CINEFLUOROGRAPHIC STUDY OF VELOPHARYNGEAL FUNCTION BEFORE AND AFTER SURGICAL REMOVAL OF TONSILS AND ADENOIDS

A Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirement for the Degree

Master of Science

by

Andrew Shing-Gaye Yip

Department of Dental Science

March, 1969

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ABSTRACT

Obstruction of the nasal and nasopharyngeal passages has long been considered to be an important etiological factor in mouth breathing, abnormal swallowing patterns, abnormal growth and development of the jaws and malocclusion.

Since enlarged adenoids are common findings among children under the age of thirteen years, when they are undergoing a period of rapid growth, it is felt that such enlarged adenoids, together with their associated enlarged tonsils, might have some ill-effects upon the function of the velopharyngeal area.

The purpose of the present study was to investigate the movement of velopharyngeal structures in children who required surgical removal of both the tonsils and adenoids between the ages of five and fourteen years. The sample consisted of twenty-eight Caucasian children, of whom seventeen were boys and eleven were girls.

The velopharyngeal mechanism, both in deglutition and in speech, before and after surgery was studied by means of Cinefluorography. All

cinefluorographs were obtained by a lateral plane projection, at a film speed of 30 frames per second. The velopharyngeal movements during deglutition and speech were recorded on the cine films, using a standardized sequence. Individual frames were then carefully selected on a Tagarno movie projector and analysed on a 16 mm Vanguard Motion Analyser, using a standardized set of angular and linear measurements (with the palatal plane and pterygo-maxillary fissure as anatomical reference landmarks).

The following conclusions were drawn from both the statistical analysis and subjective evaluation of the results:

1. The presence of enlarged tonsils and adenoids does alter the mechanism of velopharyngeal function both in deglutition and in speech. However, their effect upon the functions in the oral cavity was not found to be as dramatic as was suggested by previous studies.
2. 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 velopharyngeal closure in speech.
3. The findings support the hypothesis that the urge of nasal breathing is strong and that oro-nasal breathing is more common in tonsil and adenoid cases than mouth breathing. Nasal breathing was found to have resumed in the majority

of cases following the removal of both the tonsils and adenoids.

4. 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 was common and might easily be blocked by excessive catarrh and swollen nasal mucosa in some cases.

5. The antero-posterior dimension of the nasopharyngeal isthmus at the level of the palatal plane had increased after surgery with improvement of the nasopharyngeal airway. The area of contact between the soft palate and the posterior pharyngeal wall during velopharyngeal closure was wide due to the presence of the adenoidal mass before surgery, and was smaller and more posteriorly placed after surgery.

6. The movement of the soft palate in closing the nasopharyngeal isthmus during deglutition and speech was found to be "sluggish" prior to surgery but became more active post-operatively.

7. The time required for one complete swallowing cycle was found to increase in tonsil and adenoid cases with variations between stages of deglutition depending on the physical size of the tonsils or the inflammatory state of

the structures in the oropharynx.

8. Enlarged tonsils and adenoids were not found to be important causes of teeth apart swallow and tongue thrusting both at rest and during deglutition.

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CHAPTER I

INTRODUCTION

Attempts have been made for many years to establish a causal relationship between mouth breathing and malocclusion of teeth. It has been suggested that a contracted and protruded maxilla, high palatal vault and Angle's Class II division 1 type of malocclusion which constitute the so-called "Adenoidal Facies" are the products of mouth breathing. To date, there is still insufficient evidence to demonstrate any direct correlation between mouth breathing and malocclusion.

Mouth breathing may be defined as habitually breathing through the mouth. The important etiological factors of mouth breathing have been said to be narrow nasal and nasopharyngeal passages as well as enlarged pharyngeal tonsil (adenoids).

In children, enlarged adenoids are often, if not always, found with enlarged tonsils. If enlargements of these lymphoid tissues are common causes of mouth breathing, children possessing such conditions may have to alter the posture and the pattern of movements of the structures surrounding the oropharyngeal areas both at rest and during function. Should a child with enlarged tonsils and adenoids have 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 the posterior oral apertures would have to be opened by separation of the lips and also by separation between the soft palate and the dorsum of the tongue. Lip separation at rest is not an uncommon finding in children. However, a break of the posterior oral seal at rest may be considered to be abnormal and requires either an elevation of the soft palate, or a drop of both the mandible and the tongue, or, a combination of both. When this happens, the postures of the mandible, tongue, lips, as well as the hyoid bone will change, and there may be an associated alteration of the functional positions of the surrounding structures.

Most orthodontists nowadays agree to the fact that teeth erupt into an environment influenced by the surrounding musculature, and that persistent forces exerted by these muscles can move teeth. Therefore, a lack of balance of the orofacial muscles and the exertion of abnormal muscle forces may cause the development of a malocclusion or an exaggeration of a developing malocclusion.

Since enlarged tonsils and adenoids occur commonly in children during their growing period, any alteration of the posture and functional positions of the structures in the velopharyngeal as well as the oropharyngeal areas may lead to abnormal functions in the oral and pharyngeal areas with ill-effects upon the growth and development of the facial skeleton and malalignment of teeth.

The purpose of this study is 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. Since deglutition and speech are two of the important functions that can be studied by means of cinefluorography, they are chosen for the present investigation which centers, objectively, upon the position and patterns of movements of the velopharyngeal structures, the tongue, lips, mandible, and the hyoid bone, with the hope of providing further information as to the "form and function" relationship of these structures.

CHAPTER II

REVIEW OF LITERATURE

General Considerations:

"Tonsils" and "Adenoids" are part of the lymphoid tissues that form the Waldeyer's ring of the pharynx. The Waldeyer's ring consists of the pharyngeal tonsil, the faucial (or Palatine) tonsils, the lingual tonsils and the lymphoid masses along the posterior pharyngeal wall, including those in the lateral recess or Fossa of Roenmuller. The function of this group of lymphoid tissues is to provide a line of defence against infection in the upper respiratory and pharyngeal regions. However, when this form of defence mechanism is overcome, these lymphoid masses may themselves become sites of infection, leading to their surgical removal.

The term "Tonsils" has been used to represent the faucial tonsils and the term "Adenoid" has been used to denote the pharyngeal tonsil when it has become hypertrophied (Nelson 1964).

In children, the major disturbances of both the tonsils and adenoids are infection and hypertrophy, with hypertrophy often being secondary to infection. Although these lymphoid tissues are relatively large during childhood, their removal is often indicated when they have become chronically infected, causing mechanical obstruction of the nasal air flow. Enlarged adenoids can cause such obstruction of the nasopharynx and hypertrophic tonsils can interfere with swallowing as well as breathing (Nelson 1964). In order to breathe past them, the child may have to lift the tonsils with the soft palate, thus further reducing the space in the nasopharynx. Occasionally, instances arise where the chronically infected tonsil is small and embedded. In such a case, the above mentioned functional aberration may not be seen.

Other lymphoid tissues in the pharynx may also become infected but play a very minor role in the above changes.

The expression "Tonsils and Adenoids" has become such a familiar term that it is frequently overlooked that one condition may require attention and not the other. In fact, there are circumstances when it is desirable to remove the adenoids and to leave the tonsils, though the converse is not always the case. Nelson (1964) stated: "Although both tonsils and adenoids are usually removed at the same operation, there are good reasons for making the decision for tonsillectomy and adenoidectomy separately, especially in children under four or five years of age."

The Pharyngeal Tonsil (or Adenoid):

The pharyngeal tonsil is composed of masses of lymphoid tissue that are situated in the uppermost part of the posterior wall of the nasopharynx above the level of the soft palate behind the posterior nasal openings. Gardner, Gray and O'Rahilly (1963) believed that nasopharyngeal tonsil should be a better term for pharyngeal tonsil. Normally, these lymphoid masses are arranged in ridges covered by pseudo stratified ciliated columnar epithelium. However, when they have become hypertrophied because of infection or nasal congestion, they are diagnosed as adenoids. In that case, the ridges may fill a large part of the nasopharynx.

When the pharyngeal tonsil is viewed in the mid-saggital plane from the lateral aspect, it appears as a convex mass attached to the undersurfaces of the body of the sphenoid and the basilar part of the occipital bone and faces the nasal surface of the soft palate.

Using Bolton Cephalometric Roentgenograms, Todd (1936) followed the natural history of the adenoid mass in children. He found that the adenoid mass tended to appear at about the age of twelve months. It then increased in size to about the third year when it became stationary until adolescence. Thereafter, it gradually decreased in size.

In 1954, Subtelny carried out a longitudinal cephalometric roentgenographic study of 15 subjects who had no history of adenoidectomy. He reported that the adenoid tissue followed a specific cycle of growth. He found that the adenoid increased in size from about the sixth month of postnatal life, and became well formed by the age of two years, occupying approximately one-half of the nasopharyngeal space. The growth of the adenoid was mainly downward and forward, reaching its peak at about the age of 10 to 12 years. Thereafter, it decreased in size and in an upward and backward direction. By adulthood, the adenoid had completely atrophied.

From the above, it appears that the pharyngeal tonsil does follow a specific cycle of growth. Its size increases from about the sixth month of postnatal life and becomes well-formed at about three years of age. From then on until adolescence, it increases in size at a slower rate. By adulthood, it decreases in size and atrophies. Due to investigatory difficulties the size of the pharyngeal tonsil has only been studied in the antero-posterior dimension radiographically. Its exact size in relation to the nasopharyngeal space has not been studied. At the present time there has been no study using an objective method of measurement and no standards of normal for the pharyngeal tonsil.

The Faucial Tonsils:

The faucial tonsil is an oval mass of lymphoid tissue that is situated in a triangular space between the palato-glossal and palato-pharyngeal arches on either side of the oropharynx and bounded by the soft palate above and the posterior part of the tongue below. Each faucial tonsil projects for a variable distance into the oropharynx and may be divided into two parts: (a) an inferior projecting part, and (b) a superior "embedded" part which is often found to be "buried" in the muscles of the soft palate. The medial surface is covered by stratified squamous epithelium which invades the substance of the tonsil to line a number of deep, narrow crypts called the tonsillar pits. The lateral surface is formed by the capsule of the tonsil which is attached by loose areolar tissue to the pharyngo-basilar fascia covering the adjacent muscles (Last 1966). This loose areolar tissue renders possible complete removal of the tonsils in the operation of tonsillectomy without damage to the surrounding structures (Gray's 1958). The antero-inferior part of the capsule is firmly attached to the side of the tongue. Behind this point, it receives the insertion of some muscle fibers from the Palatoglossus and Palatropharyngeus muscles (Gray's 1958, Gardner, Gray and O'Rahilly 1963 and Cunningham's 1964). This lateral aspect of the tonsil has been described to extend beyond the limits of the medial surface. It extends superiorly into the soft palate, inferiorly into the posterior part of the tongue and anteriorly into the Palatoglossal Arch (Gray's 1958 and Cunningham's 1964). Because of its anatomical situation, each of the faucial tonsils is closely related to the Superior Constrictor, the Palatopharyngeus, the Stylopharyngeus, the Styloglossus and the Palatoglossus muscles (Gray's 1958, Cunningham's 1964 and Last 1966). The consensus of opinion is that in early childhood, the tonsil has a protective function against infections. Later in life, this function becomes less important and the tonsil atrophies. On this theory, persistent and repeated inflammation of cervical glands draining the tonsil area may be regarded as evidence that infection has broken down the protective barrier of the tonsil. Under such circumstances, the tonsil has become, instead of a protection, a focus of infection.

The growth and development of the tonsils have not been studied as an individual entity, but Scampion R. E. et al (1930) had shown that growth of the lymphoid tissues of the body reached their peak at the age of about twelve years.

Relation of Enlarged Tonsils and Adenoids to Oral Functions:

Truesdell and Truesdell (1937) suggested that conditions of the oral cavity and throat which would keep the teeth from closing, or cause the tongue to be held forward from its normal position, could produce abnormal swallowing. They believed that if the tonsils were infected, sore or tender, the tongue would be carried to a more forward position in order to relieve tension on those parts in the oropharynx. This in itself would cause the tongue to come further forward.

In observing an atypical swallowing, Rix (1946) stated that deglutition helped to drain the nasopharynx as well as to moisten and to refresh the oral and pharyngeal mucous membrane. He believed that the most detergent type of swallow was the normal swallow with the teeth together, and that in an atypical swallow, the self-cleansing action of the mouth became defective. He found that an atypical swallow was commonly associated with early troubles of the upper respiratory tract. He postulated that an unhealthy nasopharynx might foster the infantile swallow, causing it to overstay its normal period which he believed to be about two and a half years, this being about the time when centric occlusion was established. It was reasoned that in the case of an unhealthy nasopharynx causing nasal obstruction," local inflammation in the area resulted in an increased pressure upon the tympanic membrane of the ear". With the jaws separated especially during swallowing, there was an increased chance for air pressures to become equalized. Therefore, he believed that an abnormal nasopharyngeal mucosa might lead to chronic hypertrophy of the tonsils and adenoids, persistent infantile swallowing and developmental defects.

In 1948, Rix further stated that there was a re-arrangement of the actions of muscles attached to the mandible and the hyoid bone when an atypical swallow was caused by early upper respiratory troubles, such as tonsils and adenoids. This might lead to a delay in maturation of the oro-facial muscular behaviour that was described by Gwynne-Evans in 1947. He believed that if nasopharyngeal troubles occurred at a time when the swallowing mechanism had not yet become fully established, the infantile swallow would continue.

Moyer (1963) stated that swollen and sore tonsils would produce pain when the tongue encroached on the pillars of the fauces. This caused the mandible to drop reflexly with the teeth becoming separated. The tongue then thrusted between the teeth during the last stages of swallowing.

Harrington (1963) stated that when the function of the oral mechanism became disturbed to such a degree that the patterns of muscle movement during chewing and swallowing were overmodified, misuse of the same organ in articulation of speech would result. He believed that there was a high incidence of chronic nasal congestion among patients with oral mechanism malfunction and suggested that allergies, mouth breathing and rhinitis should be regarded as important etiological factors of oral mechanism malfunction. This view was supported by the work of Bosma in 1962. Harrington also believed that the presence of hypertrophied tonsillar tissues and the enlarged adenoids would limit the velar action so that the velum would not impinge upon the adenoids or might not have been able to function normally in both swallowing and speech. This inactivity of the palate sometimes resulted in hyper-nasality when the enlarged adenoids had been removed. He also believed that nasal congestion would place the tongue forward from its physiological rest position or might even extend it between the teeth, causing a teeth apart swallow and abnormal pressure on the teeth.

Subtelny and Sakuda (1964) stated that excessive adenoid tissue might prevent proper naso-respiratory function by obstructing the naso-pharyngeal airway and that grossly enlarged tonsils might obstruct the oropharynx and forced the tongue forward, thus causing adverse muscular changes. They believed that in severe cases, the tip of the tongue might habitually lie between the anterior teeth, causing incomplete eruption of these teeth. Removal of the enlarged tissues would reposition the tongue in its normal position with subsequent eruption of the incisors.

The effects of enlarged tonsils and adenoids upon the velo-pharyngeal function and tongue posture has not been well studied.

Subtelny (1954) and Subtelny and Baker (1956) studied the velo-pharyngeal mechanism using a combined cephalometric roentgenographic and cephalometric laminagraphic method on twenty children between ages of four to twelve years. Records were taken of these subjects both before and after surgical removal of adenoid tissues. They found that prior to surgery, the velopharyngeal closure took place between the soft palate and the adenoid tissue. The dorsum of the tongue, instead of resting against the soft palate at rest, had moved downward and forward away from the soft palate. Removal of the adenoids increased the nasopharyngeal space between the nasal surface of the resting soft palate and the posterior wall of the nasopharynx, thus improving the nasorespiratory function. Removal of the adenoid and tonsillar tissues restores the contact between the soft palate and the dorsum of the tongue. Greater muscular activity of the soft palate was assumed to have taken place to overcome the increased distance for proper naso-pharyngeal closure. They also found that the amount of soft palate affecting the closure was reduced after surgery and that the area of contact between the soft palate and the posterior pharyngeal wall was more posteriorly placed.

In 1958, Ricketts reported his cephalometric roentgenographic study on 30 children (23 girls and 7 boys) with an average age of eight years. Records were taken from these children both before and after adenoidectomy, tonsillectomy, or both, at an interval of about six months. He found that an average of 8 mm. of adenoid tissue was removed in adenoidectomy cases. After adenoidectomy, there was a retraction of the tongue in an upward and backward direction. The removal of large tonsils appeared to be followed by great changes in tongue posture. He also found that cases requiring adenoidectomy showed smaller nasopharyngeal dimensions than the control samples.

From the literature reviewed so far, it appears that most authorities agree that enlarged tonsils and adenoids can cause mouth breathing, though they disagree on the percentage of enlarged tonsil and adenoid cases that actually cause mouth breathing. The effects of enlarged tonsils and adenoids upon the functions of the oro-naso-pharyngeal areas, however, have not been adequately and objectively studied. In view of the above, the following sections will be reviewed hoping that a better working knowledge of the subject will be of benefit for the present study.

The Pharyngeal Growth:

The pharynx is that part of the digestive tract that is bounded by the posterior portion of the cranial base above, the cervical vertebrae behind and the back of the facial skeleton in front. From above downwards, it lies behind the nasal cavities, the oral cavity and the larynx respectively. At the level of the sixth cervical vertebra behind the cricoid cartilage of the larynx, it becomes continuous with the oesophagus. In the present study, only the nasal and the oral parts of the pharynx will be discussed.

The pharynx, on the whole, is composed of muscles lined by mucous membrane. Its size and shape will therefore be influenced by the surrounding bony structures (Schuller 1920 and Ricketts 1954). Because of this, the growth and development of its bony framework as well as the related soft tissues should be reviewed.

Keith and Campion (1922) compared dried skulls of different ages, and pointed out that growth at the spheno-occipital synchondrosis should be considered as an important factor for the increase in dimensions of the pharyngeal space.

The comparative study by Krogman (1930) on skulls of Anthropoids and Man suggested that the antero-posterior growth in the body and greater wings of the Sphenoid could lead to an increased antero-posterior dimension of the pharynx.

Todd and Tracy (1930) studied the skulls of American Negroes. They found that the cranial base size was attained by the age of seven years. Any further increase of the pharyngeal space could only be provided by the forward movement of the face.

A longitudinal Cephalometric Roentgenographic study of 142 children between the ages of three months and nineteen years was carried out by Rosenberger (1934). He agreed with other studies that growth in the body and greater wings of the sphenoid as well as the growth of the basilar part of the occipital bone would increase the antero-posterior dimension of the nasopharynx. In addition, he found that the entire nasal skeleton drifted forward with growth and thus contributed to the antero-posterior increase of the nasopharyngeal dimension. He further stated that growth of the wings of the sphenoid as well as the forward migration of the hard palate with the nasal skeleton would help to widen the nasopharynx. His findings indicated that the growth pattern of the nasofacial region became established during the first five years of life. Thereafter, growth occurred in a remarkably orderly manner.

Brodie (1941) reported his Cephalometric Roentgenographic study on the growth of the human head from the third month to the eighth year of life. He found that with growth, the posterior nasal spine moved downward and forward until approximately the end of the second year. From then on, the hard palate moved almost vertically downward away from the base of the skull in a parallel manner.

A longitudinal Cephalometric Roentgenographic study was carried out by King (1952) on 50 children between the ages of three months to sixteen years. He found that the antero-posterior dimension of the pharynx was established in early infancy. He supported Brodie's study (1941) that the Pterygoid process in man became stable by the end of the second year. He also suggested that the increase in depth of the pharynx contributed to the spheno-occipital synchondrosis might have been minimized by the forward growth of the anterior arch of the atlas. The considerable increase in the vertical growth of the pharynx was brought about by the descent of the hard palate, the pterygoid processes, the mandible, the hyoid bone and the vertical growth of the cervical vertebrae. The position of the hyoid bone was also noted to have changed from above the level of the mandibular symphysis in infancy to a level below it in the adult. The hyoid bone kept a constant distance from the vertebral column until puberty when it moved forward slightly.

Using a combination of Cephalometric Roentgenography and Cephalometric Laminagraphy, Subtelny (1954) reported that the vertical dimension of the pharynx continued to increase until about the age of fifteen years when growth of the maxilla had completed. He also found that the distance between the posterior nasal spine and the soft tissue of the posterior pharyngeal wall at the level of the palatal plane increased during the period of study. His Cephalometric Laminagraphic study of 1955 further demonstrated that growth in width of the naso-pharynx appeared to become stable during the second year of life.

Ricketts (1954) suggested that the angle formed by the anterior and posterior cranial bases could play an important role in the antero-posterior dimension of the nasopharynx. He found that a large cranial base angle was often associated with a large antero-posterior dimension of the nasopharynx.

In discussing the craniofacial regions, Scott (1955) stated that growth in height of the pharyngeal area was regulated to a large extent by the cartilages of the cervical vertebrae. His opinion on the antero-posterior dimension of the nasopharynx went along with that of Keith and Campion (1922) and Todd (1930) to be attributed by growth at the Spheno-occipital Synchondrosis.

Graber (1956) supported the idea that both the cranial base angle and growth at the Spheno-occipital Synchondrosis were the controlling factors of the antero-posterior dimension of the nasopharynx. He believed that such dimension would undoubtedly be increased since the Spheno-occipital Synchondrosis activities continued into adult life. This brought the posterior pharyngeal wall in a downward and backward direction. He also stated that the early growth of the neural structures might be associated with the early establishment of the lateral pharyngeal dimension.

From the above, it appears that the width of the nasopharynx is established early in childhood. The major part of the antero-posterior dimension of the nasopharynx becomes established also during the early part of childhood though further increase can still occur during the growing period, depending on growth of the Spheno-occipital Synchondrosis and the existing cranial base angle. Since the vertical growth of the nasopharynx continues until the age of about fifteen years, it may further influence the antero-posterior dimension of the nasopharynx.

Studies of the Hyoid Bone:

The hyoid bone is a horse-shoe bone that surrounds the anterior and lateral aspects of the larynx above the thyroid cartilage. It is suspended by ten muscles and has no bony articulation (Gray's 1958). Because of its muscle attachments, the hyoid bone is intimately related to and influenced by:

the base of the skull,
the pharynx,
the tongue,
the mandible,
the thyroid cartilage,
the sternum, and
the scapula.

Parson (1909) studied they hyoid bone by dissection. He found that ossification of the hyoid bone began in the body and then progressed to the greater horns, with complete ossification around the age of fourteen years. He also found that there was a rapid increase in length of the greater horns during the first year. Thereafter, the increase was slow until adulthood.

Mainland (1945) considered the hyoid bone as a platform so that when one group or groups of muscles became fixed, the other muscles attached to it might act from it.

Brodie (1950) studied the chain of muscles encircling the head and neck regions. He considered the hyoid bone to play an important part in maintaining the posture of the head and jaws, and suggested the importance of the hyoid bone and the tongue in performing the functions of both respiration and deglutition because of their close association with the larynx. However, Last (1955) pointed out that the prevertebral muscles were the important flexors of the head.

Sicher (1960) described the hyoid bone as the skeleton of the tongue and Bosma (1963) believed that the hyoid bone played an important role in keeping the airway open, especially during the early periods of life.

In his study of pharyngeal growth, King (1952) found that with age, the hyoid bone moved from a position above the mandibular symphysis in infancy to a position below it in the adult. The descent was rapid during infancy, early childhood, and puberty, the last spurt being accompanied by a slight forward movement. In addition, he found that a change in the head position would lead to a change in the hyoid position.

A longitudinal cephalometric roentgenographic study of 115 children between the ages of three to nineteen years was reported by Bench in 1963. He demonstrated that with growth, the hyoid bone moved downwards with the cervical vertebrae, varying between the third and fourth cervical vertebrae. The descent of the hyoid bone appeared to be consistent with the lowering of the tongue and moved progressively away from the lower border of the mandible.

