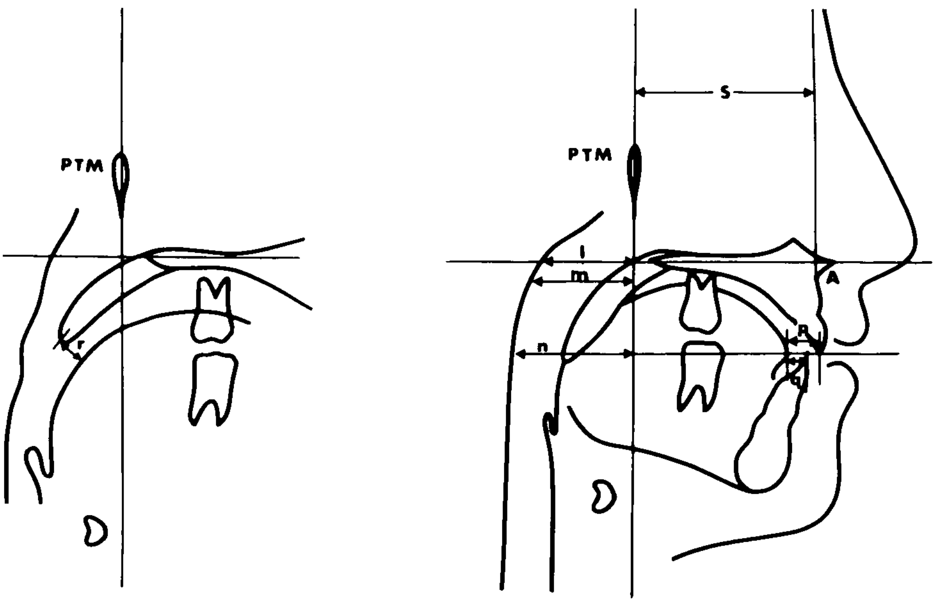

Fig. 4 Diagrams showing the linear measurements in the horizontal dimension and the separation between the soft palate and the posterior part of the tongue.

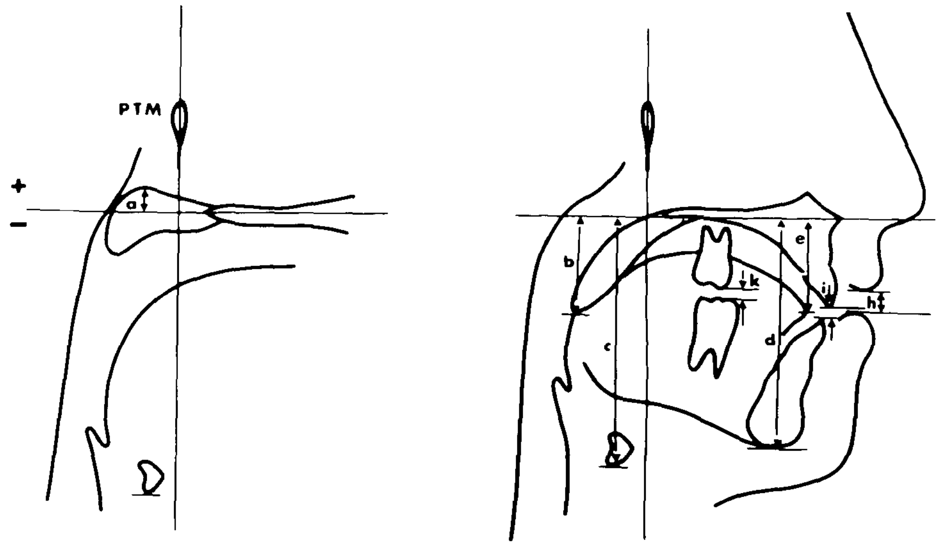

Fig. 5 Diagrams showing the linear measurements in the vertical dimension.