In studying the "Tongue Thrust Syndrome", Anderson (1963) concluded that there was no relation between tongue-thrust syndrome and tonsillitis or the relative vertical position of the hyoid bone.

Stepovich (1963) used a series of cephalometric roentgenographic films to study the position of the hyoid bone in the same individual. He found that the position of the hyoid bone differed from film to film even with the greatest of care, and concluded that static cephalometric records were unreliable when they were used to study the position of the hyoid bone.

<u>Growth of the Soft Palate:</u>

The Soft Palate or Velum is composed of muscles and fibrous tissues. It is covered by mucous membrane on both the nasal and the oral surfaces. It is attached anteriorly to the posterior margin of the hard palate and laterally to the muscles of the pharyngeal wall.

Its posterior edge is free. At rest, the soft palate forms an angle with the hard palate with the oral surface in contact with the dorsum of the tongue.

A Cephalometric Laminagraphic study on twenty children with an average of twelve and a half years of age was carried out by Ricketts (1954). He found that the soft palate tended to adapt itself to the surrounding structures. When the antero-posterior dimension between the hard palate and the anterior arch of the atlas was small, the soft palate exhibited a smaller angle with the hard palate, suggesting a form and function relationship.

The longitudinal cephalometric roentgenographic study by Subtelny (1957) on thirty subjects, however, showed that there was a marked increase in length of the soft palate during the first two years of life. This period was then followed by a "levelling-off" period, with resumption of growth after the age of four or five years. This second growth period was found to be less rapid but steady, ending in early adulthood. There was no difference in the growth pattern between the male and the female, though the average length of the soft palate was found to be slightly greater in the male. The soft palate also showed a rapid growth in thickness during the first year of life. From then on, the increase was small and reached its maximum at the age of fourteen to sixteen years. The angular relationship between the soft and hard palates also changed with age. With growth, the soft palate formed a smaller angle with that of the hard palate and became closely related to the downward and forward growth of the facial skeletal and the vertical growth of the pharynx.

Velopharyngeal Closure:

During swallowing and the production of most speech sounds, the soft palate is raised by muscular action from its resting position and comes into contact with the posterior pharyngeal wall. Under such circumstances, the oropharynx is separated from the nasopharynx and the action performed is called nasopharyngeal closure. The major muscles involved are:

(1) Muscles of the Soft Palate,

(2) Levator Palati Muscles,

(3) Palatopharyngeus Muscles, and the

(4) Pharyngeal Constrictor Muscles.

The Palatal muscles are all arranged in pairs with one on each side. They are attached to the Palatal Aponeurosis so that when acting together, they can function symmetrically. Podvinec (1952) stated that these muscles of the soft palate formed an interlacing network without any raphe. The muscles crossed the midline and became united with the muscle fibers of the opposite side. He concluded that these muscles might function together.

During the initial phase of velopharyngeal closure, the Tensor Palati Muscles tighten and lower the anterior part of the soft palate at the junction of the hard and soft palates. This is followed by the action of the Levator Palati muscles which are the main muscles for raising the soft palate. The Palatopharyngeus muscles and finally the Pharyngeal Constrictors then complete the velopharyngeal closure. The part played by the latter two muscles depends on the type of function involved.

Contraction of the Palato-glossus muscles depress the sides of the soft palate but pull the tongue upwards and backwards as well as narrowing the oropharyngeal isthmus during swallowing. Their action tends to oppose that of the Levator Palati and the Tensor Palati in swallowing. The Palato-glossus muscle arises in the oral surface of the Palatal Aponeurosis. It is inserted into the posterior part of the side of the tongue inside the anterior pillars of the fauces (Palato-glossal arch).

The Levator Palati muscles are inserted into the nasal surface of the Palatal Aponeurosis. They are the chief levators of the soft palate. During velopharyngeal closure in speech when the soft palate is raised upward and backward to contact the posterior pharyngeal wall, two dimples may be seen on the oral aspect of the soft palate that corresponds to the points of insertion of these muscles (Podvinec 1952 and Calnan 1953).

The Palatopharyngeus muscles arise in the nasal surface of the Palatal Aponeurosis. They pass into the lateral and posterior walls of the pharynx inside the posterior pillars of the fauces (Palato-pharyngeal arch) on each side. Their action is probably closely related with the Palatoglossus, the Levator and the Superior Constrictor muscles during swallowing and in speech. Oldfield (1941) believed that contraction of the Palatopharyngeus muscles helped to obliterate the sides of the nasopharynx during nasopharyngeal closure.

The Musculus Uvulae, on contraction, elevates and shortens the Uvula. Podvinec (1952) pointed out that this muscle was the only longitudinal muscle of the soft palate, locking all the muscles of the soft palate from above.

The Constrictor muscles of the pharynx may be divided into the Superior, the Middle, and the Inferior Constrictors of the pharynx. During velopharyngeal closure, only the Superior Constrictor muscle is involved. The upper part of this muscle is concerned with speech and swallowing, whilst the lower part with swallowing only (Morley 1966).

In 1930, Whillis described the palatopharyngeal sphincter. He stated that the upper fibers of the Superior Constrictor muscle formed a sphincter by travelling around the pharynx to be inserted into the soft palate. He also stated that in speech, the contraction of this sphincter caused an inward movement of the lateral pharyngeal wall, and occasionally, a horizontal elevation on the posterior pharyngeal wall, just above the lower margin of the soft palate. This horizontal elevation is the so called "Passavant's Ridge", whose existence in normal individuals has been questioned by some authorities. Observations by Bloomer (1953) on two patients with facial clefts suggested that there was no forward movement of the posterior pharyngeal wall during speech, blowing and swallowing and that contraction of the Palatopharyngeus muscle might play a part in nasopharyngeal closure. Calnan (1953) suggested that this ridge might represent hypertrophy of the Superior Pharyngeal Constrictor muscle in cleft palate patients and that it might play a more important role in swallowing rather than speech.

Radiographic studies by Ardran and Kemp (1955), however, did demonstrate the existence of the "Passavant's Ridge" during speech in some individuals with normal palatal and pharyngeal conditions.

Townshend (1940) considered that the muscle fibers forming the "Passavant's Ridge" were part of the Palatopharyngeus muscle. He believed that these muscle fibers blend with the Superior Constrictor as soon as they left the palate. He also considered that the ridge of Passavant was not essential for nasopharyngeal closure.

Morley (1966) stated: "Whether or not the ridge of Passavant is concerned in nasopharyngeal closure, it is apparent that complete closure of the nasopharyngeal airway is a normal function and that such closure does not occur at only one level in the pharynx, but that there is extensive contact between the heaped-up mucosa of the nasal surface of the soft palate and the posterior pharyngeal wall."

In 1952, Podvinec suggested that the nasopharyngeal closure was the result of the interaction between two muscle slings - one was formed by the Tensor Palati, Levator and the Superior Constrictor, the other was formed by the Palatoglossus and the Palatopharyngeus. During velopharyngeal closure, the levator sling raised the soft palate with the Palatopharyngeus relaxed and stretched. Then both the posterior pillars of the fauces came together and in firm opposition to the posterior pharyngeal wall. The Superior Constrictor muscles were considered to be synergic in lifting the palate and in approximating it towards the posterior pharyngeal wall.

In 1963, Braithwaite described the levator and palatopharyngeal slings as having a common insertion in the palate. During action, the palate became interposed and steadied by the interaction of these muscles. The two muscle groups might be considered as muscles arising from the petrous bone of its own side, crossed within the soft palate and inserted into the pharyngeal wall of the opposite side.

McCollum et al (1956) and Morley (1966) suggested that non-nasal speech was closely correlated with inward movement of the lateral pharyngeal wall. These authorities believed that the mobility of the pharyngeal wall was just as important as the mobility of the soft palate in velopharyngeal closure and that such closure should not be considered in only an antero-posterior dimension.

According to the standardized anatomy texts, the Vagus and the Accessory nerves supply motor fibers to the muscles of the pharynx and to those of the soft palate with the exception of the Tensor Palati. However, Podvinec (1952) stated that both the Levator and the Superior Constrictor might have a double innervation. In addition to the motor fibers from the pharyngeal branches of the Vagus, the Levator Palati might also have received motor fibers from the Facial nerve via the Greater Superficial Petrosal nerve and the Superior Constrictor muscle from the Glossopharyngeus nerve. He therefore postulated that the coordination for swallowing may differ from that for speech, with swallowing insured by the Glossopharyngeus and the Vagus and speech insured by the Vagus and Facial nerves.

Closure of the Nasopharyngeal Isthmus in the Production of "E" Sound:

It has been established that the most consistent physical factor that is often found to be associated with hypernasality is a failure of the soft palate to contact the pharyngeal wall to obtain a seal of the nasopharyngeal isthmus during speech. Subtelny (1961), Ashley et al (1961), Kirkpatrick (1963), Moll (1965) and others have pointed out that recent radiographic techniques have enabled many studies to be made in establishing the movement, size and relative position of various structures in velopharyngeal closure during the production of all the vowels and most of the oral consonant sounds.

Calnan (1953) observed the nasopharyngeal structures of a fifty-three year old patient who had a wide opening through the lateral wall of the nose, cheek and maxillary sinus following the excision of an advanced carcinoma of the cheek and antrum. He related his clinical observation with that of cine-radiography, and found that there was only a slight difference in the general mechanism of producing vowels, nasal consonants and plosive consonants. He reported that of all the vowel sounds, the sound "EE" produced the maximum elevation of the velum to a level well above the hard palate. This elevation was at its maximum at the junction of the middle and posterior thirds of the soft palate, and that in pronouncing the word, "Peter", the velum rose for the plosive "P" to near its maximum.

Therefore, it seems logical to assume that the production of the "E" sound would be a useful way of radiographically assessing the adequacy of velopharyngeal closure in speech.

Cinefluorographic Study of Normal Deglutition:

Deglutition is one of the important functions performed by the Stomatognathic system. With the advance of the cinefluorographic technique, the dynamics of swallowing have been studied by authorities of various disciplines. It is generally agreed that during swallowing, the bolus (the substance to be swallowed) is passed distally by a series of muscular actions that suggest a highly integrated reflex control and co-ordination. Wildman et al (1964) called this the theory of Integral Function of Swallowing. The following is a summary of the findings which have been described by Johnstone (1942), Saunders et al (1951), Ardran and Kemp (1955) and Ramsey (1955):

The Preparatory Stage of Deglutition:

As soon as the bolus is introduced into the mouth, the tongue acquires a characteristic swallow-preparatory position. Both lateral and antero-posterior cinefluorographs have shown that the tongue forms a dorsal depression, surrounded by a peripheral seal. The anterior seal is obtained by the tip of the tongue against the palatal mucosa and the maxillary anterior teeth. Similarly, lateral seal is obtained by the sides of tongue against the buccal teeth and the adjacent palatal mucosa. The posterior seal is obtained by the palato-lingual valve which is formed by the posterior portion of the tongue behind the bolus, the pillars of the fauces and the soft palate. In this way, the bolus is prevented from entering the pharynx prematurely.

The Oral Stage of Deglutition:

As soon as the decision to swallow has been made, the anterior portion of the tongue is pressed firmly against the roof of mouth. The depression in the posterior portion of the tongue for the bolus deepens as the bolus is moved towards the oropharynx. With the peripheral seal still in action, the tongue moves progressively backward until it comes to the junction of the hard and soft palates. Ardran and Kemp (1955) described this backward movement of the bolus as "a tooth paste being squeezed from a tube." Ramsey (1955) named this progressive narrowing and obliteration of the lumen behind the bolus as a "stripping action". The presence of a peripheral seal in deglutition has been supported by recent oral myometric studies (Kydd 1957, Abrams 1958, Winders 1958 and 1962).

The Pharyngeal Stage of Deglutition:

As the tongue is approaching the junction of the hard and soft palates, the soft palate elevates upward and backwards to contact the posterior pharyngeal wall, thus closing the nasopharyngeal isthmus. At the same time, the posterior portion of the tongue moves forward slightly to create more room for the passage of the bolus. Finally, the bolus is squeezed through the pharynx into the oesophagus by the action of the tongue and the pharyngeal muscles.

The movements of the epiglottis during deglutition have been a subject of controversy. Using animal experiments, Magendie (1783-1855) has demonstrated that the epiglottis turns downward and backward during the pharyngeal stage of swallowing, as a first line of defence for the protection of the entrance of the larynx. However, the fluoroscopic study by Barclay (1930) on deglutition suggested that the epiglottis played no part in protecting the airway and that it remained erect during swallowing "like a rock under a waterwall". With improved cinefluorographic technique, Saunders et al (1951), Ramsey et al (1955), and Ardran and Kemp (1955) have shown that the epiglottis does turn downward and backward during swallowing.

Movements of the Hyoid Bone:

Since the hyoid bone is closely related to the lingual, pharyngeal and laryngeal suspensory system, its positional change during the act of swallowing must demonstrate the integrated activities of the regulated structures at the various stages.

Bosma in 1957 stated that as the bolus reached the hypopharynx, there was an abrupt elevation of the larynx. The relation of this laryngeal elevation and the hyoid bone should indicate the motions of the laryngeal sphincter.

Shelton et al (1960) described the three phases of hyoid movement during normal deglutition. The first phase included the simultaneous upward movement of the hyoid, elevation of the larynx, and dorsal movement of the pharyngeal portion of the tongue. This occurred prior to the descent of the bolus. The second phase included a strong anterior movement of the hyoid bone, ranging from "nearly directly ventrad to oblique cephaloventrad". The third phase included the return of structures to their positions before swallowing with the hyoid bone moving in an obliquely downward and backward direction.

However, the observation by Ramsey (1955) demonstrated that the movements of the hyoid bone varied with the size of the bolus. He found that the hyoid bone had a stronger forward movement during its upward and forward climb, when the bolus was large. But with a small bolus, the hyoid movement was first upward and then forward. He stated that "the regularity of these responses gives the impression that the motor centers are receiving precise 'information' as to bolus size".

The observation of Ardran and Kemp (1955) generally supported those of Ramsey and Shelton. In addition, they found that the hyoid bone first moved upward to the lower border of the mandible and then forward as the bolus descends. However, they stated that these movements appeared to be combined in some individuals.

From the above, it appears that the hyoid bone does move upward and forward to make room for the passage of the bolus down towards the oesophagus.

An initial upward and backward displacement of the hyoid bone was observed by Bosma (1957) and Saunders and Davis (1951). Wildeman et al (1964) explained that such backward movement might be due to tilting of the wings of the hyoid that was often found to be associated with the movement of the lateral pharyngeal wall during the early stages of swallowing.

Studies on Abnormal Deglutition:

In 1937, Truesdell and Truesdell published their study on deglutition. They concluded that people with normal occlusion swallowed with the teeth together and they considered that swallowing with the teeth apart was an abnormal type of swallow.

Rix (1946) described the "teeth apart swallow" with the tongue placed between the teeth, and acting against the lips and the cheeks. He considered this type of swallow to be a retention of the infantile type of swallowing pattern. He also noted that abnormal swallowing was often associated with a lisp.

Gwynne-Evans in 1948 and 1951 also considered that the abnormal muscular behaviour in abnormal swallowing was the result of a persistent infantile pattern, and suggested that such pattern was a problem of maturation. He further classified swallowing behavior as somatic, which was normal, and viceral, which was abnormal, reflecting the visceral origin of the oro-facial musculatures.

Straub (1951) reported his investigation of 237 patients exhibiting abnormal swallowing habits. He took a detailed case history of each patient with particular reference to the type of feeding and the length of liquid diet. He found that all the 237 patients were bottle-fed at some stage during infancy. He therefore believed that improper bottle feeding was the cause of abnormal swallowing habits, and that bottle feeding with an over-long nipple and large holes encouraged tongue thrust swallowing.

Hovell in 1955 gave a full description of atypical swallowing habits and classified atypical swallowing actions into:

(1) Anterior tongue thrust with teeth together,

(2) Anterior tongue thrust with teeth apart, and

(3) Teeth-apart swallow with no tongue thrust.

In 1948, Ballard first published his studies on normal and abnormal postural patterns. In 1957, he suggested that tongue thrusting behaviour might be endogenous or adaptive. He believed that the endogenous type was derived genetically and that the adaptive type was a reflex attempt to maintain an anterior oral seal when incompetent lip posture or skeletal dysplasia had made the maintenance of normal anterior oral seal impossible. Ballard believed that the adaptive habits were not perverse habits but arose subconsciously and reflexly. He also believed that this type of swallow would change when it was given a new environment such as following orthodontic treatment, and that in the case of open-bite that accompanied endogenous tongue thrust, the condition often improved during maturation.

In discussing malocclusion, speech and deglutition, Subtelny and Subtelny (1962) supported the concept that tongue thrust swallowing might be either primary or adaptive to malocclusion.

Tulley (1964) described three types of oral behavior patterns as: adaptive, habit activities and endogenous. He used his "habit activities" type to represent residual childish activities of the orofacial musculature, and supported Ballard's view that adaptive patterns were the response of the orofacial musculature to incompetent lip postures and skeletal dysplasia. He further stated that the endogenous type might include a wide range of neuromuscular disorders of obscure central origin.

Cleall (1965) used a standardized cinefluorographic technique to study the resting posture and patterns of movement of the oropharyngeal structures under normal and abnormal conditions. He found that the stomatognathic system could adapt rapidly to changes in the local oral environment, and that individuals possessed characteristic and reproducible oropharyngeal resting postures and movement patterns during swallowing. He concluded that the positions and positional changes of the oropharyngeal structures during deglutition were greatly influenced by the local skeleto-dental configuration, and that the neuromuscular co-ordinating mechanisms were highly developed and sensitive to any local change of environment.

CHAPTER III

MATERIALS AND METHODS

I. Sample:

The present sample consisted of twenty-eight Caucasian children, of whom seventeen were boys and eleven were 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 in Manitoba, and were seen by one of the eight attending otolaryngologists who participated in the present study. All of these children were seen because of a history of recurrent upper respiratory tract infection, and were judged by the attending otolaryngologist 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. The criteria used in diagnosis were:

(1) Recurrent attacks of upper respiratory tract infection,

(2) Clinically enlarged tonsils and adenoids,

(3) Chronic inflammation of the tonsils and

(4) Involvement of the regional lymph nodes.

Except for the frequent bouts of upper respiratory complaints, none of these children were suffering from any other illnesses. Those patients with accompanying middle ear infection were not included in the present investigation.

II. Records:

The cinefluorographic records were obtained at the time the child was admitted for surgery. The time lapse from initial diagnosis to hospital admission ranged from four to six weeks. A complete history and physical examination was performed for each child by the otolaryngology resident at the time of admission.

All cinefluorographic records were obtained by a lateral plane projection, at a film speed of 30 frames per second. Although a film speed of 60 frames per second had been used previously by other investigators (Ramsey 1955, Cleall 1965), it was felt that a film speed of 30 frames per second would be adequate for the present study of velopharyngeal closure in tonsil and adenoid cases. The movements of the oro-naso-pharyngeal structures during deglutition and speech were recorded on the cine films, using a standardized sequence. A similar sequence was obtained from each patient six weeks after surgery when normal function had been restored.

The Postero-anterior projection was not taken for the present study because such projection is too difficult to interpret. In the study of movement, such as that of deglutition, anything that limits the movement of the head and its associated structures should be considered unphysiologic (Cleall 1965). Therefore, a head holding device was not used in the present investigation.

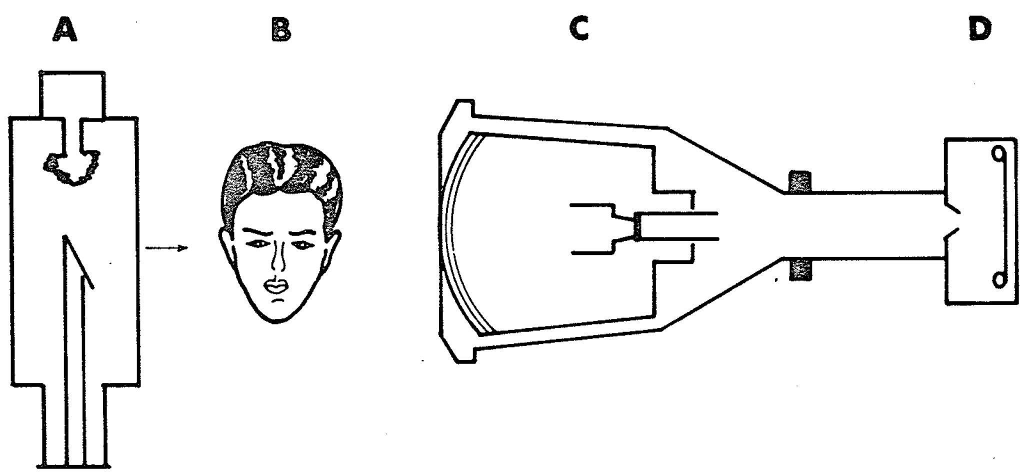
In order to reduce both unnecessary radiation exposure and undesirable head movement, each patient was rehearsed prior to the actual cine recording procedure. Patients were instructed to stand relaxed and watch a small object placed at eye level approximately five feet away. The tongue was quickly dried with a piece of clean sterile gauze and a line of radiopaque paste was painted on the midline of the tongue and lips to help identify these structures. About 5 c.c. 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 was carried out in an unhurried manner, and lasted less than 40 seconds.

III. Cinefluorographic Equipment:

The cinefluorographic equipment was provided by the Winnipeg Children's Hospital, and 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 (Figure 1). A television monitor was connected to the unit to help locate the patient's head and also the areas to be studies. Using fluoroscopy, finer adjustments for contrast and clarity of both the hard and soft tissues could then be made prior to the actual taking of the cine records. The 16 mm cine camera was synchronized with the X-ray tube and set to run at a speed of 30 frames per second.

Although the amount of radiation exposure for cinefluorography was considered to be higher than that needed for cephalometric roentgenography, the use of image intensification and unit synchronization has helped to reduce radiation exposure to a minimum. Within the six

DIAGRAMMATIC DESCRIPTION
of
CINEFLUOROGRAPHIC EQUIPMENT



A X-Ray Source

B Patient

C Image Intensifier

D 16 mm Camera

Figure 1. Showing in diagram form the cinefluorographic equipment used in the present study.

week period when all the necessary swallowing and speech sequences were recorded, each patient was subjected to less than 80 seconds of expossure time.

An attempt was made to keep the central beam as close as possible to the region of the maxillary first permanent molar so that magnification and distortion might be kept at its lowest level. The reason for the greater degree of distortion and magnification in cinefluorography as compared to conventional cephalometric roentgenography, is due to a shorter target to patient distance and a longer patient to image distance. By using an uniform wire grid, Cleall (1965) has shown that the progressive linear magnification from the central beam to the periphery is in the order of 14 per cent. Such error was considered to be less in magnitude than the errors associated with the technique used for analyzing the cine records. This greater degree of error is caused by the difficulty in locating the anatomical landmarks which are plainly visible in motion but become less well defined when the image is projected from stationary frames.

IV. Cinefluorographic Analysis:

After the cine films had been examined repeatedly on a Tagarno* movie projector (Figure 2), suitable frames for the study of resting postures, swallowing and speech were selected. It was decided to analyze five frames per sequence (four frames in swallowing and one frame in the "E" sound). Figures 3a, b, c, d, and e show the four stages of swallowing which starts from stage 1, or the so-called rest

*Tagarno 16 movie projector - Philips Electronic Equipment Ltd., 540, Marjorie St., Winnipeg 21, Manitoba.

position, from which movements are initiated. The second stage (Stage 2) represents the stage when the tongue tip has moved forward to establish contact with the upper incisors or palatal mucosa. The third stage (Stage 3) shows that the dorsum of the tongue has pressed on the palate from anterior backwards to reach the junction of the hard and soft palates. The fourth stage (Stage 4) shows that the hyoid bone has reached its highest and most forward position. Following the fourth stage, the swallowing sequence was completed by the return of the structures to the resting posture. This final stage is designated stage 5 but was not analyzed due to the fact that it was similar to stage one.

Figures 4a and b show the frame selected for the analysis of the "E" sound on pronouncing the first part of the word "Peter".

A time analysis was carried out for each swallowing cycle from stage 1 to stage 5. In choosing a swallowing cycle, a nondemanded saliva swallow was preferred. If this was not available in that sequence, a suitable demanded saliva swallow or the swallowing of 5 c.c. of water would be used to take its place. There is general agreement by investigators that the swallowing of a small amount of liquid is very close to a basic saliva swallow. Since a radiopaque paste was used in the present study to help identify the midline oral structures, some degree of distortion of the swallowing pattern might occasionally be encountered during the voluntary stage of deglutition because some children just simply dislike to have anything painted on their tongue. When this happened, the distorted swallowing pattern would have to be replaced by a more suitable swallow in that sequence.

Figure 2. Diagram showing the Tagarno Movie Projector, used for the subjective appraisal of the cinefluorographic films.

Figure 3a: 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 highest and most forward position.

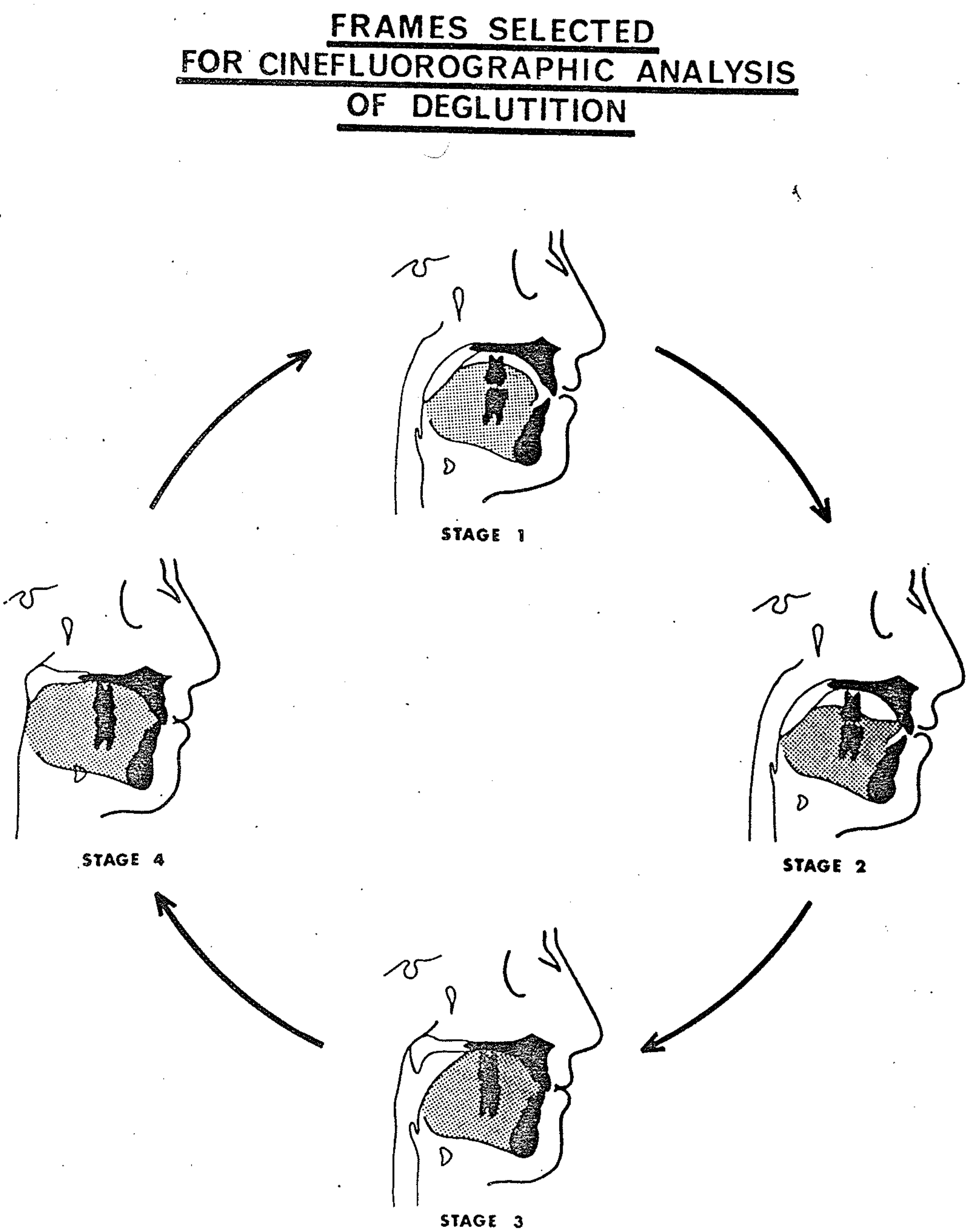

FRAMES SELECTED
FOR CINEFLUOROGRAPHIC ANALYSIS
OF DEGLUTITION
STAGE 1
STAGE 2
STAGE 3
STAGE 4

Figure 3a.

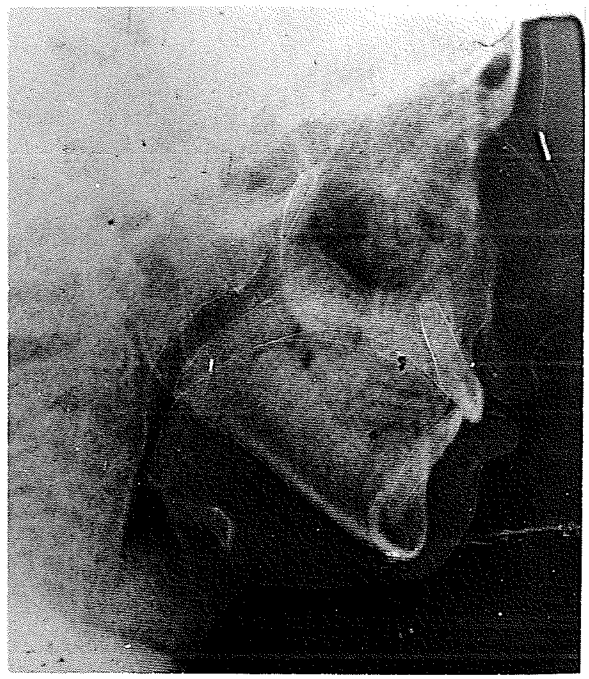


Figure 3b: Frame selected for stage 1 of deglutition

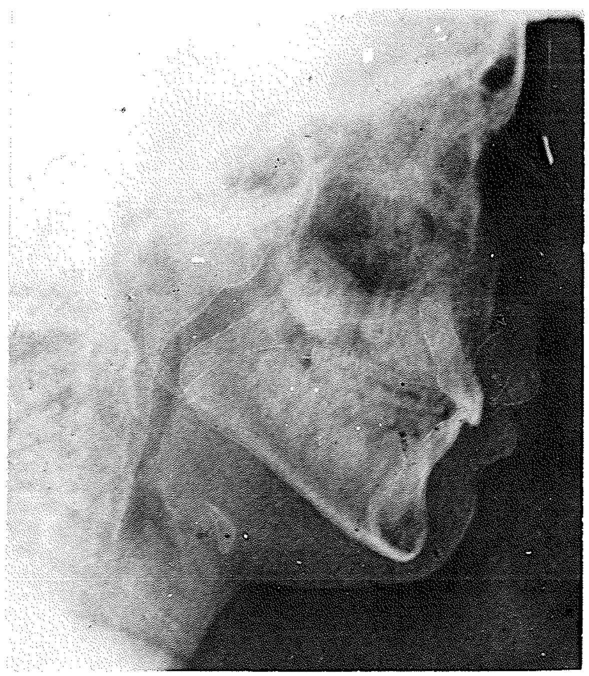


Figure 3c: Frame selected for stage 2 of deglutition

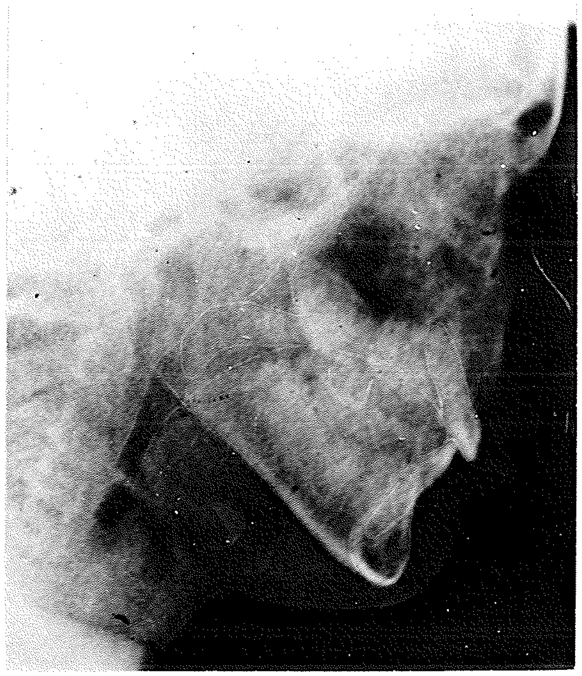
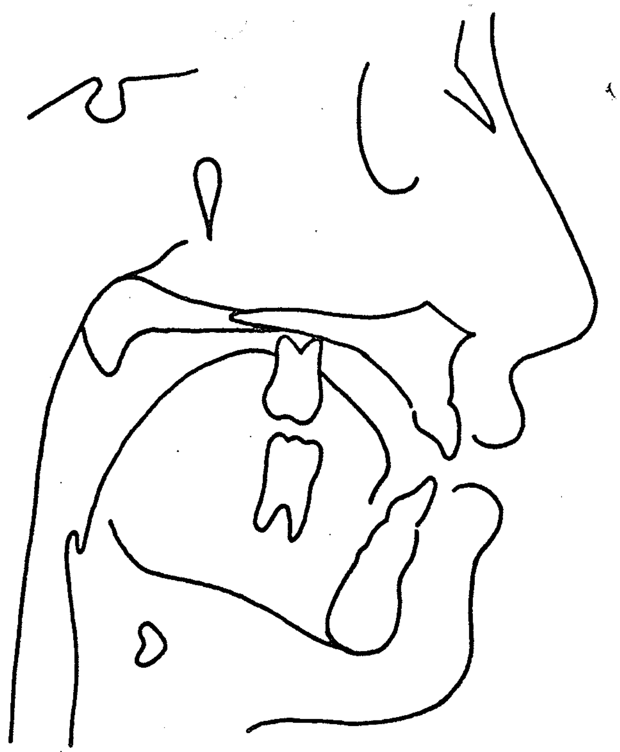


Figure 3d: Frame selected for stage 3 of deglutition

Figure 3e: Frame selected for stage 4 of deglutition



PRODUCTION OF "E" SOUND

Figure 4a: Diagram showing the production of "E" sound.

Figure 4b: Frame selected for cinefluorographic analysis of "E" sound

The cinefluorographic analysis of the individual frames was carried out on a 16 mm Vanguard Motion Analyzer* (Figure 5). 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. The palatal plane was used because it could be accurately located in all the frames being studied. From the palatal plane, and the vertical projections from the registration points on this plane, the positions of the soft palate, posterior pharyngeal wall, mandible, tongue, lips and hyoid bone were measured both in the vertical and horizontal dimensions. The definition and abbreviation of various landmarks and reference points and planes that were used are found in the Glossary.

(1) Angular Measurements: (measurements were estimated to the nearest one-half of one degree).

The angular measurements were divided into two groups:

The first group of angular measurements consisted of angles formed with the palatal plane at the registration of R, where the palatal plane intersected the vertical projection of the pterygo-maxillary fissure (Figure 6).

Angle A is the angle formed with the incisal tip of the mandibular central incisor, giving the position of the mandibular central incisor in the vertical dimension.

Angle B is the angle formed with the tip of the tongue, giving the position of the tongue tip in both the vertical and horizontal dimensions.

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* Vanguard Motion Analyzer - Vanguard Instrument Corporation, 20 W. Centennial Avenue, Roosevelt, L.I., N.Y.

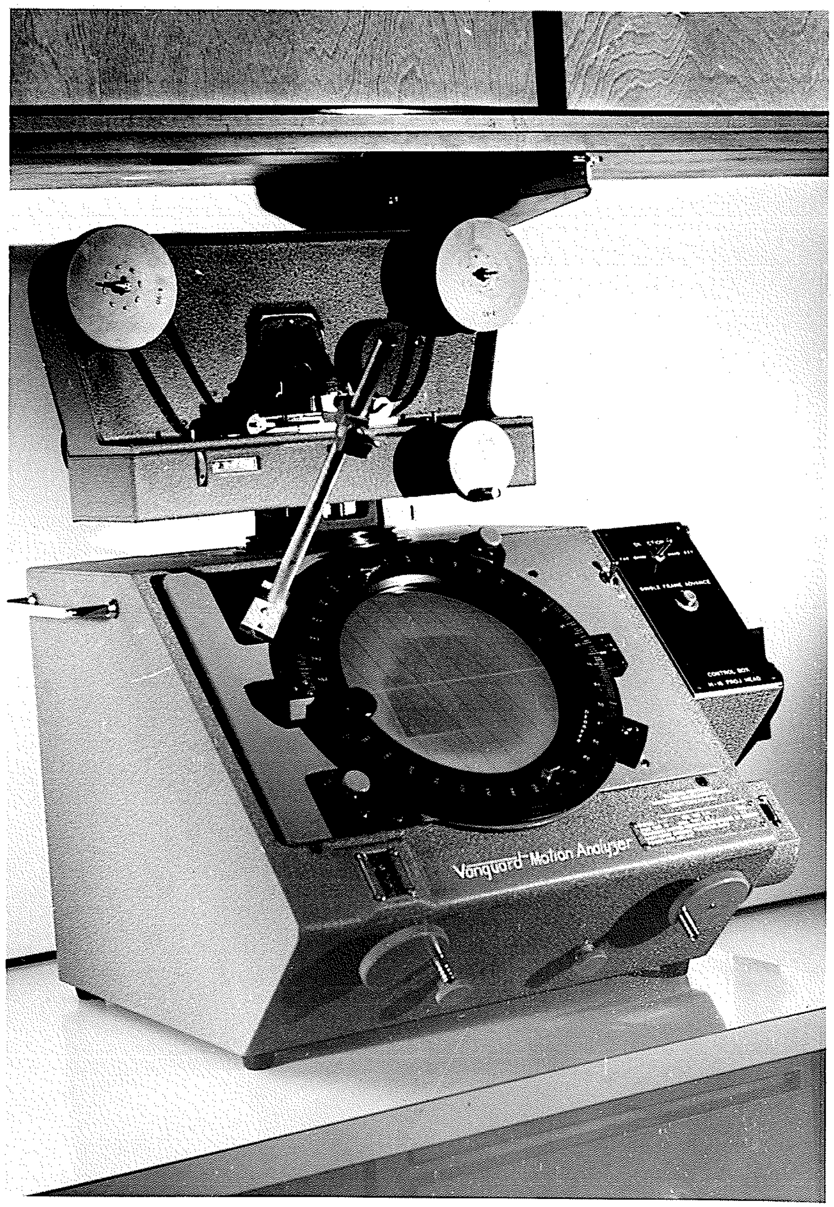

Figure 5. Diagram showing the Vanguard Motion Analyzer - this equipment was used for the frame by frame analysis of the cinefluorographic films.

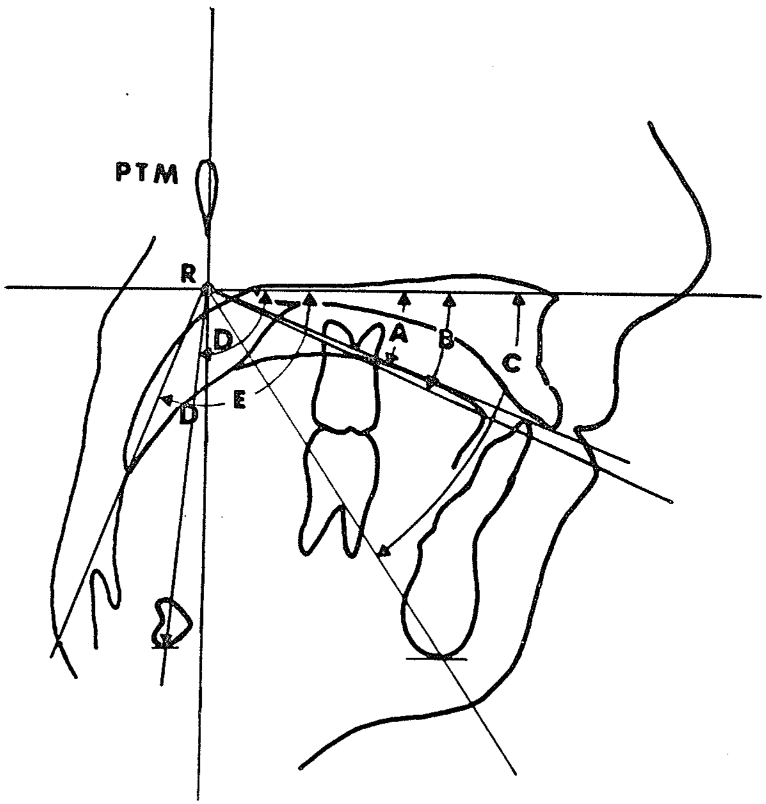

FIG 6
Registered at R

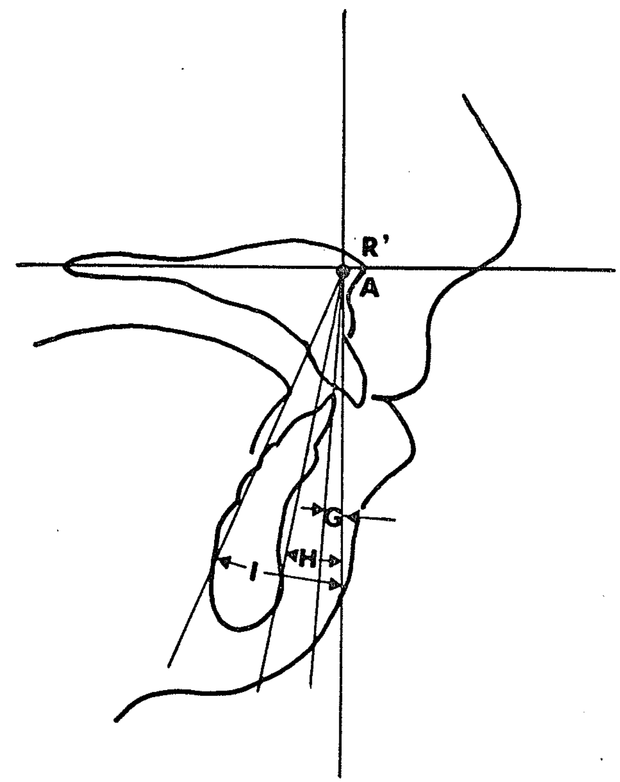

FIG 7
Registered at R'

ANGULAR MEASUREMENTS

Figure 6. Diagram showing the Angular Measurements registered at R.
Figure 7. Diagram showing the Angular Measurements registered at R'.

DUPLICATES OF FIGURES 6, 7, 8, 9, 10 AND 11

This removable set of diagrams should be removed and will be found helpful during the reading of the results.

CINEFLUOROGRAPHIC ANALYSIS

ANGULAR AND LINEAR MEASUREMENTS USED FOR THE ANALYSIS OF EACH INDIVIDUAL FRAME

Angular Measurement:

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 f is the distance between the palatal plane and lower lip line.

Length g is the distance between the palatal plane and the dorsum of the tongue.

Length h is the distance between the upper and lower lips.

Length i is the interincisal distance.

Length j is the distance between the maxillary central incisor and the lower lip line.

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.

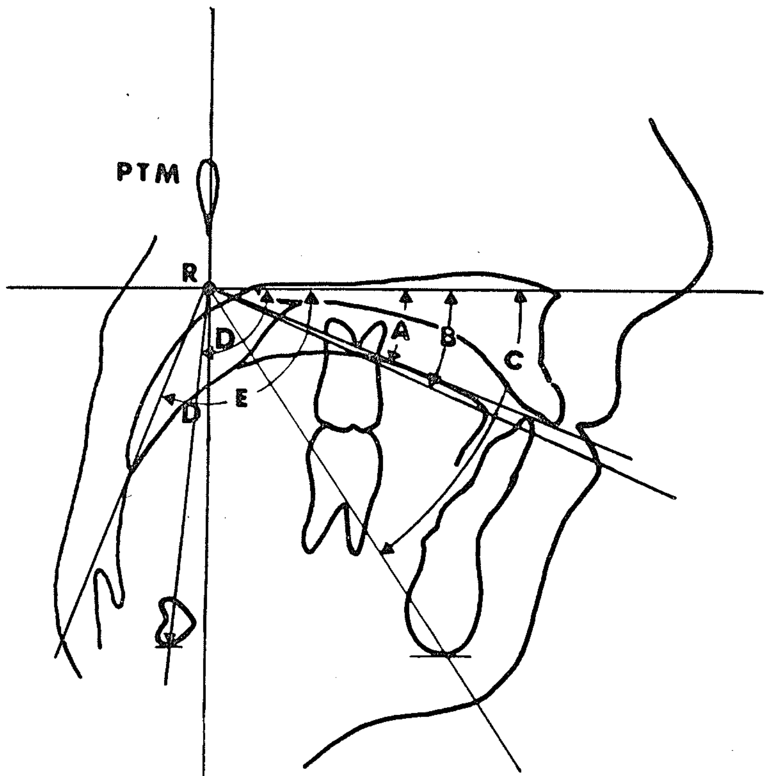

FIG 6
Registered at R

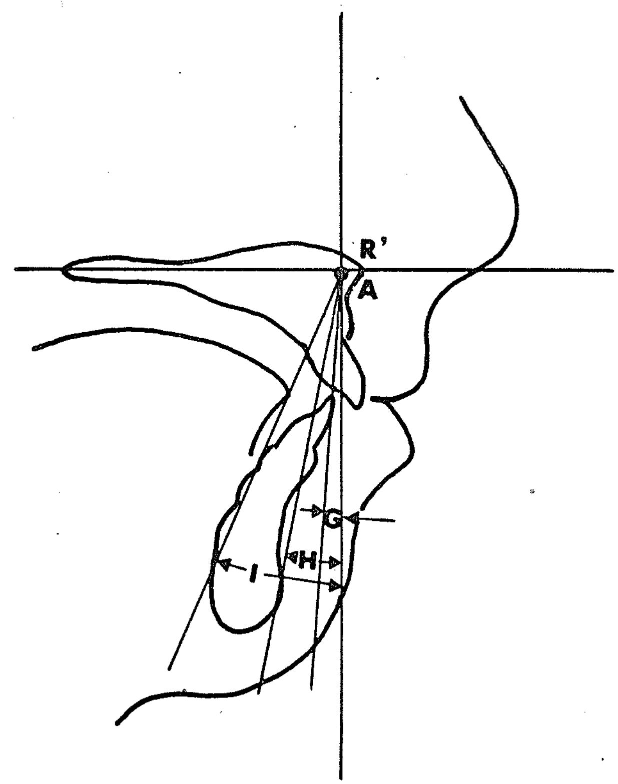

FIG 7
Registered at R'