An effort was made to reduce the errors in the linear measurements due to variation in the individual patient's size. This was accomplished by measuring the distance between point A and the pterygomaxillary fissure (PTM), since these two bony landmarks are fairly accurately discernible on the cine films. This value "S" (Fig. 4) on each frame was measured and the mean of this value (Sm) for each patient was calculated from all the frames measured. Each linear measurement was divided by the value of "S" of that frame to give a ratio. The ratio so obtained was multiplied by the value of (Sm) of that patient to eliminate magnification error. Each linear measurement was then further corrected by the standard magnification factor for the Vanguard Motion Analyzer to give, as close as possible, the true dimension of the linear measurement in the midsagittal plane.

All the angular and linear measurements were recorded on a computer sheet and then subjected to standard statistical evaluation including means, standard deviations, test for significance, and correlation coefficients.

Results

I. *Time Analysis of Deglutition*

A time analysis of the sequence of movement during the act of swallowing between the initial and final resting position resulted in no statistical significance being found between the various stages of deglutition before and after operation. The average time required for one complete swallowing cycle was 1.56 seconds before operation and 1.40 seconds after operation, indicating a trend that patients with enlarged tonsils and adenoids required a longer time to perform a swallowing cycle. The reason for this might be related to the physical size of the tonsils or the inflammatory state of the structures found in the oropharyngeal area.

II. *Velarpharyngeal Closure* (Tables I, II and III)

The height of the velum was found to have risen to above the level of the palatal plane at Stage 3, reaching its maximum value at Stage 4 of deglutition. During the production of "E" sound, the velar height (length *a*) was found to be significantly greater than that at Stage 4 of deglutition. After

TABLE I

CINEFLUOROGRAPHIC ANALYSIS OF DEGLUTITION BEFORE OPERATION

	STAGE 1		STAGE 2		STAGE 3		STAGE 4	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
Angle A	31.7	4.1	30.4	4.9	30.9	4.6	30.9	5.0
Angle B	34.2	7.7	28.5	6.8	29.7	7.3	29.4	6.5
Angle C	63.5	4.7	62.5	5.3	63.4	4.8	63.1	5.7
Angle D	101.3	6.1	101.0	6.4	102.0	6.7	96.1	7.5
Angle E	136.4	7.2	138.6	6.1	143.9	7.6	146.3	6.6
Angle G	-6.4	6.4	-4.9	6.6	-6.0	6.3	-5.6	7.2
Angle H	-11.6	4.5	-10.2	4.4	-11.4	4.6	-11.4	4.9
Angle I	-17.2	9.6	-11.4	9.6	-10.8	10.5	-9.5	11.1
Length a	0.0	0.0	0.1	0.3	2.4	2.2	3.3	1.9
Length b	20.3	4.0	18.6	3.9	16.3	3.6	14.9	3.3
Length c	59.7	8.3	57.3	9.1	53.8	9.4	49.1	8.1
Length d	63.3	7.5	62.9	8.1	62.7	7.7	62.5	7.9
Length e	26.4	3.8	23.7	4.3	24.1	4.4	23.8	4.7
Length h	-2.6	3.0	-1.1	2.4	-1.1	2.6	-1.2	2.6
Length i	-2.3	3.7	-1.9	3.7	-1.3	3.6	-1.4	3.7
Length k	-2.9	2.0	-2.3	2.0	-2.3	1.9	-2.1	2.0
Length l	19.9	5.7	19.7	6.2	19.6	6.6	18.1	6.6
Length m	27.2	4.8	26.7	4.8	26.6	4.9	24.9	5.1
Length n	33.3	6.3	33.2	6.2	33.5	6.1	32.4	6.6
Length p	9.4	5.2	6.5	4.7	6.3	5.3	5.9	4.1
Length q	5.2	6.5	2.8	5.5	2.1	5.8	1.6	5.5
Length r	4.3	2.7	4.9	3.6	5.9	2.4	0.6	1.7