ANGULAR MEASUREMENTS

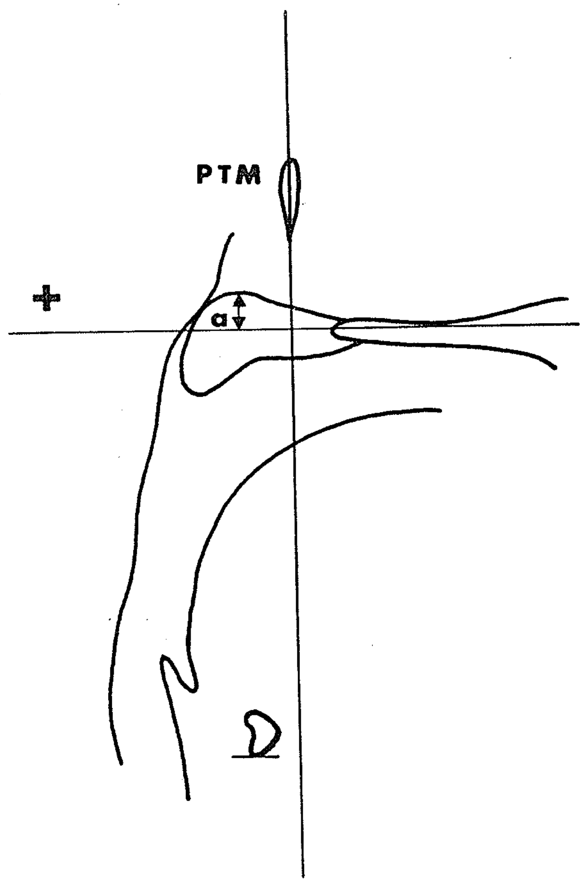

FIG 8

VELAR HEIGHT

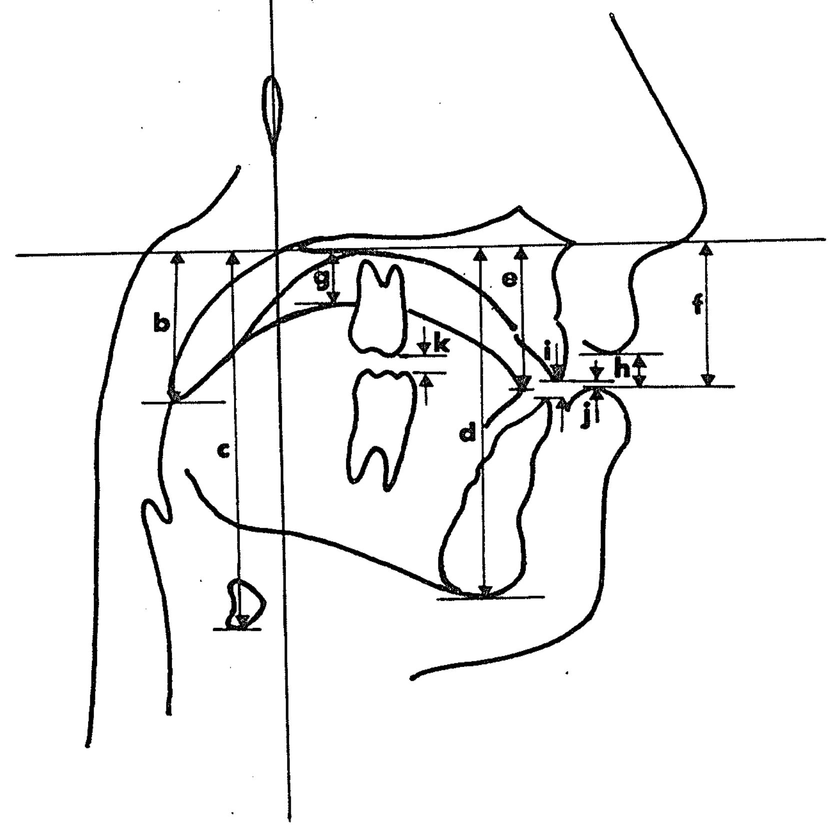

FIG 9

VERTICAL MEASUREMENTS

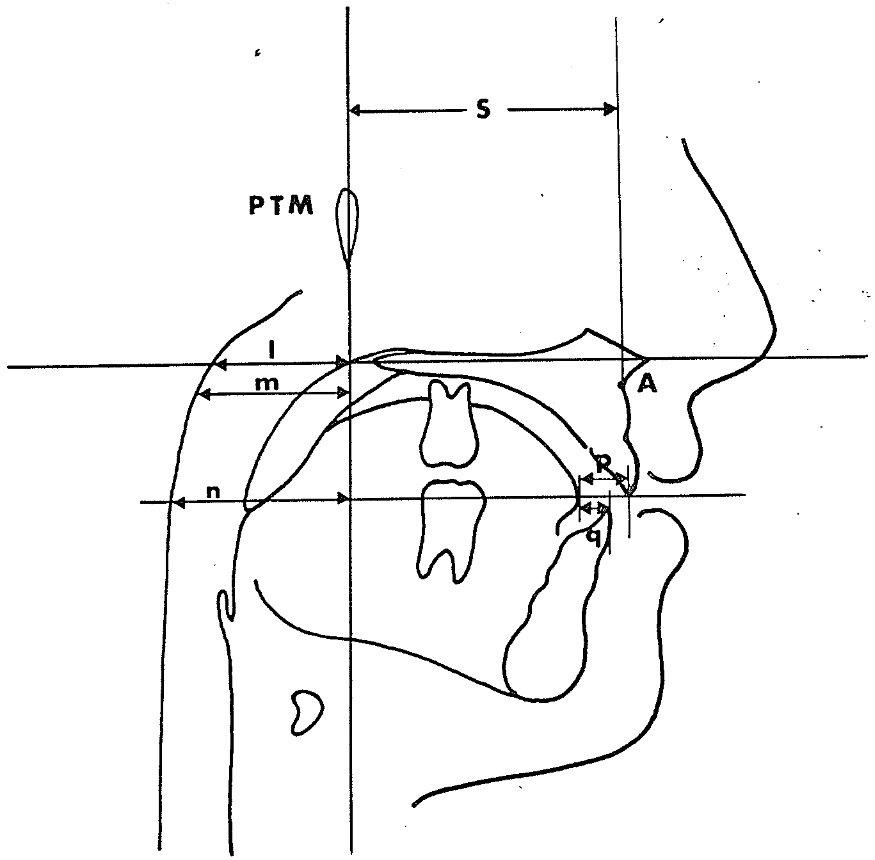

FIG 10

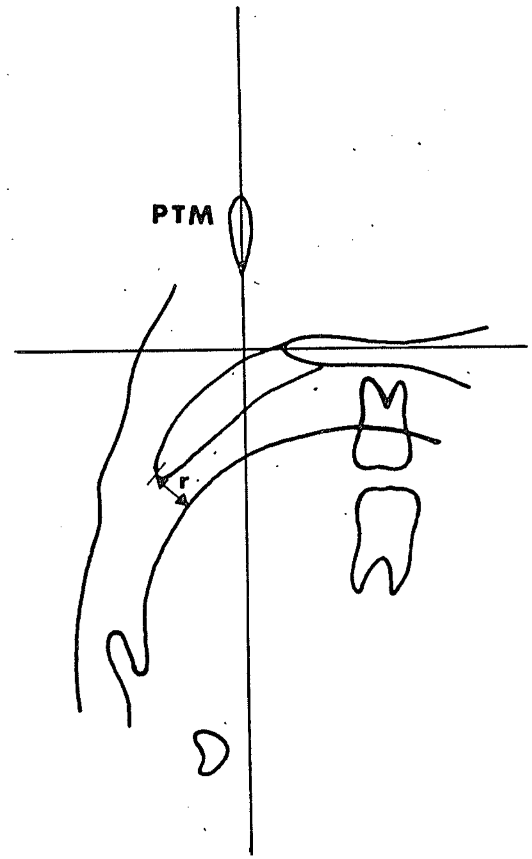

FIG 11

HORIZONTAL MEASUREMENTS

Angle C is the angle formed with menton. It gives the position of the lowest part of the mandibular symphysis in both the vertical and horizontal dimensions.

Angle D is the angle formed with the inferior border of the body of the hyoid bone, indicating the position of the hyoid bone in the horizontal dimension relative to the registration point R.

Angle E is the angle formed with the tip of the soft palate. It gives the angular relationship between the hard and soft palates as well as the position of the tip of the soft palate in both the vertical and horizontal dimensions.

The second group of angular measurements consisted of angles formed with the palatal plane at the registration of R', where the palatal plane intersected the vertical projection of point A. A negative value indicates that the structure is posterior to the vertical projection of point A; whereas a positive value indicates that the structure is anterior to the vertical projection of point A (Figure 7).

Angle G is the angle formed with the tip of the mandibular central incisor, giving the position of the mandibular central incisor in the horizontal dimension.

Angle H is the angle formed with pogonion, giving the position of the most anterior part of the mandibular symphysis in the horizontal dimension.

Angle I is the angle formed with the tip of the tongue, giving the position of the tongue tip in the horizontal dimension.

(2) Linear Measurements: (measurements were estimated to the nearest one-tenth of a millimeter).

The linear measurements were also divided into two groups:

The first group of linear measurements consisted of measurements in the vertical dimension (Figures 8 and 9).

Length a: This gives the height of the velum from the palatal plane, and measures only the height of the velum when it has projected above the level of the palatal plane during velopharyngeal closure.

Length b: This measures the distance of the tip of the soft palate from the palatal plane, giving its vertical position from the palatal plane.

Length c: This gives the vertical position of the inferior border of the body of the hyoid bone from the palatal plane.

Length d: This gives the vertical position of the lowest part of the symphysis of the mandible from the palatal plane.

Length e: This gives the vertical position of the tongue tip from the palatal plane.

Length f: This gives the vertical position of the lower lip line from the palatal plane.

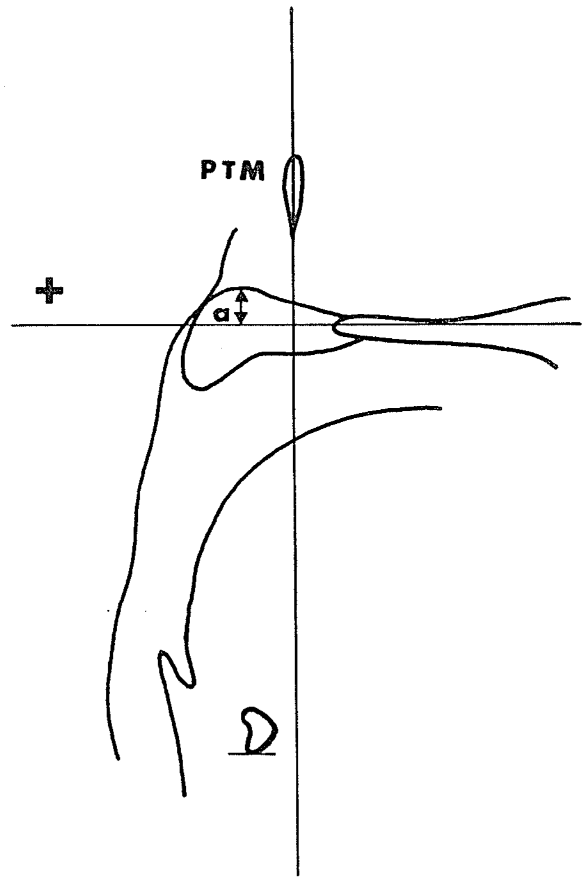

FIG 8

VELAR HEIGHT

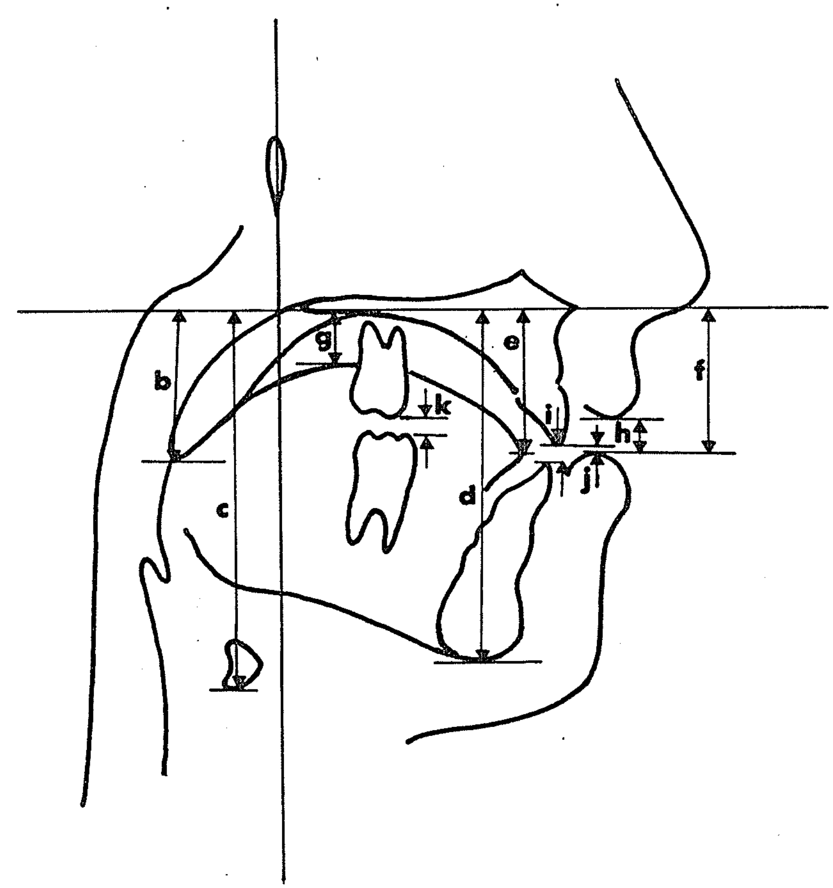

FIG 9

VERTICAL MEASUREMENTS

Figure 8. Diagram showing the Velar Height.
Figure 9. Diagram showing the Vertical Measurements.

Length g: This gives the vertical position of the highest part of the dorsum of the tongue from the palatal plane.

Length h: This measures the amount of lip separation at its narrowest point.

Length i: This measures the interincisal distance. A positive value indicates the amount of incisal overlap and a negative value indicates the smallest distance between the maxillary and the mandibular incisal tips.

Length j: This measures the distance between the maxillary central incisor and the lower lip line. A positive value indicates the amount of the lower lip overlapping the labial or lingual surface of the maxillary central incisors. A negative value indicates the separation in the vertical dimension between the tip of the maxillary central incisor and the lower lip line.

Length k: This measures the intermolar separation between the maxillary and mandibular first permanent molars or second deciduous molars.

The second group of linear measurements consisted of measurements in the horizontal dimension (Figures 10 and 11):

The distance of the posterior pharyngeal wall from the vertical projection of the pterygo-maxillary fissure was measured at three

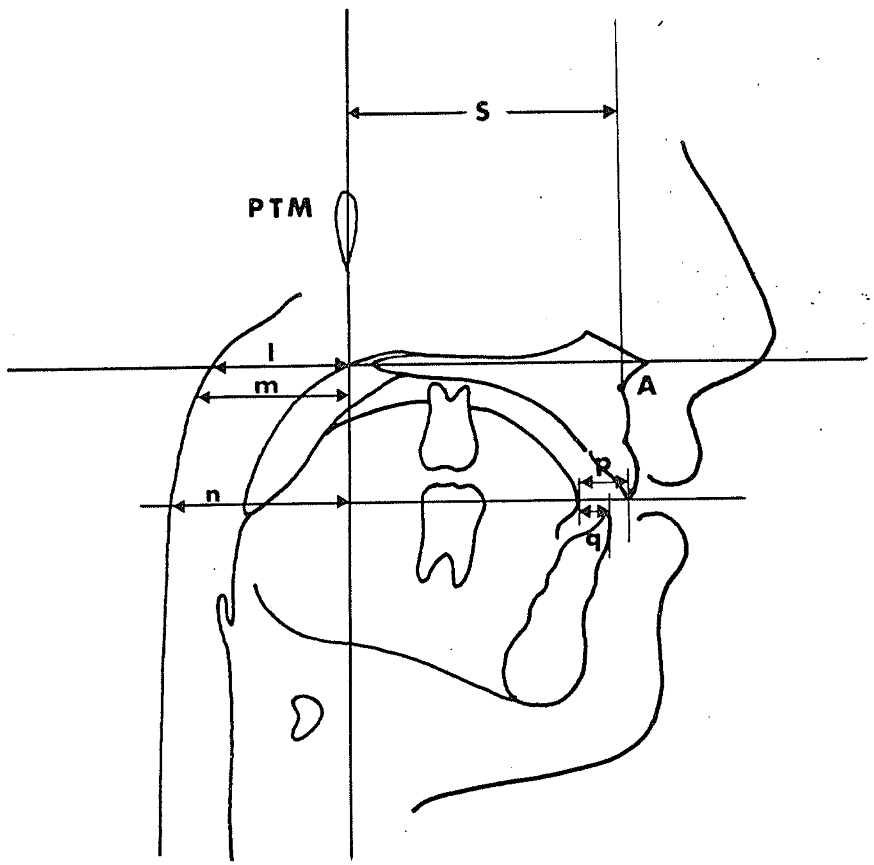

FIG 10

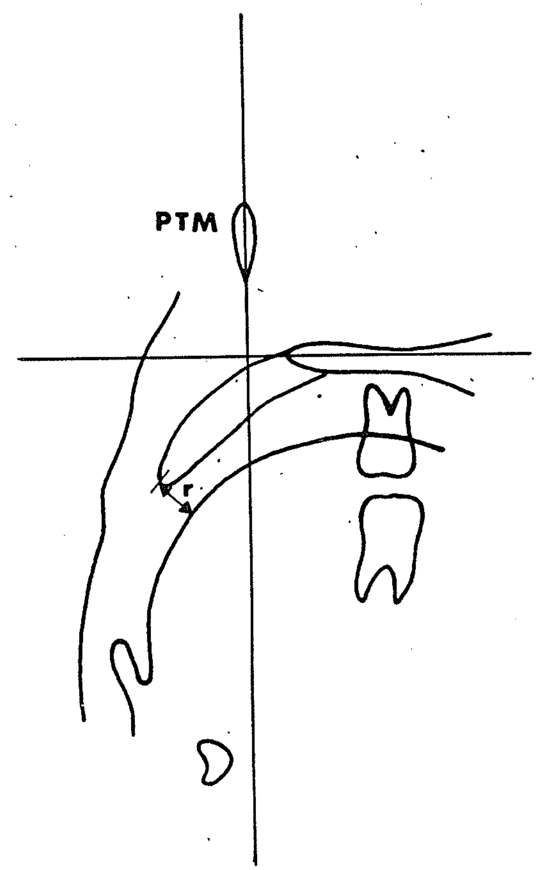

FIG 11

HORIZONTAL MEASUREMENTS

Figure 10. Diagram showing the Horizontal Measurements.
Figure 11. Diagram showing the Horizontal Measurements: Separation between soft palate and the posterior part of the tongue.

different levels, namely, length l, length m, and length n.

Length l: This gives the antero-posterior dimension of the nasopharyngeal isthmus at the level of the palatal plane.

Length m: This gives the antero-posterior dimension of pharynx at the level of point A.

Length n: This gives the antero-posterior dimension of the pharynx at the level of the maxillary central incisor.

Length p is the distance between the tongue tip and the tip of the maxillary central incisor.

Length q is the distance between the tongue tip and tip of the mandibular central incisor.

A positive value of length p or length q indicates that the tongue tip is lingual to the maxillary or mandibular incisor tip respectively. Similarly, a negative value of length p or length q indicates that the tongue tip is labial to the maxillary or mandibular incisor tip respectively.

Length r is the separation between the tip of the soft palate and the posterior part of the tongue. Any measurement obtained from length r would indicate that the posterior oral seal is absent.

V. Correction of Errors for Linear Measurements:

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 Pterygo-maxillary fissure, since these two bony landmarks are fairly easily and accurately discernible on the cine films. This distance was named "S". The value of "S" 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 mid-saggital plane.

VI. Statistical Analysis:

The raw data was obtained by direct measurement of the selected frames on the cine film, using the Vanguard Motion Analyzer. All the angular and linear measurements were recorded on a computer sheet and were then subjected to standard statistical evaluation including means, standard deviations, test for significance, and correlation coefficients.

CHAPTER IV

RESULTS

The results of the present investigation are based on statistical analysis. They will be presented in the form of tables, graphs and diagrams. The tables show the mean values, standard deviations, and the significance of difference of the means. Some of the more important tables will be found in the present chapter together with graphs and diagrams when required. The other tables and raw data will be found in the appendix.

The results of the present study will be discussed in the following sections:

I. Time Analysis of Deglutition.

II. Analysis of Variance.

III. Comparison of Mean Values:

(1) Velopharyngeal Closure.

(2) Mandibular Movement during Deglutition.

(3) Change of Tongue Position during Deglutition.

(4) Change of Lip Position during Deglutition.

(5) Hyoid Movement during Deglutition.

IV. Coefficient of Correlation ("r").

I. Time Analysis of Deglutition:

Time analysis of the sequence of movement during the act of swallowing between the initial and final resting position is shown in Table I and Table II. The difference of the mean values in various stages or between stages of deglutition before and after operation were not found to be statistically significant. This was due to the fact that the differences of the mean values were relatively small when comparing them to the wider range of standard of deviation before operation. However, the mean values did produce some interesting findings which may be expressed in the following manner.

The average time (in seconds) required for one complete swallowing cycle was 1.56 seconds before operation but was reduced to 1.40 seconds after operation. This showed 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.

When the time interval between the different stages of swallowing was compared before and after operation, it was found that the time interval between Stage 3 and Stage 4 was smaller whilst the time interval between all the other stages was larger before operation. It might be reasoned that the patients with enlarged tonsils hesitated to swallow during the voluntary stages of swallowing. However, once swallowing was initiated and the bolus reached the oropharyngeal

TABLE I

COMPARISON OF TIME ANALYSIS (IN SECONDS) FROM STAGE 1 TO STAGE 5 OF DEGLUTITION

	BEFORE OPERATION		AFTER OPERATION	
	MEAN	S.D.	MEAN	S.D.
Stage 1	0.00	-	0.00	-
Stage 2	0.30	0.20	0.20	0.07
Stage 3	0.62	0.29	0.47	0.13
Stage 4	0.97	0.45	0.88	0.28
Stage 5	1.56	0.63	1.40	0.38

TABLE II

COMPARISON OF TIME ANALYSIS (IN SECONDS) BETWEEN DIFFERENT STAGES OF DEGLUTITION

	BEFORE OPERATION		AFTER OPERATION	
	MEAN	S.D.	MEAN	S.D.
Stage 1-2	0.30	0.20	0.20	0.07
Stage 2-3	0.32	0.20	0.27	0.11
Stage 3-4	0.35	0.23	0.41	0.17
Stage 4-5	0.59	0.26	0.52	0.21

isthmus a greater effort was exerted to overcome the narrowed oro-pharyngeal isthmus caused by the enlarged tonsils and the associated discomfort in this area. The time analysis between the different stages of swallowing before and after operation is shown in Figure 12.

II. Analysis of Variance:

An analysis of variance was carried out on the mean values for both the angular and linear measurements. The results of the analysis of variables at different sources is shown in Tables III, IV, and V. Comparisons including sex, operation, sex vs operation, stages, sex vs stages, operation vs stage, and sex vs operation vs stages were made and the significance of difference tested by means of F test on the mean squares of each variable. It is important to realize that this method gives only the overall picture of the functional positions of the various structures such as that before and after operation. The detail of changes at different stages of swallowing and speech will be discussed in a separate analysis.

The results of analysis of variance showed that there were sex differences in four angular measurements and one linear measurement. Angles C, G and I were found to be significant at the 1 per cent level whilst Angle H and Length h were found to be significant at the 5 per cent level. The findings indicated that the vertical and horizontal positions of the anterior part of the mandible as well as the degree of lip separation and the horizontal position of tongue tip were different

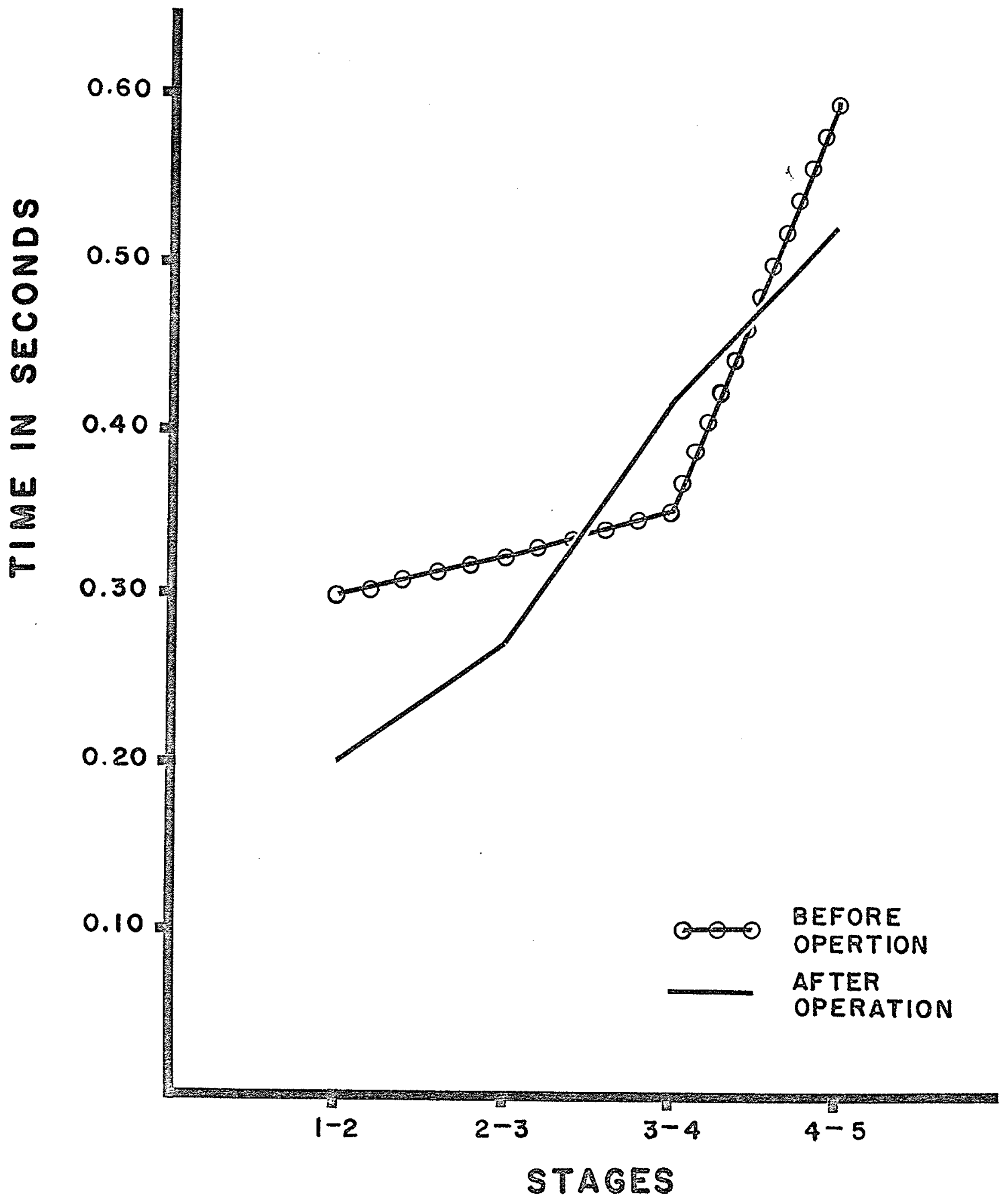

Figure 12. Graph showing the comparison of time intervals between different stages of deglutition before and after operation.

between the male and female groups. The differences found between these two groups might be associated with the characteristics of the skeletal pattern of these individuals since the sample size was not large enough to give a detailed study of the sex differences. Also, the age range in these two groups was found to vary in the present investigation, the average age for the male being eight years and the average age for the female being eleven years.

After operation, changes were noted to be present in four of the eight angular measurements and twelve of the seventeen linear measurements. The change was significant at the 1 per cent level in Angles B and I, and Lengths a, c, d, f, g, i, k, l, p, q and r. The change was significant at the 5 per cent level in Angles A and H, and Length e. The findings indicated that the positions of the tongue, mandible, hyoid bone, nasopharyngeal isthmus and velar height all showed significant changes after operation.

As was expected, there were significant changes of all the angular and linear measurements between various stages of deglutition and the production of "E" sound. The detail of these changes will be discussed in a separate analysis.

When stages were compared between the two sexes, it was found that Angle I was significant at the 1 per cent level and Lengths p and q were significant at the 5 per cent level. The findings indicate that there was a difference of the position of the tongue tip between the two sexes during the various stages of swallowing and in speech.

Significant changes among the various stages before and after operation were found to be present in Length r at the 5 per cent level, indicating that the distance between the tip of the soft palate and posterior part of the tongue had changed after operation.

No significant change was noted when comparisons were made in sex vs operation, and sex vs operation vs stage.

III. Comparison of Mean Values:

(1) Velopharyngeal Closure:

At rest, the soft palate formed an angle with the hard palate (Angle E). The mean of Angle E at rest before operation was found to be 136.4° (Table XII). During swallowing, Angle E showed a dramatic increase at Stage 3 and reached its maximum at Stage 4 (Figure 13). At Stage 4, the mean of Angle E was 148.1° in the male and 144.1° in the female (Table XI). This difference was found to be significant at the 5 per cent level, indicating that the soft palate had risen to a higher level in the male sample at Stage 4 of deglutition. During the production of "E" sound, the mean of Angle E in the male was 146.9° and 144.7° in the female showing no significant difference (Table XXII).

After operation, no significant change of the mean of Angle E was observed in either deglutition or in speech (Table XX and Table XXIV). However, when the cases were examined carefully, it was found that the resting positions of Angle E had increased in 14 per cent of cases and decreased in 50 per cent of cases. The remaining 36 per cent of cases

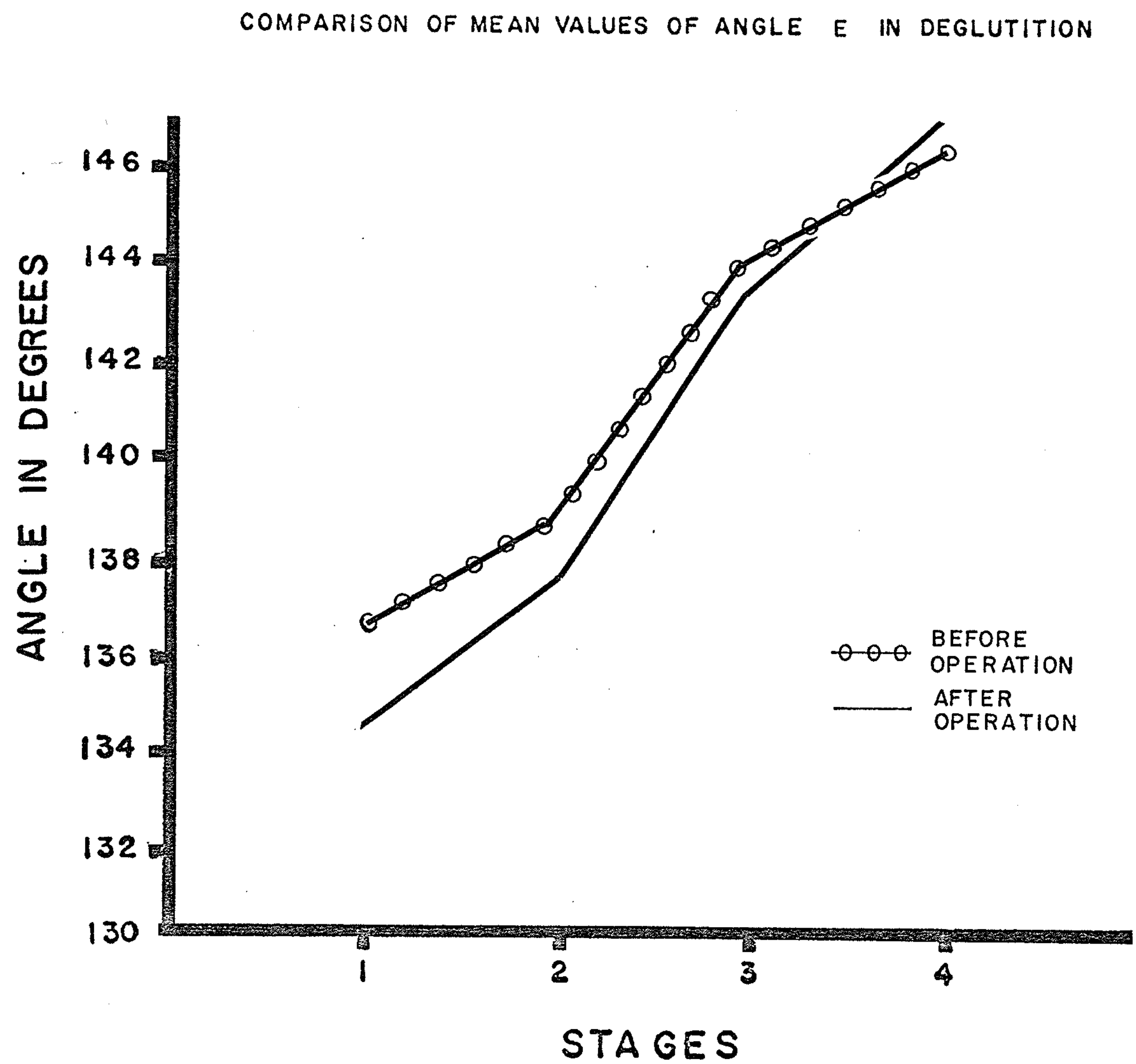

Figure 13. Graph showing the comparison of mean values of Angle E in deglutition.

showed no change of Angle E before and after operation.

Length a, the velar height, showed also a dramatic increase at Stage 3 reaching its maximum height at Stage 4 of deglutition (Figure 14). The mean of Length a at Stage 4 of deglutition was 3.3 mm before operation (Table XXI). During the production of "E" sound, Length a was found to be 4.2 mm which was significantly larger than its maximum value at Stage 4 of deglutition at the 1 per cent level (Table XXV).

After operation, no significant increase of Length a was observed in deglutition but the increase was significant at the 1 per cent level in the production of "E" sound (Table XXV). This demonstrated that the velum had risen to a higher level above the level of the palatal plane in the production of "E" sound after surgery, when the enlarged adenoids had been removed.

Length b represents the vertical distance of the tip of the soft palate from the level of the palatal plane. It showed a dramatic decrease in Stage 3 reaching its minimum value at Stage 4 of deglutition, indicating that the tip of the soft palate was closest to the level of the palatal plane at Stage 4 of deglutition (Figure 15). However, no significant difference was found between the mean values of length b at Stage 4 of deglutition and in speech before and after operation (Table XXI and Table XXV).

Length r was found to increase to a significant level at Stage 3 of deglutition (Figure 16). This indicates that the tip of the soft palate had moved away from the posterior part of the tongue when the

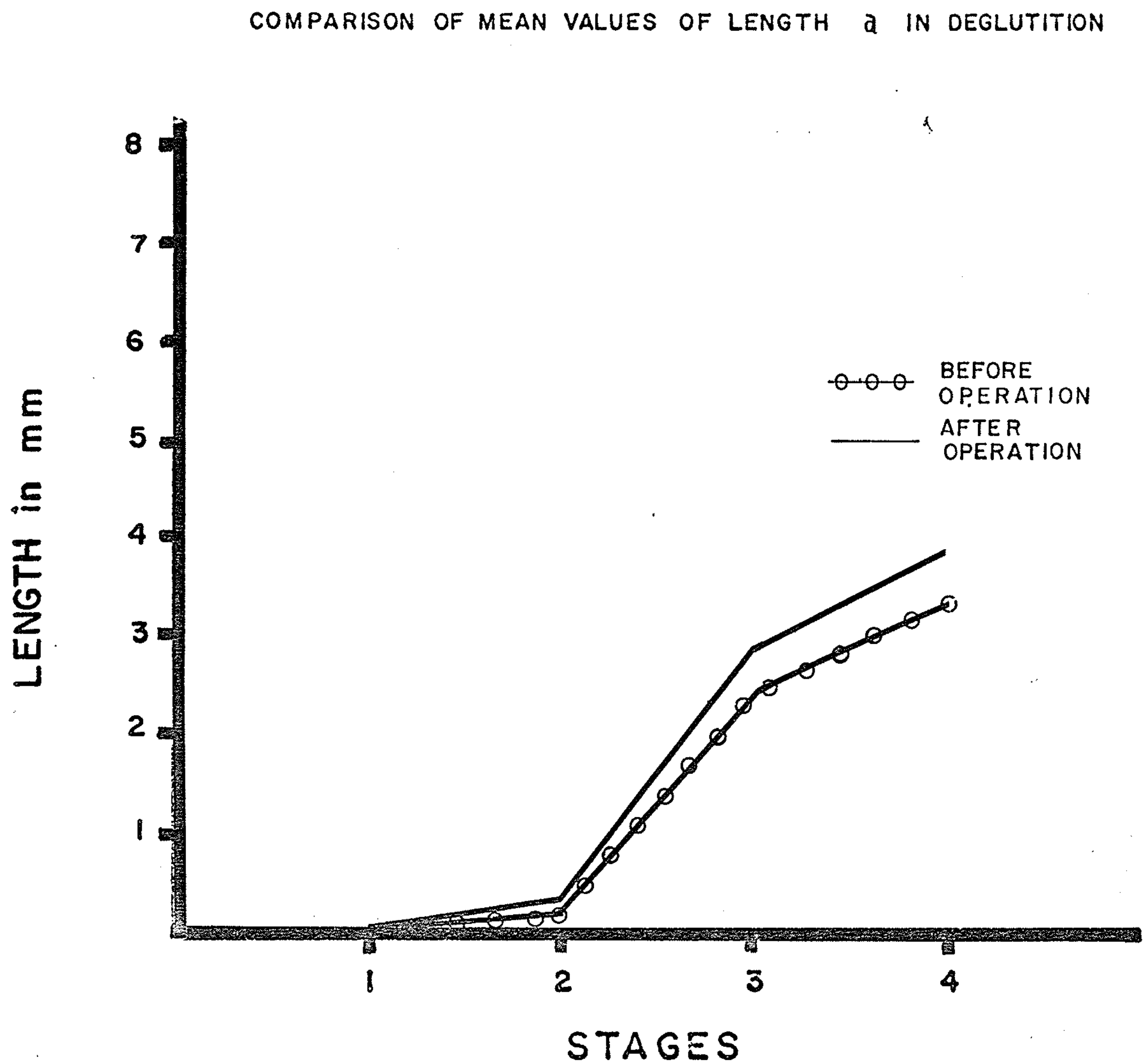

Figure 14. Graph showing the comparison of mean values of Length a in deglutition.

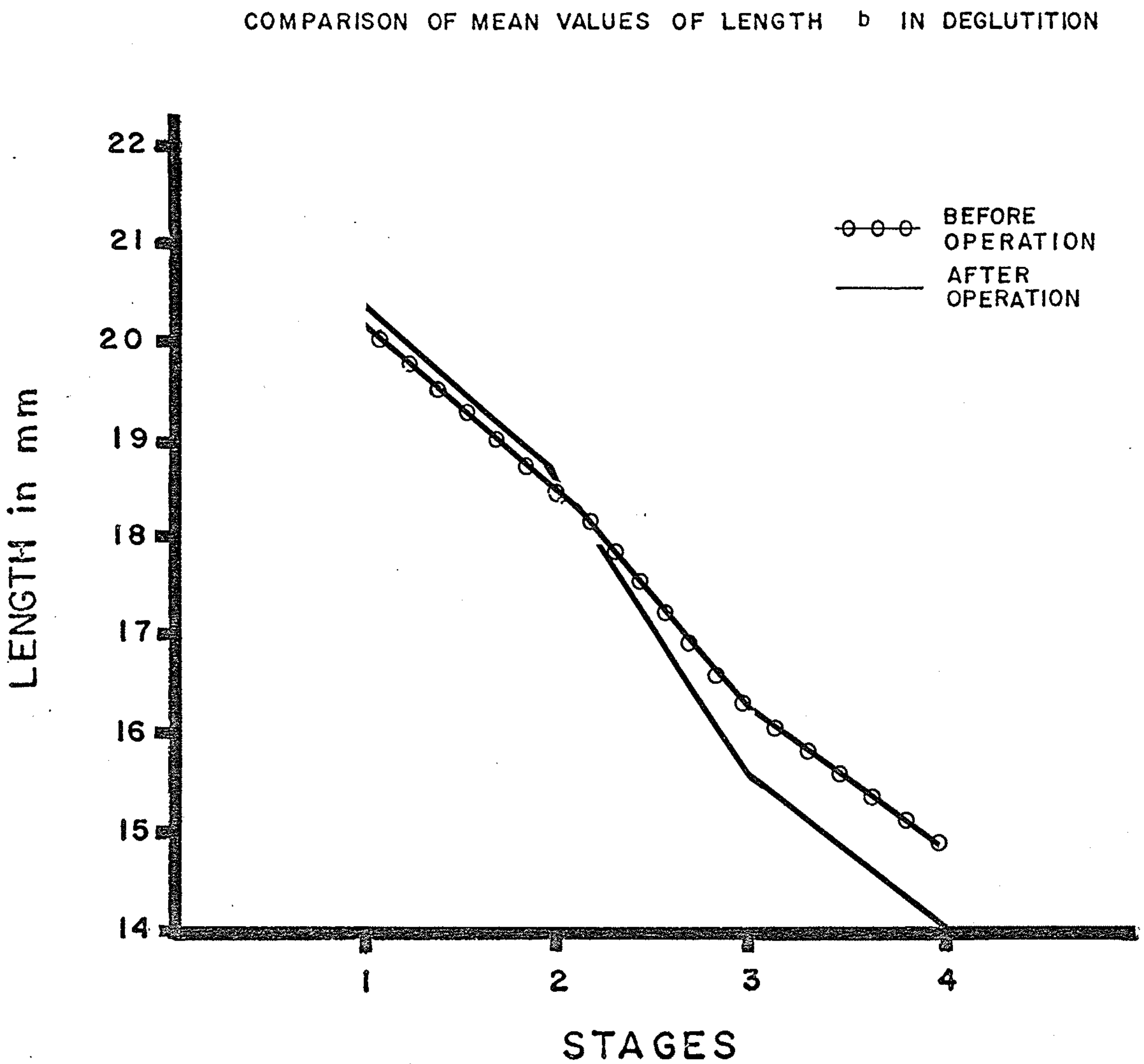

Figure 15. Graph showing the comparison of mean values of Length b in deglutition.

COMPARISON OF MEAN VALUES OF LENGTH r IN DEGLUTITION

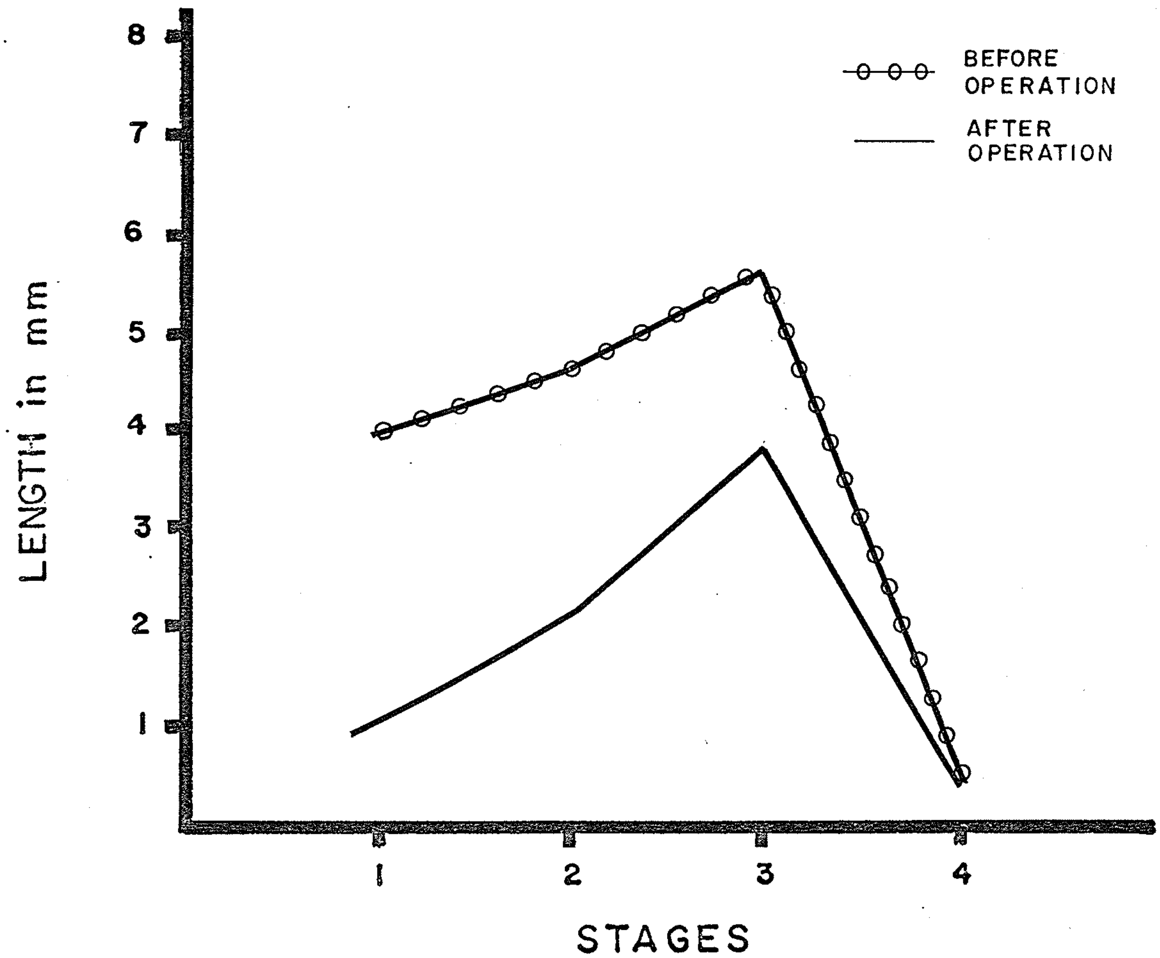

Figure 16. Graph showing the comparison of mean values of Length r in deglutition.

stripping action of the tongue against the hard palate had reached the junction of the hard and soft palates. Length r was found to decrease significantly to its smallest dimension at Stage 4 showing that there was contact of the posterior part of the tongue and soft palate at Stage 4 of deglutition.

During the production of "E" sound, Length r was found to be significantly larger than that at Stage 3 of deglutition (Tables XII, XIII and XXV). This is understandable because the functional position of the tongue was different between deglutition and speech.

The mean of Length r at rest was found to be 4.3 mm before operation and 1.3 mm after operation (Table XV). This difference was found to be significant at the 1 per cent level. This means that the posterior oral seal had improved dramatically after the removal of the tonsils and adenoids. Careful analysis of the cases in 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 demonstrated contact between the tip of the soft palate and posterior part of the tongue, that is, a posterior oral seal. Four cases showed a decrease in the separation between the tip of the soft palate and the tongue and one case showed a slight increase.

The means of Length 1 at rest was not found to be significant between the male and female samples (Table VIII). However, during swallowing, Length 1 was found to have decreased significantly at the

5 per cent level in the male group, indicating that the forward movement of the posterior pharyngeal wall at the level of the palatal plane was greater in the male group at Stage 3 and Stage 4 of deglutition (Tables X and XI).

The means of Length 1 was 19.9 mm before operation and 23.3 mm after operation (Table XV). The increase of Length 1 after operation was found to be significant at the 5 per cent level indicating that there was an increase of the nasopharyngeal isthmus in the antero-posterior dimension at the level of the palatal plane following the removal of the adenoids.

During swallowing, there was a tendency for Length 1 to decrease indicating forward movements of the posterior pharyngeal wall at the level of the palatal plane (Figure 17). The decrease became significant at the 5 per cent level at Stage 4 of deglutition after operation (Table XIII).