TABLE II

CINEFLUOROGRAPHIC ANALYSIS OF DEGLUTITION AFTER OPERATION

	STAGE 1		STAGE 2		STAGE 3		STAGE 4	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
Angle A	30.7	5.0	30.1	4.6	30.0	4.6	29.8	5.3
Angle B	31.2*	5.1	27.5	4.4	27.8	4.3	27.5	4.9
Angle C	62.6	5.6	62.6	5.3	62.5	5.6	62.5	6.3
Angle D	100.1	7.2	101.1	7.2	101.5	7.1	96.8	9.3
Angle E	134.3	8.2	137.3	8.7	143.3	7.6	146.8	6.5
Angle G	-5.2	7.5	-4.8	7.7	-6.0	7.2	-6.1	8.2
Angle H	-11.0	5.4	-11.4	5.3	-12.2	5.2	-12.1	5.6
Angle I	-14.2	8.1	-8.6	9.3	-8.0	10.5	-7.6	10.1
Length a	0.0	0.0	0.3	1.1	2.9	2.3	3.9	2.2
Length b	20.5	4.3	18.7	4.9	15.6	3.8	14.1	4.2
Length c	55.8	8.6	54.6	8.6	50.1	8.9	46.1	8.9
Length d	61.3	8.9	61.5	8.9	60.7	9.0	60.2	8.9
Length e	25.7	4.9	23.4	3.9	23.6	4.2	23.7	4.8
Length h	-1.9	2.9	-0.8	1.8	-0.9	2.7	-0.6	1.9
Length i	-1.4	4.2	-1.2	3.8	-0.9	4.0	-0.6	3.9
Length k	-2.2	1.9	-1.9	1.7	-1.8	1.9	-1.6	1.7
Length l	23.3*	4.5	22.8*	5.1	22.0	4.9	19.9	4.5
Length m	27.5	4.5	27.5	5.2	26.6	5.2	25.5	4.0
Length n	33.1	6.2	32.9	5.9	32.9	6.3	31.7	5.2
Length p	8.4	3.1	5.4	3.1	4.6	2.9	4.8	2.9
Length q	3.7	3.3	1.0	2.7	0.1*	3.3	0.2	3.2
Length r	1.3**	1.9	2.4**	2.4	4.1*	1.8	0.5	1.6

** = Significant at the 0.01 level of confidence when compared with similar values before operation

* = Significant at the 0.05 level of confidence when compared with similar values before operation

TABLE III

COMPARISON OF MEAN VALUES FOR THE PRODUCTION OF "E" SOUND

VARIABLE	BEFORE OPERATION MEAN	BEFORE OPERATION S.D.	AFTER OPERATION MEAN	AFTER OPERATION S.D.	DIFFERENCE
Angle A	33.3	4.5	32.5	4.3	0.8
Angle B	36.0	6.0	34.4	5.6	1.6
Angle C	64.8	5.0	64.1	5.2	0.7
Angle D	103.3	13.7	100.4	6.2	2.9
Angle E	146.1	6.6	146.0	7.3	0.1
Angle G	-6.7	6.6	-7.0	5.5	0.7
Angle H	-12.1	5.1	-13.0	4.9	0.9
Angle I	-20.0	7.6	-20.3	7.0	0.3
Length a	4.2	1.4	5.3	1.9	1.1**
Length b	15.9	3.2	14.8	3.5	1.1
Length c	59.9	7.5	56.4	8.5	3.5
Length d	65.2	8.9	62.4	9.5	2.8
Length e	27.5	4.6	25.9	4.5	1.6
Length h	-6.6	4.3	-6.1	3.8	0.5
Length i	-4.9	2.3	-4.3	2.4	0.6
Length k	-3.9	1.4	-3.6	1.6	0.3
Length l	20.5	5.5	21.4	5.0	0.9
Length m	27.6	4.9	26.8	3.7	0.8
Length n	34.5	6.1	33.6	5.7	0.9
Length p	11.9	3.7	11.1	3.4	0.8
Length q	7.1	4.0	6.5	2.8	0.6
Length r	8.9	3.6	7.5	4.7	1.4*

** = Significant at the 0.01 level of confidence
 * = Significant at the 0.05 level of confidence

operation, no significant increase of the velar height was observed in deglutition but a significant increase was found in the production of "E" sound, indicating that the velum had risen to a higher level above the level of the palatal plane in the production of "E" sound after surgery.