During the production of "E" sound, Length 1 did not show any significant decrease from its rest position, though it tended to decrease slightly after operation (Tables XXVII and XXIX). This seems to indicate that the posterior pharyngeal wall had adjusted itself to the change of dimension after operation.

Both Lengths m and n showed no significant difference before and after operation though these dimensions also tended to decrease at Stage 4 of deglutition (Figures 18 and 19), but remained unchanged from the resting positions during the production of "E" sound (Tables XXVII

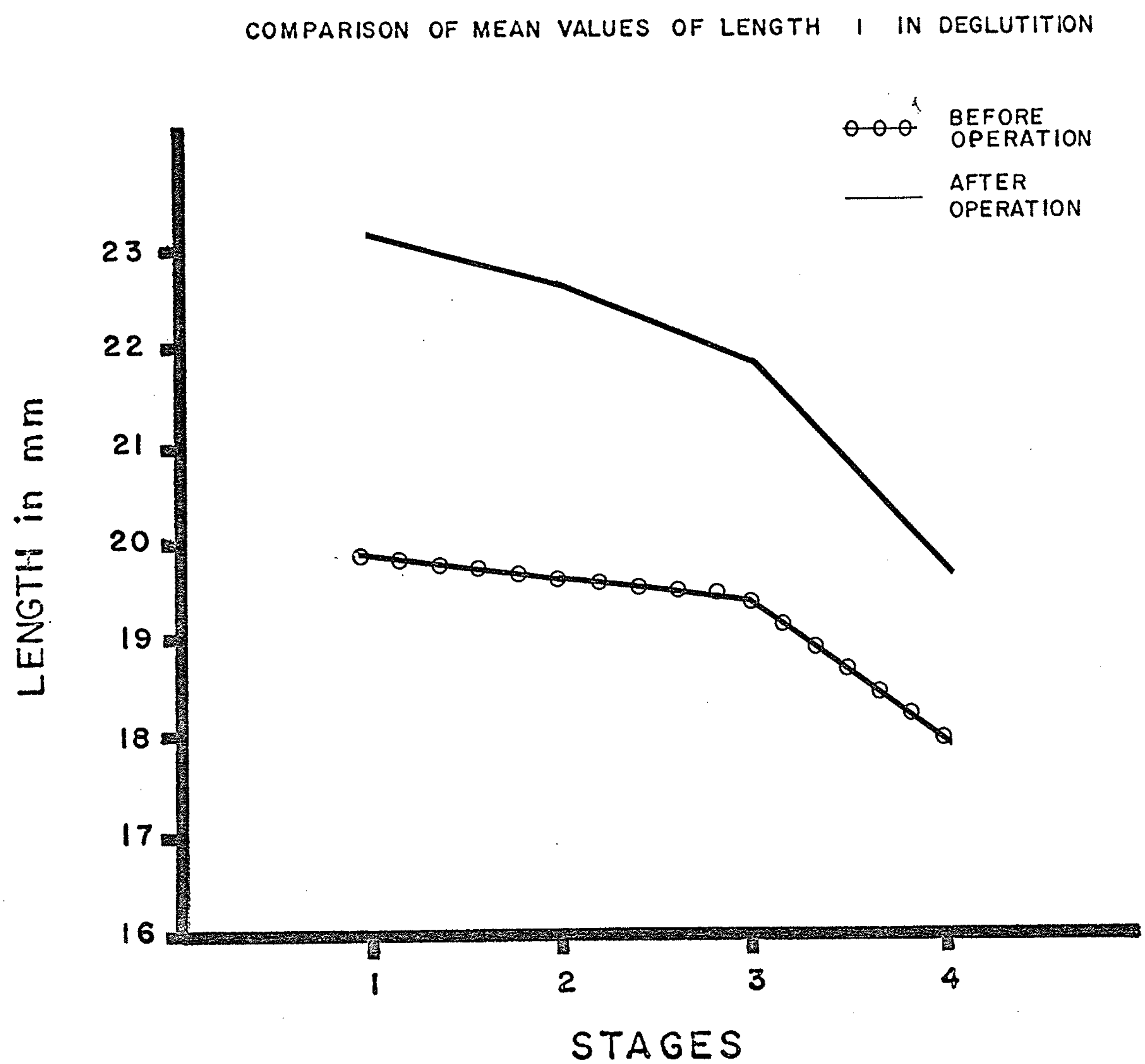

Figure 17. Graph showing the comparison of mean values of Length 1 in deglutition.

COMPARISON OF MEAN VALUES OF LENGTH m IN DEGLUTITION

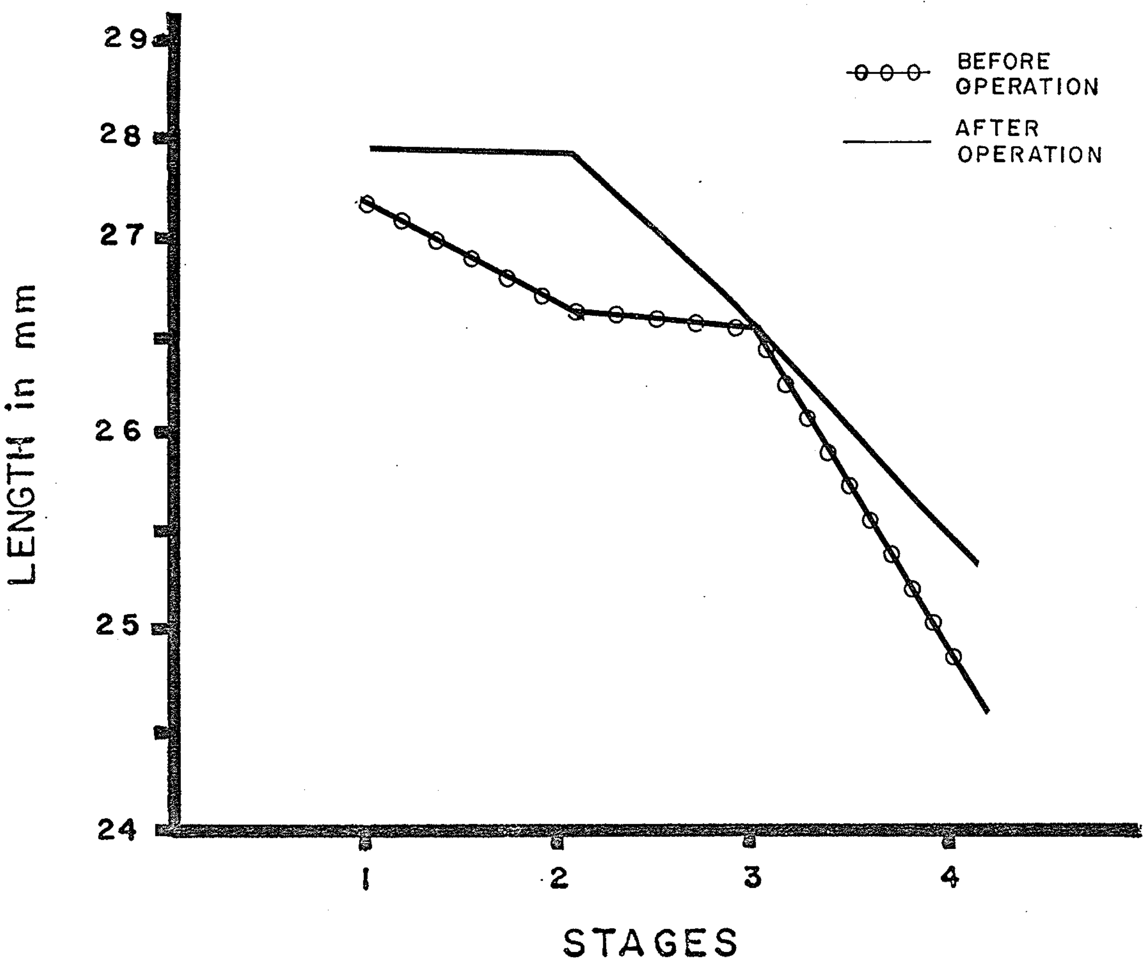

Figure 18. Graph showing the comparison of mean values of Length m in deglutition.

COMPARISON OF MEAN VALUES OF LENGTH n IN DEGLUTITION

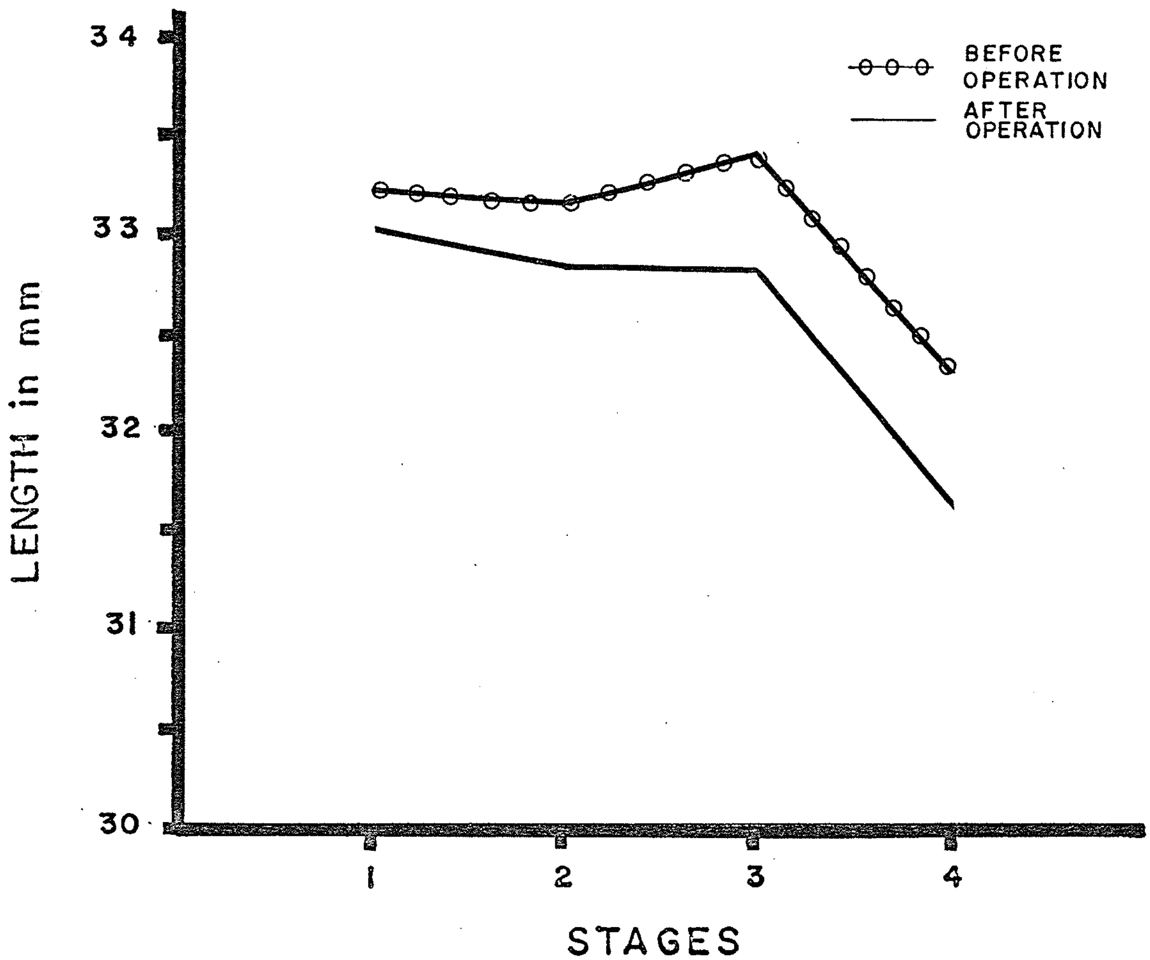

Figure 19. Graph showing the comparison of mean values of Length n in deglutition.

and XXIX).

(2) Mandibular Movement during Deglutition:

Angle A was found to be significantly larger in the male group, both at rest and in deglutition (Tables VII, IX, X and XI). The mean of Angle A at rest was 32.4^{o} for the males and 29.3^{o} for the females.

During swallowing, Angle A tended to decrease, showing that there was a tendency to swallow with the teeth coming closer together. After operation, the mandible tended to acquire a slightly more closed position at rest. This tendency was found to be the same during the act of swallowing (Figure 20).

Similar findings were observed with Angle C and Length d which also showed a tendency to decrease during the act of swallowing and with the mandible functioned in a more closed position after operation (Figures 21 and 22).

Length i represented the amount of incisal overlap. It was found to be -2.80 mm in the male and -0.36 mm in the female when the mandible was at its rest position. This finding was found to be significant at the 5 per cent level, indicating that the maxillary and mandibular incisors were further apart at rest in the male group (Table VIII).

During swallowing, Length i tended to become less negative indicating that the maxillary and mandibular teeth have the tendency to come closer together. After operation, the mean of Length i also demonstrated that the incisors tended to come into a more closed

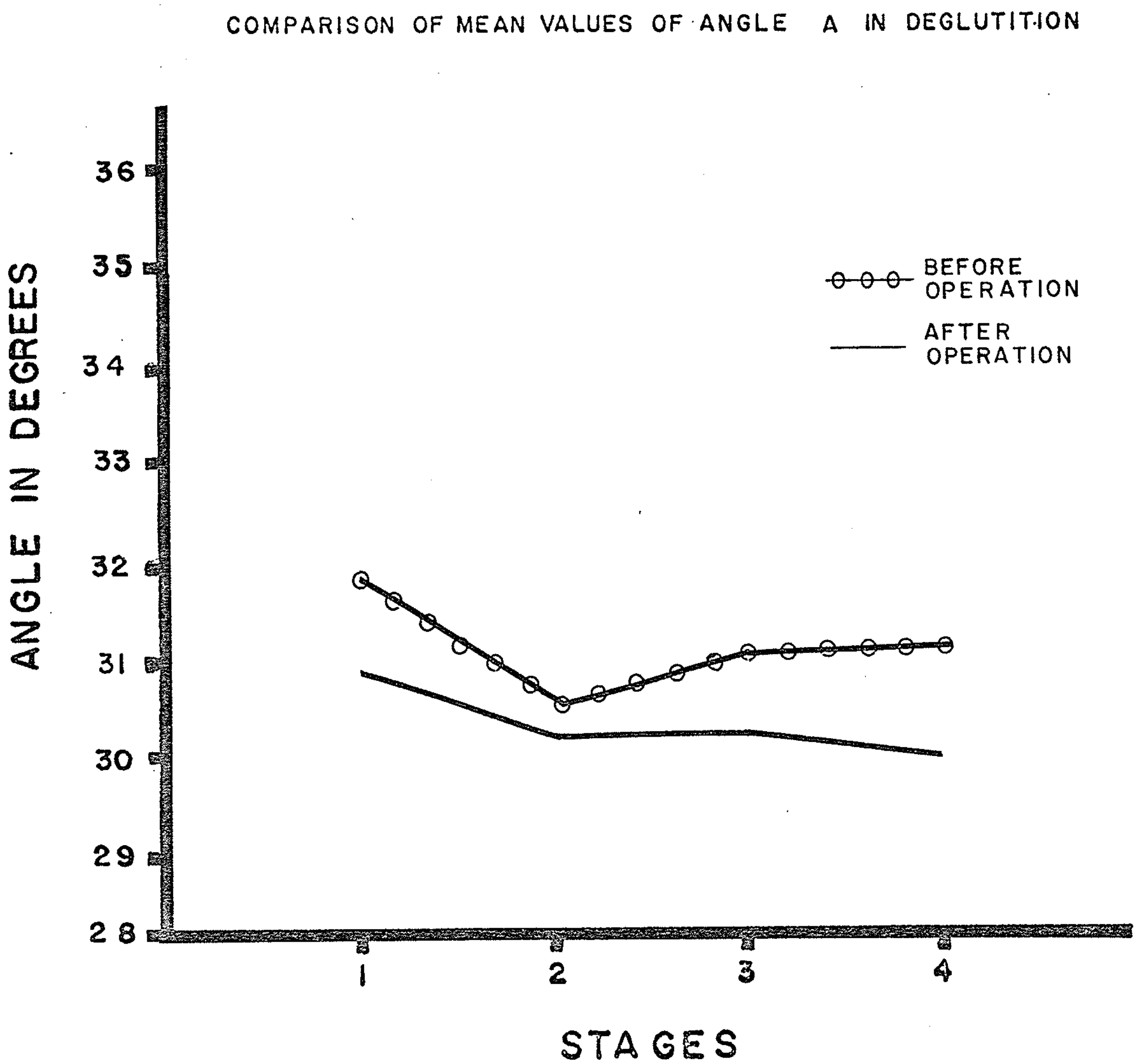

Figure 20. Graph showing the comparison of mean values of Angle A in deglutition.

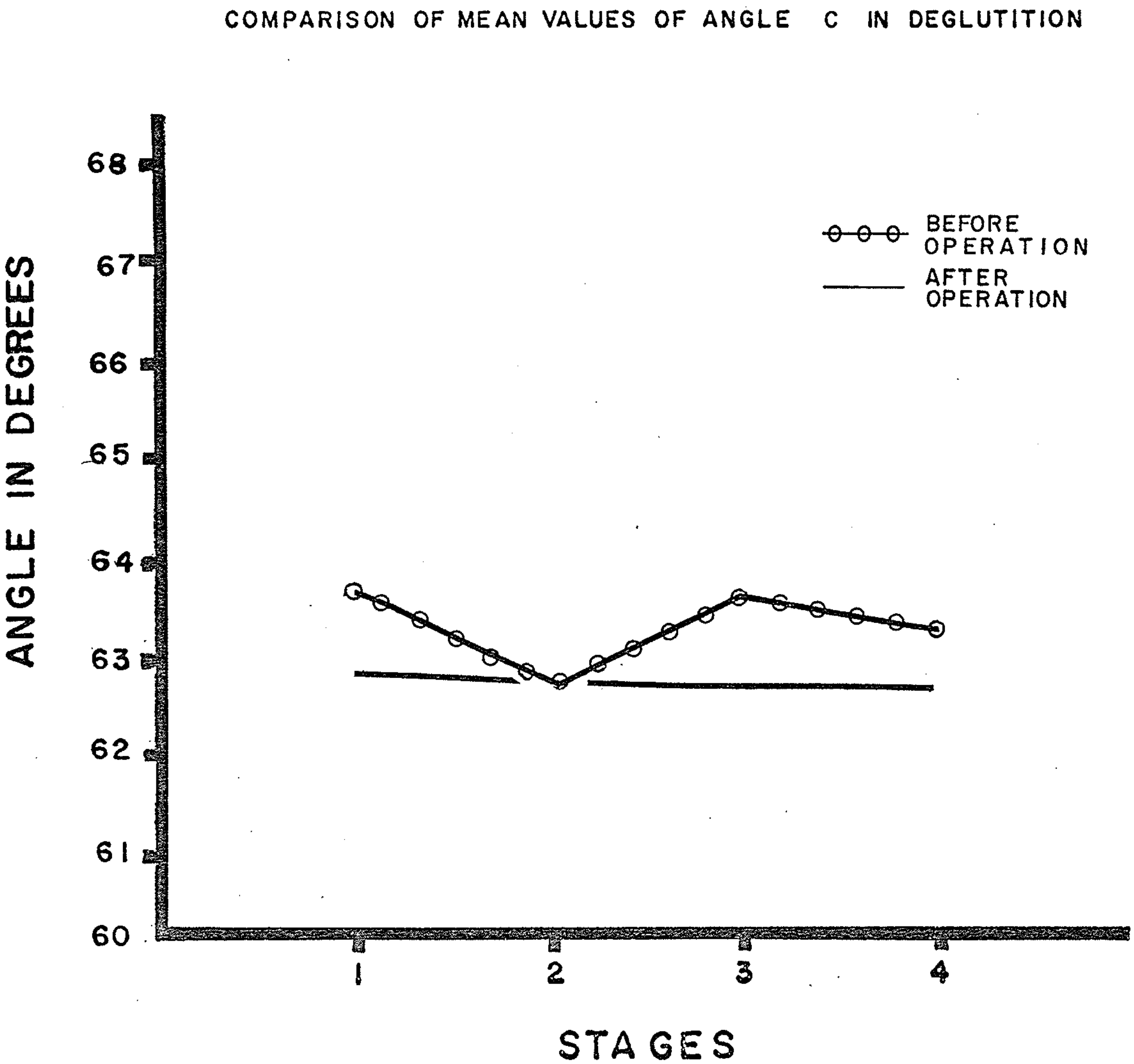

Figure 21. Graph showing the comparison of mean values of Angle C in deglutition.

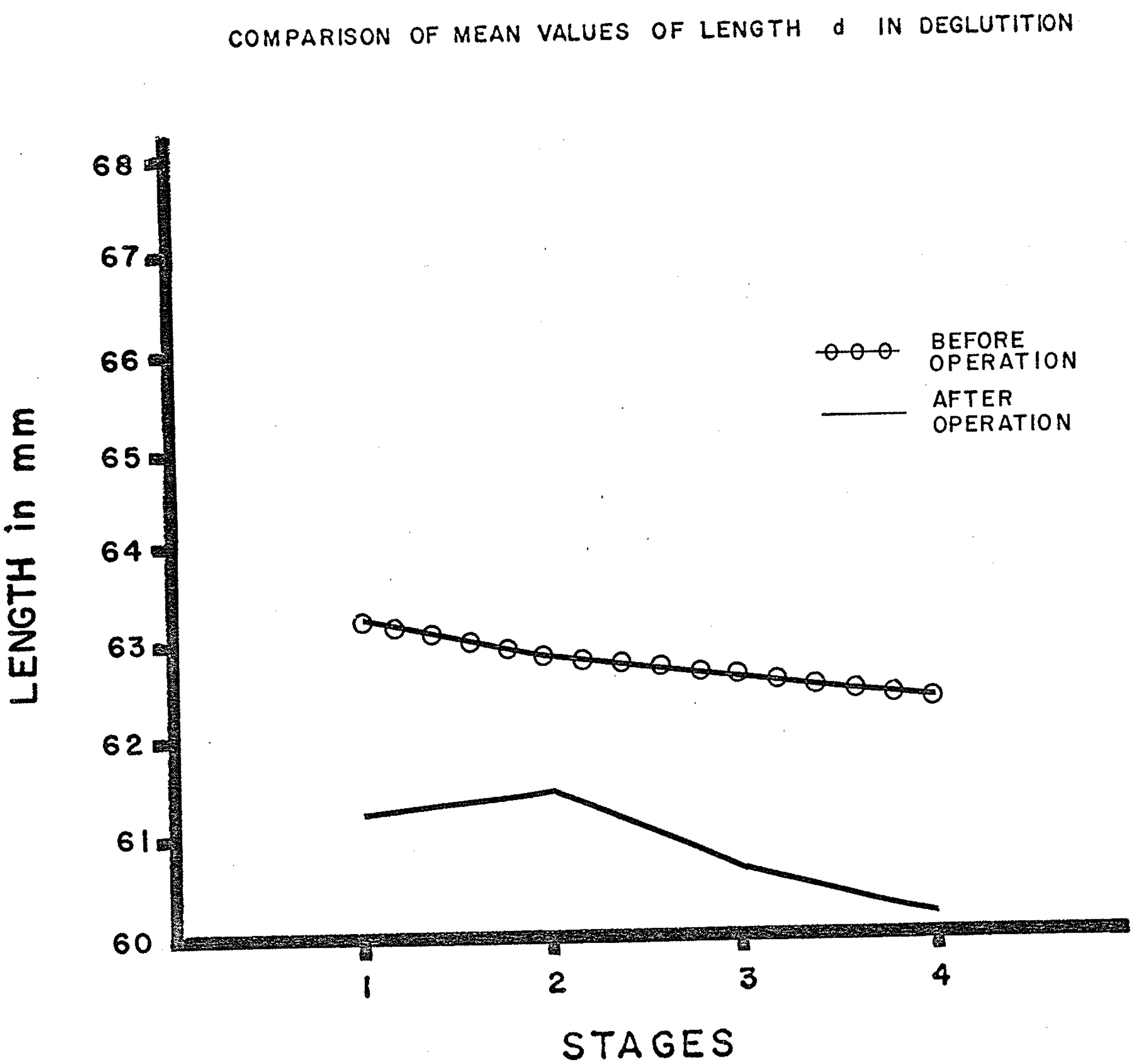

Figure 22. Graph showing the comparison of mean values of Length d in deglutition.

position both at rest and during deglutition (Figure 23).

Length k was used to measure the molar separation. During swallowing, there was a tendency for the molars to come closer together. After operation, the intermolar distance tended to decrease both at rest and in deglutition (Figure 24). However, when the cases were examined carefully it was found that twenty of the twenty-eight cases (71.4 per cent) swallowed with the teeth apart before operation. Of these twenty cases, only three swallowed with the teeth together after operation.

It was interesting to find from Figures 20, 21, and 22 that during the act of swallowing, the mandible had come to a more closed position at Stage 2 than at any other stages of deglutition.

At rest, Angle G was found to be significantly larger at the 1 per cent level in the males than in the females (Table VIII). This finding was reinforced by the mean of Angle H which was also significantly larger at the 5 per cent level in the males. Since both these measurements represented the position of the mandible in the horizontal dimension, it was concluded that the mandible was more retrognathic in the males than the females in the present investigation. The change of Angles G and H at rest was not found to be significant after operation (Table XIV, Figures 25 and 26).

(3) Change of Tongue Position during Deglutition:

The functional positions of the tongue tip were represented by Angle B, Angle I, Length c, p and q. Length g represented the position

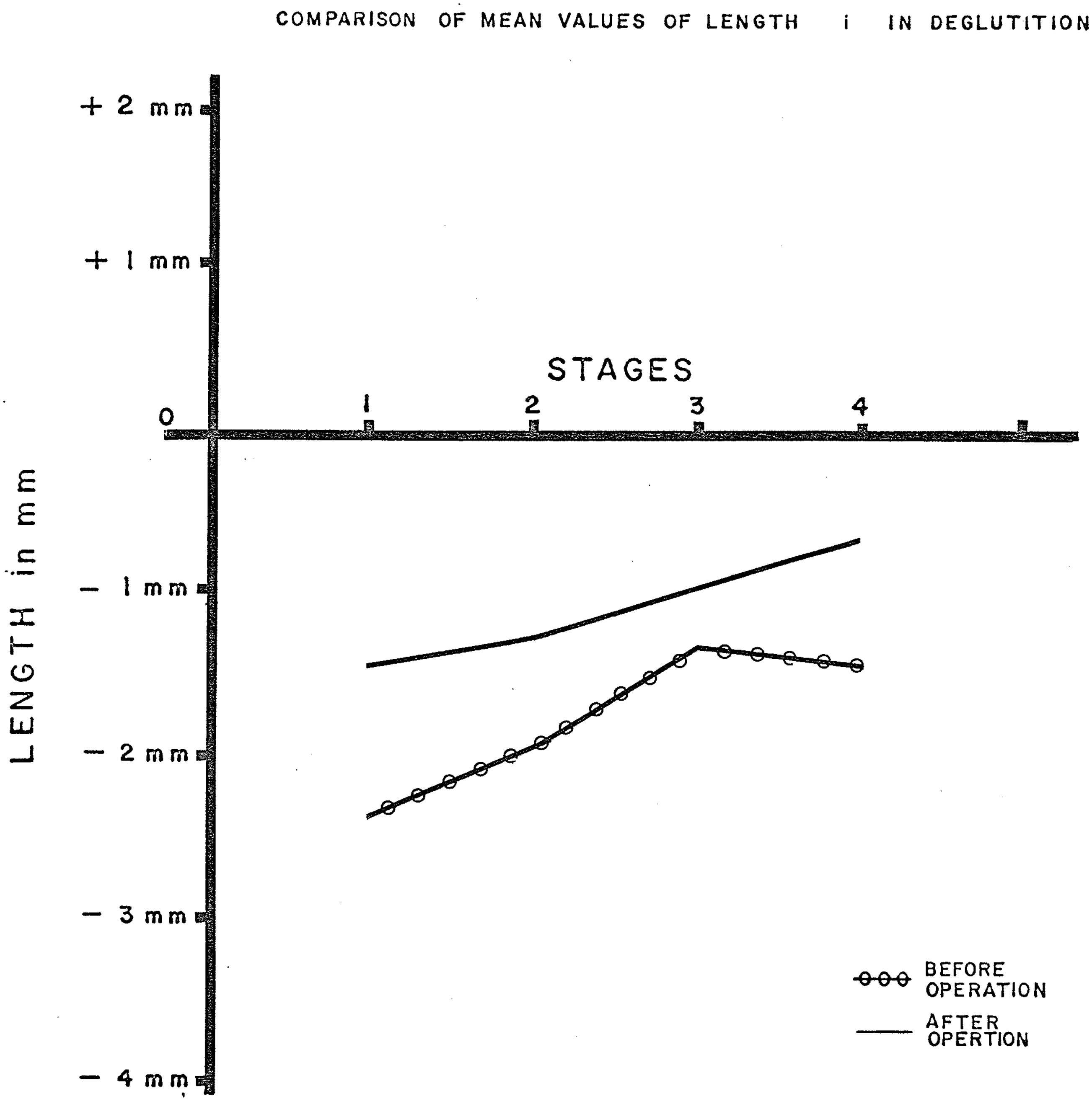

Figure 23. Graph showing the comparison of mean values of Length i in deglutition.

COMPARISON OF MEAN VALUES OF LENGTH k IN DEGLUTITION

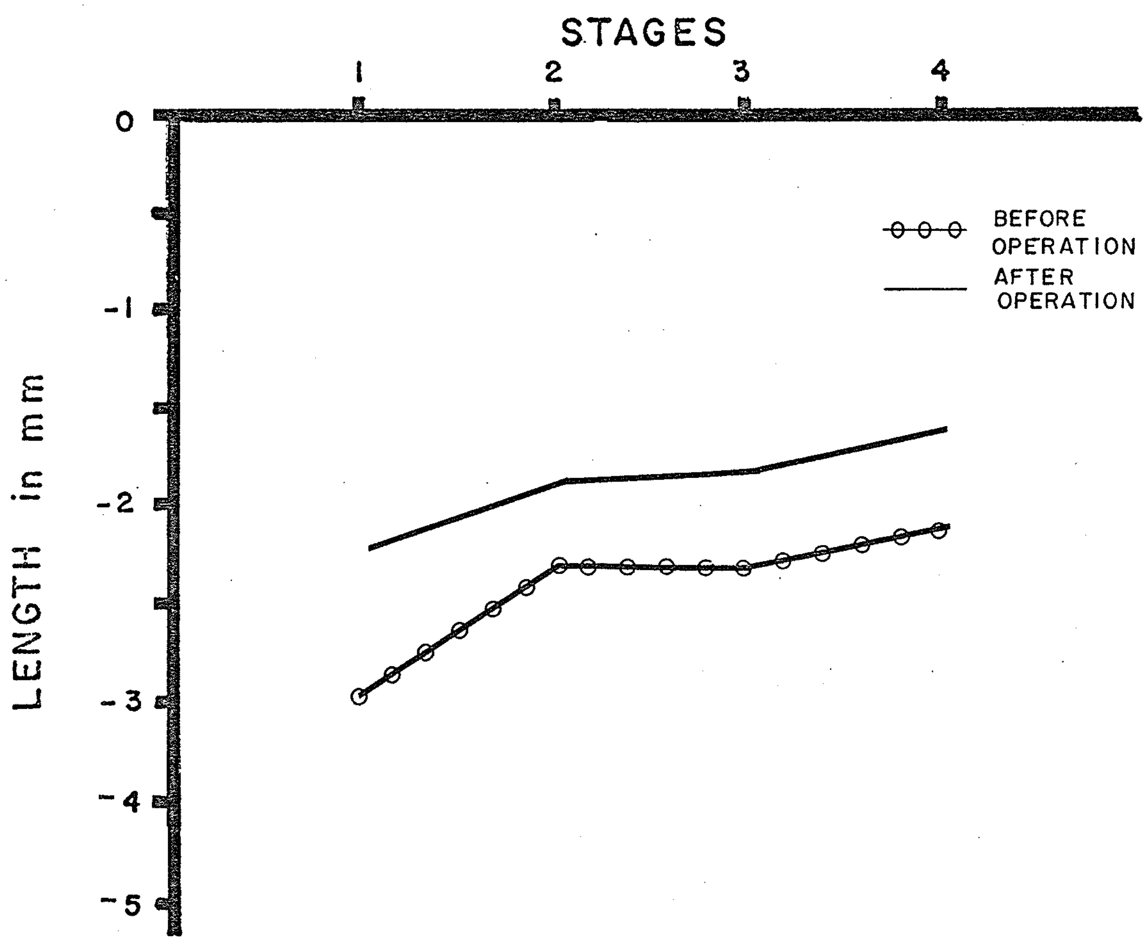

Figure 24. Graph showing the comparison of mean values of Length k in deglutition.

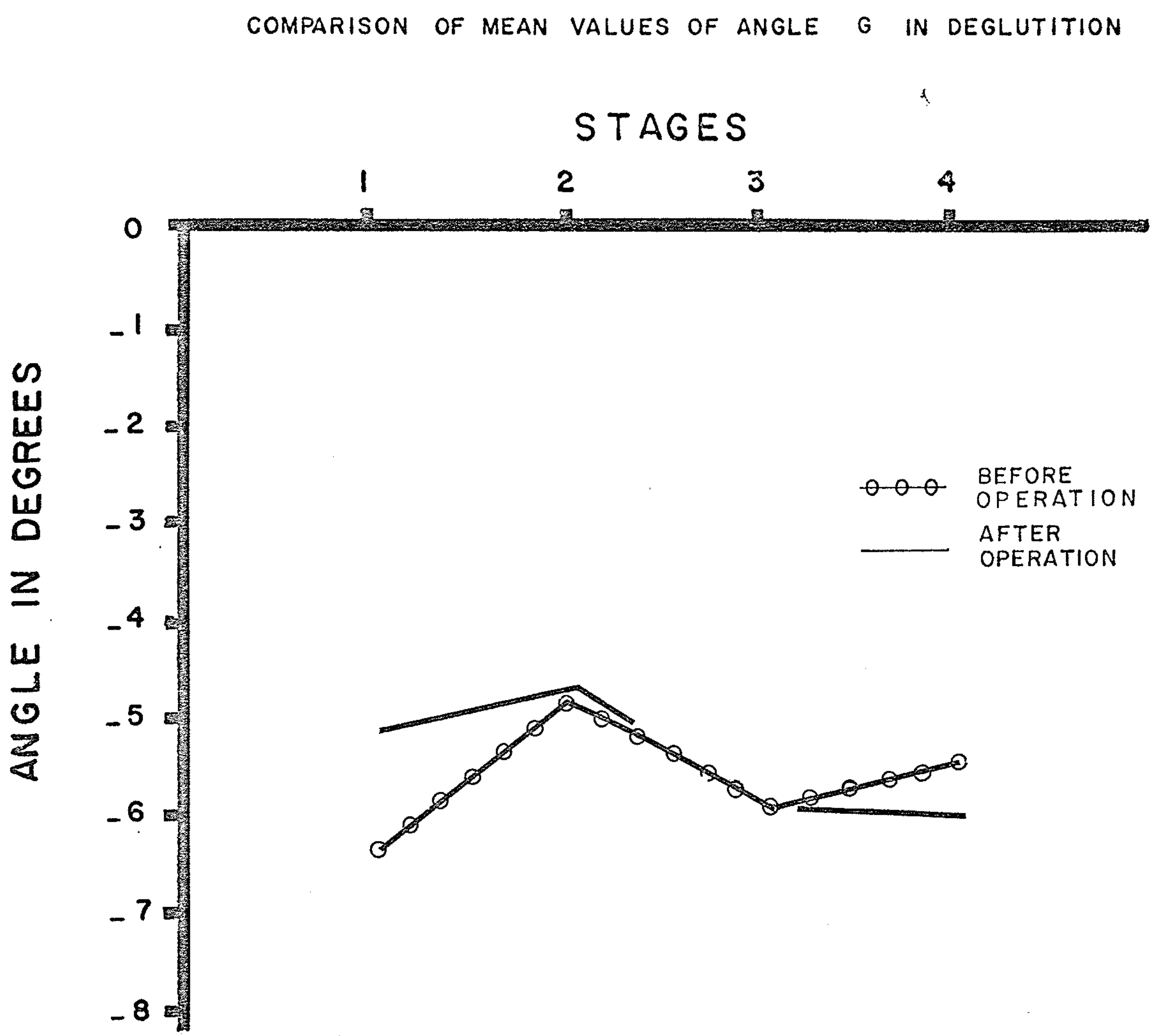

Figure 25. Graph showing the comparison of mean values of Angle G in deglutition.

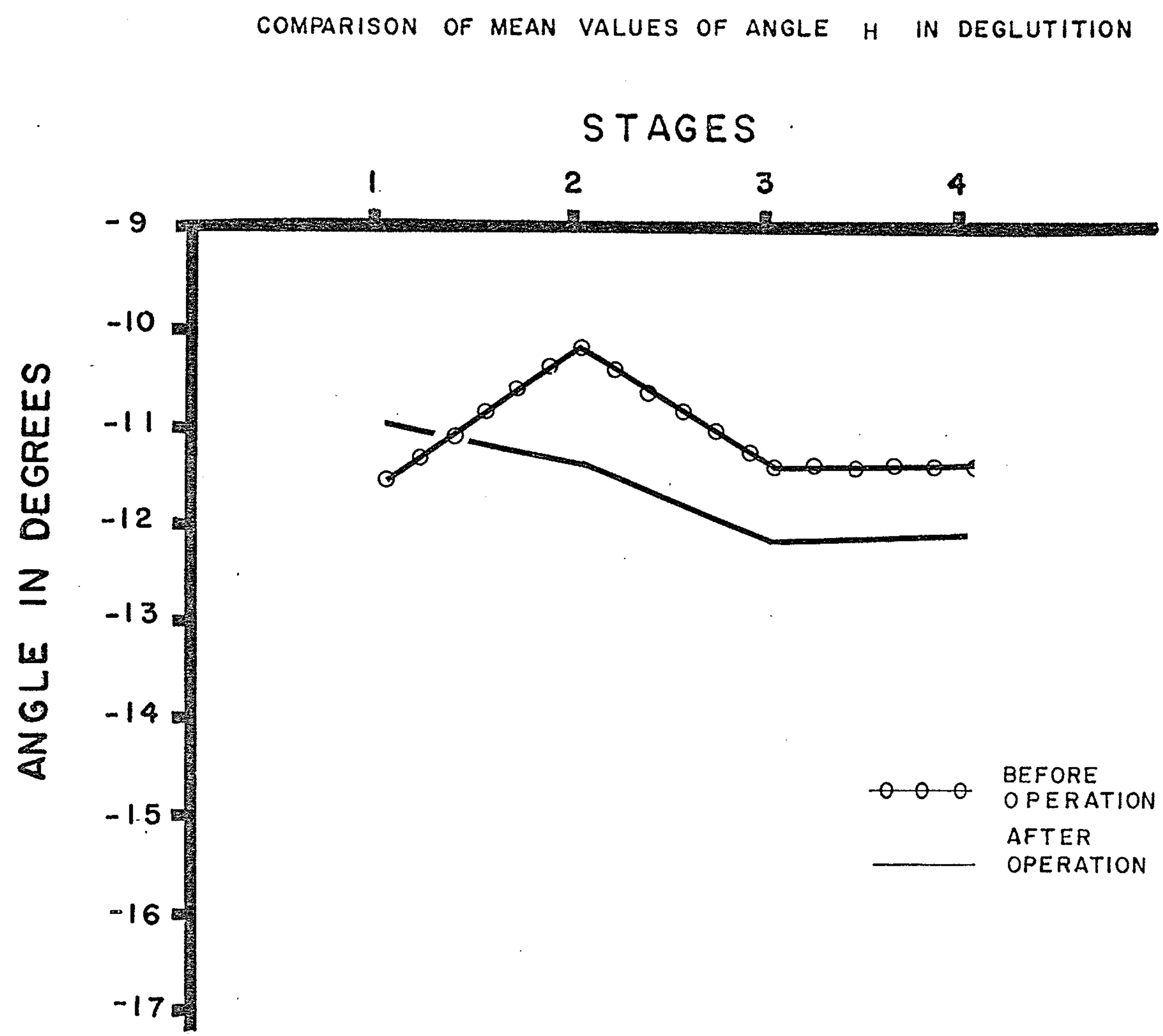

Figure 26. Graph showing the comparison of mean values of Angle H in deglutition.

of the dorsum of the tongue and Length r, which demonstrated the relationship of the posterior part of the tongue with the tip of the soft palate, has already been discussed.

Angle B did not show any significant difference between the male and the female at rest. However, during swallowing, Angle B decreased showing that the tongue tip had moved in an upward and forward direction, with the decrease slightly more marked at Stage 2 than Stages 3 and 4 (Figure 27). This change of functional positions of the tongue tip from its position at rest was found to be significant at the 1 per cent level between the male and the female (Tables IX, X and XI), showing that the movement of the tongue tip was more marked in the female group. When the change of Angle B was compared before and after operation, it was found that the decrease of Angle B in deglutition was at the 1 per cent level before operation but at the 5 per cent level after operation (Tables XII and XIII). This difference was brought about by the fact that Angle B at rest was significantly smaller at the 5 per cent level (Table XIV), indicating that the resting position of the tongue tip was in a more upward and forward direction after operation.

Length e did not show any significant difference between the male and the female both at rest and during swallowing. However, it did demonstrate a similar pattern of movement as that of Angle B in swallowing, both before and after operation (Figure 28) though Length e decreased significantly at the 5 per cent level from rest during all stages of swallowing before operation (Tables XII and XIII).

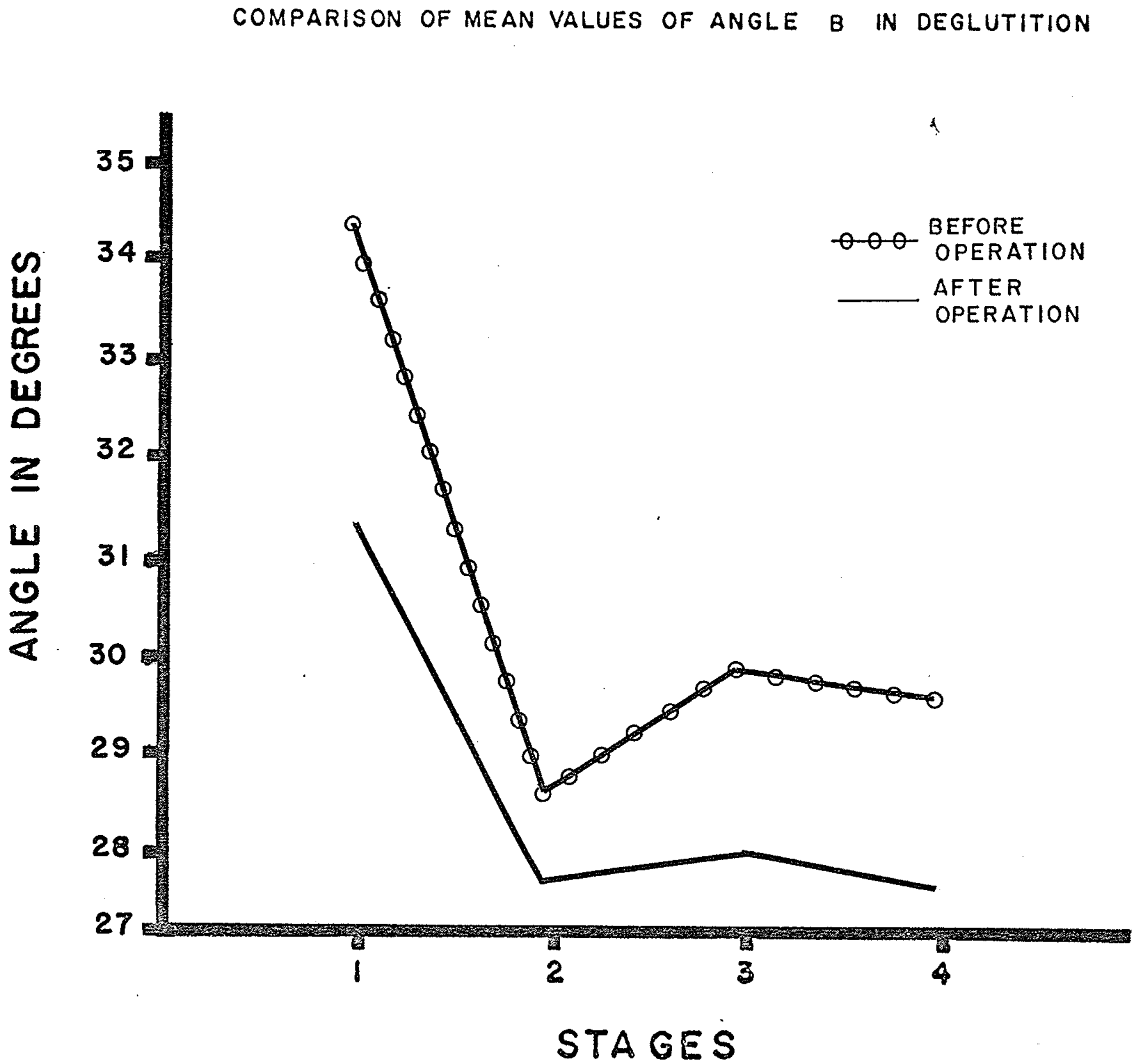

Figure 27. Graph showing the comparison of mean values of Angle B in deglutition.

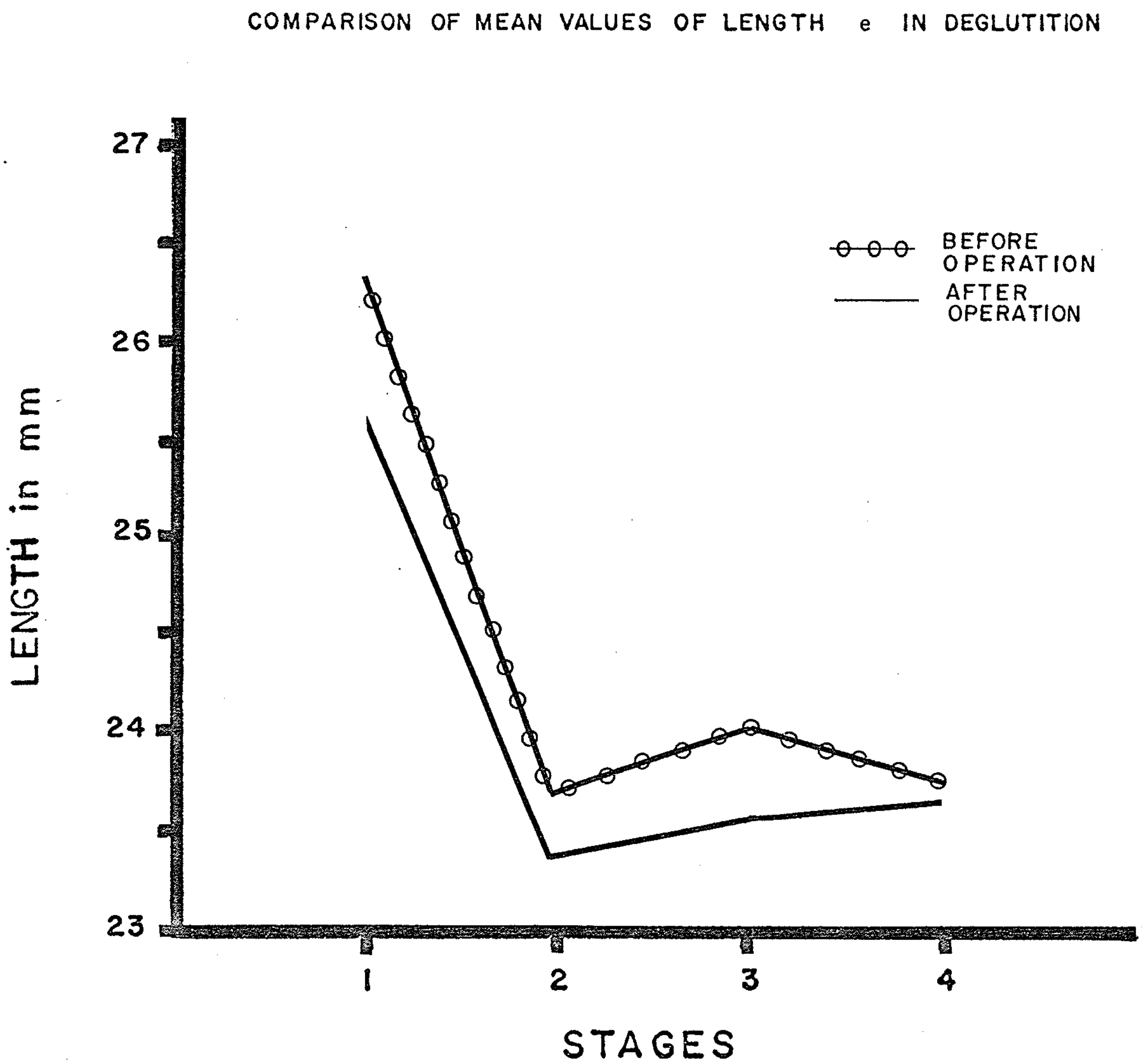

Figure 28. Graph showing the comparison of mean values of Length e in deglutition.