At rest, the separation between the soft palate and the posterior part of the tongue (length *r*) was significantly larger before operation than after operation. This means that the posterior oral seal had improved dramatically after the removal of the tonsils and adenoids. The present study revealed that twenty of the twenty-eight cases (71.4 per cent) showed a lack of posterior oral seal before operation. However, after operation, fourteen of the twenty cases (50 per cent) demonstrated contact between the soft palate and posterior part of the tongue, that is, a posterior oral seal. Four cases (14.3 per cent) showed a decrease in the separation between the soft palate and the tongue and two cases showed a slight increase (7.1 per cent).

The anteroposterior dimension of the nasopharyngeal isthmus at the level of the palatal plane at rest was found to have increased significantly after the removal of the adenoids. During swallowing the posterior pharyngeal wall tended to come forward. Such forward movement of the posterior pharyngeal wall at the level of the palatal plane became significant at Stage 4 of deglutition after surgery. No significant forward movement of the posterior pharyngeal wall was observed during the production of "E" sound both before and after operation.

III. *Oral Change during Deglutition*

During swallowing, the upward and forward movement of the tongue tip from its position at rest was found to be significantly more marked before operation due to a higher and more anterior resting position after operation.

Tongue thrusting beyond the lower incisors during swallowing was present in ten cases (36 per cent) before operation and eight (28.6 per cent) after operation. All the tongue-thrust cases had teeth apart swallow both before and after operation.

Seventeen of the cases in the present study (60.7 per cent) demonstrated lips apart at rest prior to surgery. However, after operation, five of these seventeen cases (17.9 per cent) had acquired lips together at rest. Although the remaining twelve cases still had lips apart posture, there was a tendency for the lips to come closer together.

IV. *Change of the Hyoid Position*

During swallowing the hyoid bone tended to move slightly upward and backward at Stage 3, before coming upward and forward at Stage 4. The positions of the hyoid bone appeared to be in a more upward and forward position both at rest and during all the stages of swallowing after operation.

V. *Coefficient of Correlation*

The coefficient of correlation (r) of selected pairs of variables before and after operation was considered only when the value of "r" was significant at or beyond the five per cent level of confidence.

At rest a positive correlation was obtained between the angle of the soft palate with the hard palate (Angle *E*) and the anteroposterior dimensions of the oropharynx at three different levels. These findings indicate that a larger horizontal dimension of the pharyngeal area was often associated with a relatively more horizontally placed soft palate.

After operation positive correlation was found between the velar height (length *a*) and the anteroposterior dimension of the nasopharynx (length *l*) in Stage 4 of deglutition and in the production of "E" sound. This indicates that, as the horizontal dimension of the nasopharyngeal isthmus had increased following the removal of the adenoidal mass, the velum had moved to a higher position during velarpharyngeal closure.

At rest, positive correlation also was found between the vertical dimension of the mandible (angle c and length *d*) and the anteroposterior dimension of the oropharynx at the level of the maxillary incisors (length *n*). This indicates that, as the mandible is farther apart at rest, the horizontal dimension of the oropharynx increases, demonstrating the tendency that oral breathing requires a larger dimension in the oropharynx.

Both at rest and during function the mandibular opening (angles a and c) was found to be positively correlated with the anteroposterior position of the hyoid bone (angle d). Also, the horizontal position of the hyoid bone (angle d) was found to have a positive correlation with the angle of the soft palate (angle e) as well as the anteroposterior dimensions of the oropharynx at various levels (lengths *l*, *m* and *n*). These findings indicate that the hyoid bone had adjusted itself to the altered positions of the various structures in the pharynx due to the presence of the enlarged tonsils and adenoids.

Correlation coefficients (r) of the various pairs of variables representing the mandible, mandibular incisors and the tongue all show that these structures were well related to one another both at rest and during swallowing indicating that these structures moved as a unit in all stages of deglutition. The positions of the tongue tip to these structures at rest and during swallowing were found to be correlated at a higher level of confidence after the removal of the tonsils and adenoids.

Discussion

It has been suggested that children with enlarged tonsils and adenoids exhibit abnormal postures and activities in the pharyngeal areas which could lead to secondary changes of the structures in the oral cavity. If such adverse postures and activities were allowed to continue during the growing period, mouth breathing, abnormal swallowing patterns, and tongue thrusting, it is suggested, could develop causing abnormal growth and development of the jaws and malocclusion. Although the present study deals with children in their growing period, the dimensional change of the various structures due to growth should be discounted in view of the short period of six weeks during which the pre and post operative films were taken.

The functional changes of the oral and pharyngeal structures due to the presence of enlarged tonsils and adenoids have shown that these structures had adapted themselves to the altered environment in order to carry out the vital functions of respiration, deglutition and speech.

The present study supports the findings of James and Hastings[6] that oronasal breathing is more common in tonsil and adenoid cases than mouth breathing. It also supports the findings of Gwynne-Evans and Ballard[5] that nasal breathing is resumed in the majority of cases as soon as the tonsils and adenoids are removed by improving the nasopharyngeal airway. None of the cases in the present study demonstrated a complete obstruction of the nasopharynx by the adenoids when the acute phase of infection was being controlled prior to surgery. Partial obstruction of the nasopharynx or nasopharyngeal isthmus was common in all cases and an air passage was clearly visible although sometimes it was found to be narrow and might easily be blocked by excessive catarrh and swollen nasal mucosa.

It appears that in the cases where the tonsils were excessively enlarged, the radiographic picture of the soft palate often showed an abnormal or irregular outline as was described by Ricketts[8]. There was also an apparent lack of posterior oral seal radiographically, because the soft palate was elevated to a varying degree by the physical size of the enlarged tonsils. After operation, these cases were found to have acquired a normal outline of the soft palate with the soft palate forming a smaller angle with the hard palate and a competent posterior oral seal. In those cases where both the tonsils and adenoids were unduly enlarged, oral breathing would require a fairly large drop or forward positioning of the mandible with changes of tongue position if mouth breathing were to take place. However, these latter cases were not found to be common.

In order to breathe through the mouth, there must be a channel for the air current to pass through the oral cavity. To achieve this, both the anterior and posterior oral seals have to be opened with the lips separated, teeth apart and the soft palate separated from the posterior part of the tongue. The present study showed that fourteen (50 per cent) of the twenty-eight cases had demonstrated separations in both the anterior and posterior regions of the oral cavity. This suggests that 50 per cent of cases did use the mouth to assist breathing when both the tonsils and adenoids were enlarged. However, after operation, only four (14.3 per cent) of the fourteen cases continued to demonstrate a lack of both anterior and posterior oral seals indicating that the mouth might still be used to assist breathing.

The present investigation has shown that enlarged tonsils and adenoids do alter the oropharyngeal mechanism in swallowing. The results suggested that swallowing was relatively "sluggish" and that the oropharyngeal mechanism had adjusted itself to overcome the partial obstruction in the oropharynx. After operation, the sluggishness in deglutition was found to have disappeared and the time required for one complete swallowing cycle was comparable to that of the normal sample which was described by Cleall[4].

The mechanisms for velarpharyngeal closure were found to be essentially the same in both deglutition and in most of the speech sounds. However, the velar height was found to be slightly higher in producing the word "Peter" when the "E" sound was preceded by the plosive "P", thus supporting the findings of Calnan[3]. After the removal of the enlarged adenoids, the antero-posterior dimension of the nasopharyngeal isthmus had increased with improvement of the nasopharyngeal airway. During velarpharyngeal closure, the soft palate was found to be more posteriorly placed having a smaller area of contact with the posterior pharyngeal wall. These findings support those which were reported by Subtelny[11]. In addition, the velar height was found to have risen to a higher level above the level of the palatal plane after the removal of the enlarged tonsils and adenoids especially during the production of "E" sound.

Teeth-apart swallow has been suggested to be a type of abnormal swallow. Some authorities believe that inflamed tonsils and adenoids are important causes of such an abnormal swallow[10,13]. However, the present study does not substantiate this hypothesis. Though the incidence of teeth-apart swallow was found to be higher in tonsil and adenoid cases, only two out of the twenty such cases swallowed with the teeth together after operation. This seems to suggest that teeth-apart swallow might not be caused by enlarged tonsils and adenoids and that this type of swallow might be characteristic of these individuals whether or not they have enlarged tonsils and adenoids.

It has been suggested that enlarged tonsils may cause forward positioning of the tongue both at rest and during deglutition[12,13]. The present investigation, however, does not support this hypothesis. The tongue was not found to protrude beyond the incisal edge of the lower incisors at rest. In fact, the position of the tongue tip was found to be more lingually placed in the oral cavity before operation. The explanation for such a tongue position may be based on the fact that once the anterior oral seal has become broken, the tongue would acquire a more lingual position in the oral cavity behind the mandibular incisors. However, after operation, the position of the tongue tip at rest was found to have taken a more upward and forward position indicating a possible re-establishment of the anterior oral seal.

During swallowing thirty-six per cent of cases showed tongue thrust before operation. After operation, the percentage of cases showing tongue thrust decreased to only twenty-eight per cent. This relatively small reduction of tongue thrust cases suggests that enlarged tonsils and adenoids do not appear to be important causes of tongue thrusting though they may have exaggerated the picture of tongue thrusting during the acute stages.

The position of the hyoid bone was found to show minor changes both in the vertical as well as the horizontal dimension. Such changes may be used as indicators for fine adjustment of the various muscles attached to the hyoid bone so that vital functions in the oral and pharyngeal areas may be carried out without interference from the enlarged tonsils and adenoids.

Summary and Conclusions

A cinefluorographic study of the resting posture and the pattern of movement of the oronasopharyngeal structures before and after surgical removal of both tonsils and adenoids was carried out on twenty-eight children. The findings from both statistical analysis and subjective evaluation of the results were as follows:

1. The oral and pharyngeal structures in children with enlarged tonsils and adenoids adapted themselves to the altered environment in order to carry out the important functions of respiration and deglutition and during velarpharyngeal closure in speech.
2. The radiographic findings indicate that oronasal breathing is more common in tonsil and adenoid cases than mouth breathing. Nasal breathing was found to have resumed in the majority of cases as soon as both the enlarged tonsils and adenoids had been removed.
3. When the acute phase of infection was being controlled prior to surgery, complete obstruction of the nasopharynx by the adenoids was rare and partial obstruction of the nasopharynx or nasopharyngeal isthmus was common.
4. The anteroposterior dimension of the nasopharyngeal isthmus at the level of the palatal plane had increased after surgery with improvement of the nasopharyngeal airway.
5. The area of contact between the soft palate and the posterior pharyngeal wall in velarpharyngeal closure was wide due to the presence of the enlarged adenoids before surgery, but was smaller and more posteriorly placed after operation.
6. The elevation of the velum in the production of "E" sound was

found to be higher after the removal of both the tonsils and adenoids.

7. Enlarged tonsils and adenoids were not found to be important causes of teeth-apart swallow and tongue thrusting.

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