At rest, Angle I was not found to be significantly different between the male and the female groups, and before and after operation. However during deglutition, Angle I was found to be more positive (Figure 29) showing that the movement of the tongue tip was significantly more forward at the 1 per cent level (Tables XII and XIII). This forward movement was significant at the 1 per cent level in the female group indicating that the tongue tip was more active in the female than the male during the act of swallowing (Tables IX, X, and XI).

Both Lengths p and q substantiated the finding of Angle I indicating that the tongue tip had moved significantly more forward in the horizontal dimension during the act of swallowing both before and after operation (Figures 30 and 31). At Stage 3 after operation, Length q was found to be significantly smaller at the 5 per cent level indicating that the tongue tip was closer to the lower incisor (Table XIX). Careful examination of the cases in the present study showed that tongue thrusting beyond the lower incisors during swallowing was present in ten cases (36 per cent) before operation. Only two of these ten cases failed to demonstrate tongue thrusting after operation. In these two cases, the tongue went beyond the lower incisal tip for only about 2 - 3 mm before operation whilst in the other eight tongue thrust cases, the tongue had thrusted beyond the lower incisors varying from 2 mm to 7 mm. All the tongue thrust cases had teeth apart swallow both before and after operation. Even the two cases which showed no tongue thrusting during swallowing had teeth apart swallow after operation.

COMPARISON OF MEAN VALUES OF ANGLE I IN DEGLUTITION

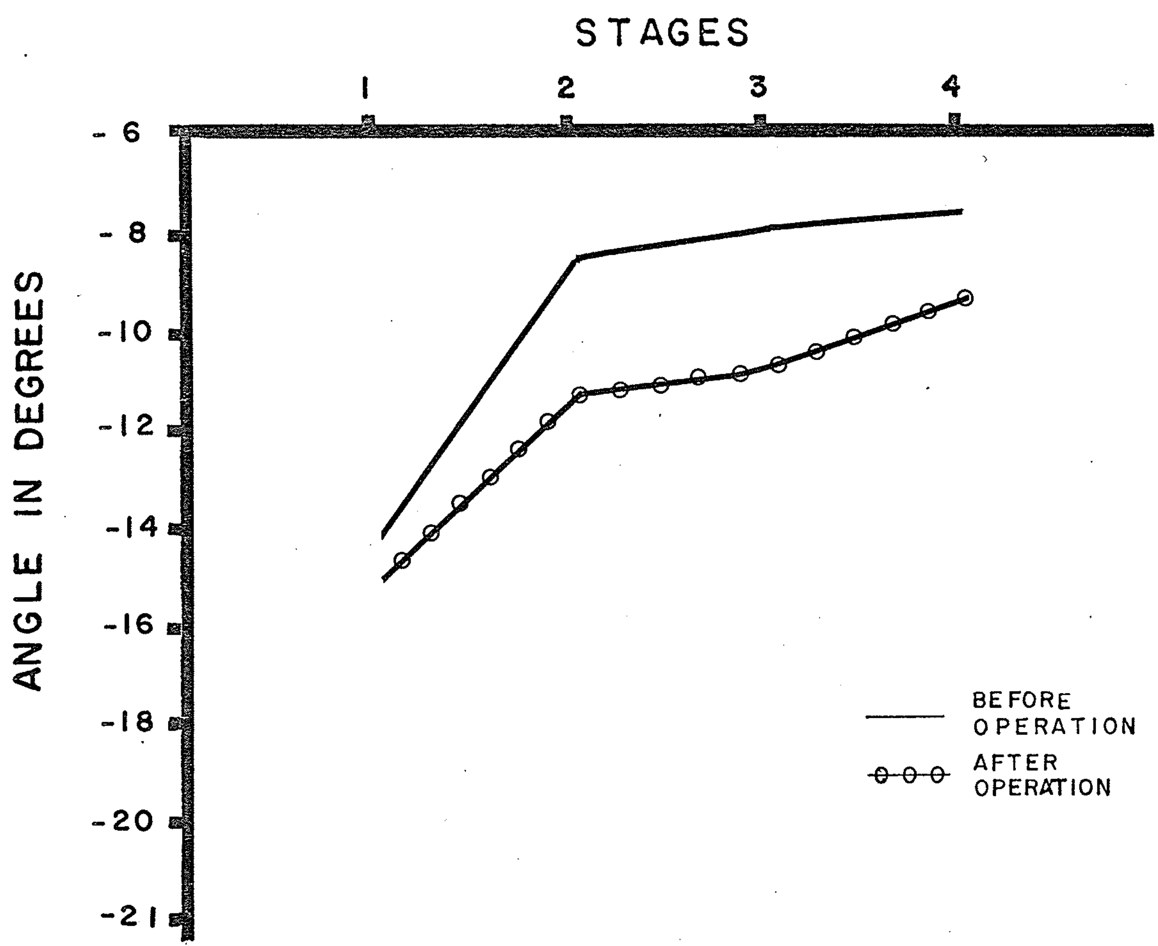

Figure 29. Graph showing the comparison of mean values of Angle I in deglutition.

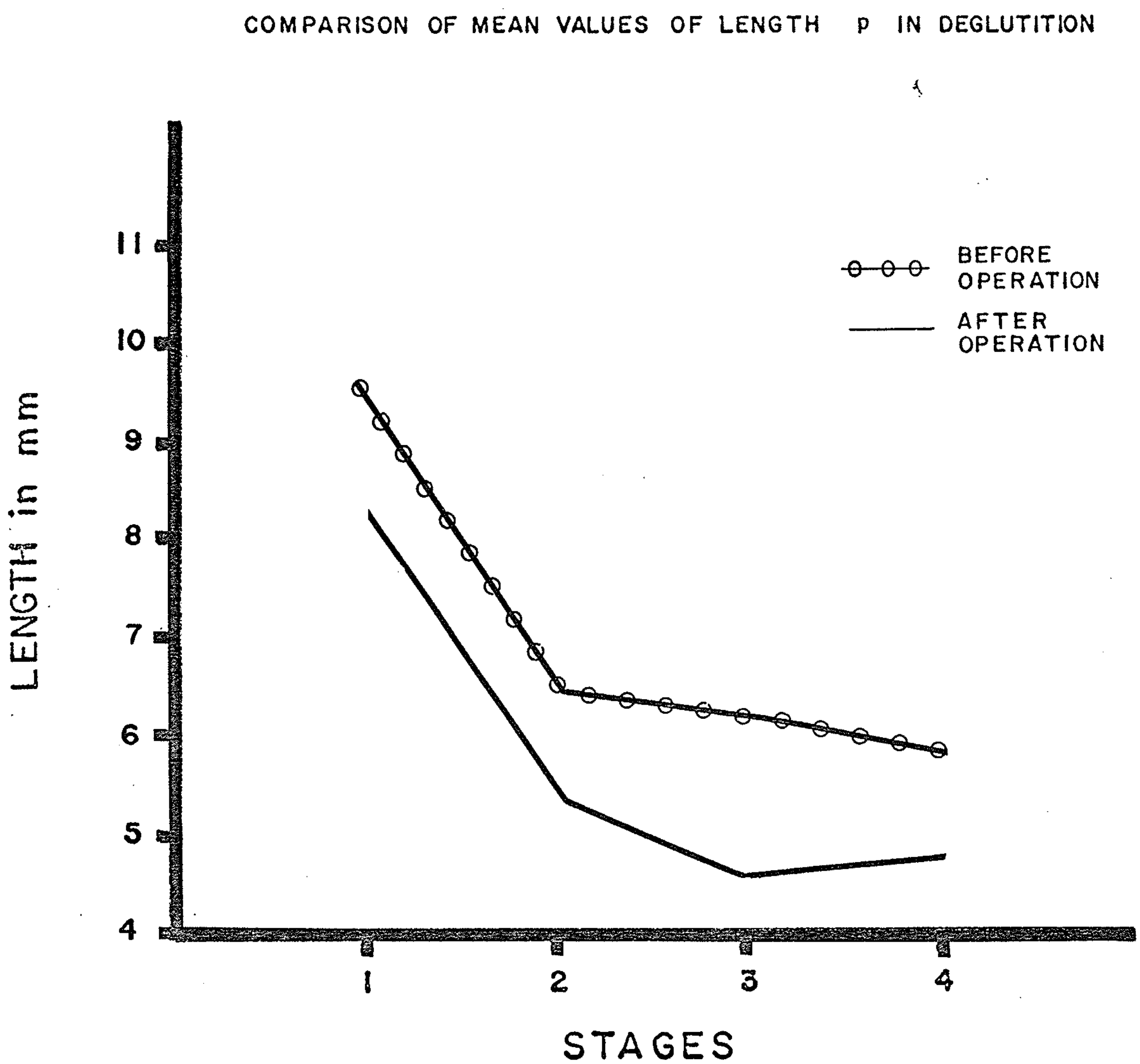

Figure 30. Graph showing the comparison of mean values of Length p in deglutition.

COMPARISON OF MEAN VALUES OF LENGTH q IN DEGLUTITION

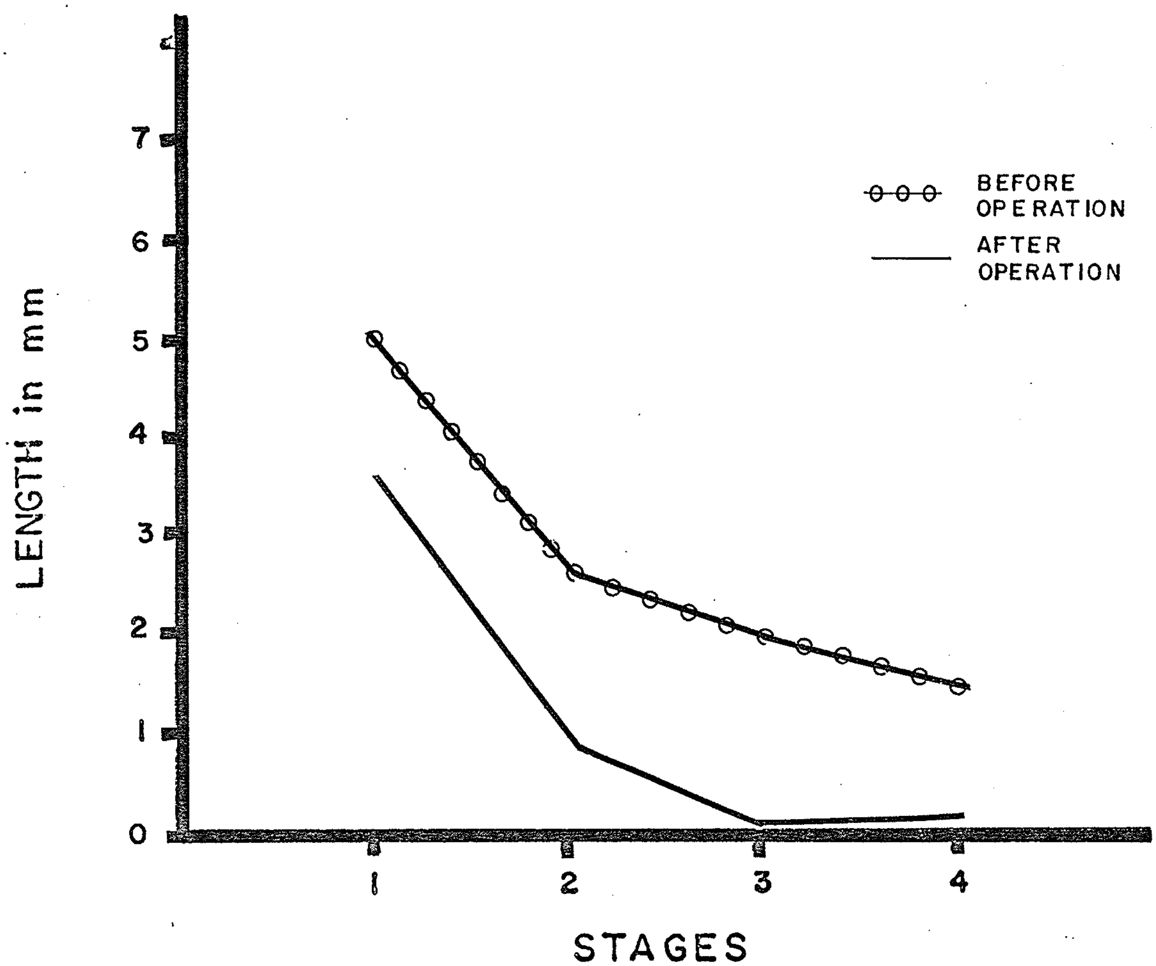

Figure 31. Graph showing the comparison of mean values of Length q in deglutition.

Length g was found to decrease significantly at the 1 per cent level in Stage 3 and Stage 4 of deglutition both before and after operation (Tables XII and XIII). This means that the dorsum of the tongue was closest to the hard palate during these two stages of swallowing. After operation, Length g tended to be smaller both at rest and in deglutition indicating that the dorsum of the tongue had functioned in a higher position, bringing it into closer relationship with the hard palate (Figure 32).

(4) Change of Lip Position during Deglutition:

At rest, the mean of Length f was 25.8 mm in the male sample and 24.6 mm in the female sample (Tables VI and VII). This finding indicated that the lower lip was lower in the male sample when relating it to the palatal plane, though the difference was not found to be significant. During swallowing, Length f tended to decrease (Figure 33). Its pattern of movement during the various stages of swallowing was similar to that of Angle A indicating that there was a close relationship between the lower lip and the mandibular incisors when Figure 20 was compared with Figure 33.

After operation, Length f was found to have decreased in all stages of deglutition indicating that its functional positions were closer to the palatal plane.

Length h represented the amount of lips separation. It was found that the resting position of Length h was significantly larger in the

COMPARISON OF MEAN VALUES OF LENGTH g IN DEGLUTITION

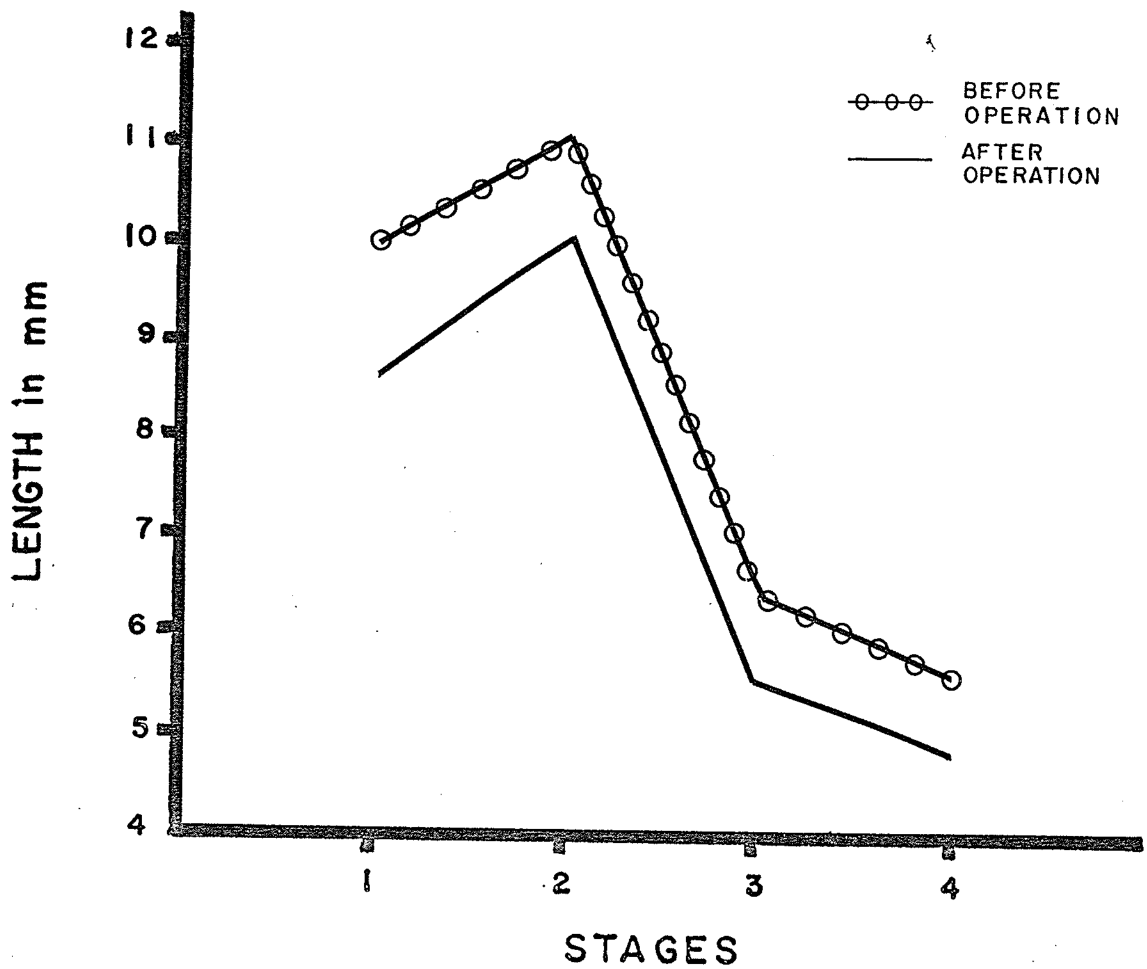

Figure 32. Graph showing the comparison of mean values of Length g in deglutition.

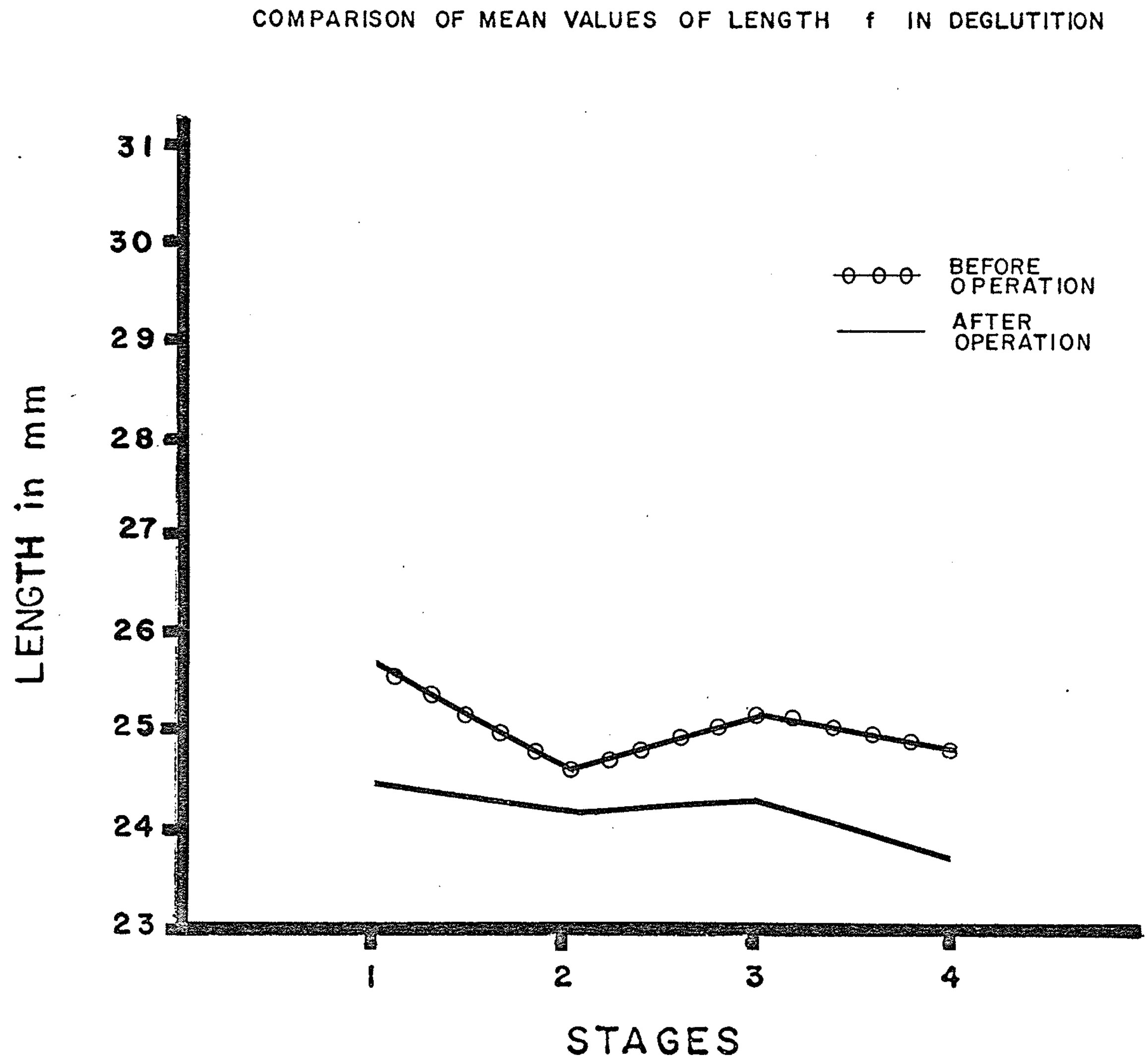

Figure 33. Graph showing the comparison of mean values of Length f in deglutition.

at the 5 per cent level (Table VIII). Seventeen of the cases in the present study (60.7 per cent) demonstrated lips apart at rest. Of these eleven were males and six females. After operation, five of the seventeen cases had acquired lips together at rest. Of these five cases, four of them were males and one female. During swallowing, Length h decreased significantly at the 5 per cent level indicating that there was a tendency for the lips to come together in deglutition (Tables XII and XIII). After operation, the lips appeared to be less separated both at rest and during swallowing as is shown in Figure 34.

Length j represented the overlap of the lower lip over the labial surface of the maxillary incisors. At rest, the mean of Length j was found to be -0.2 mm in the male and +0.5 mm in the female (Tables VI and VII). Though the difference of these mean values was not found to be significant it did substantiate the findings of Length f, indicating that the lower lip was in a higher position among the female sample. During swallowing, Length j tended to become more positive indicating that there was a tendency for the lower lip to overlap the labial surface of the maxillary incisors (Figure 35). Length j at rest was -0.3 mm before operation but became +0.5 mm after operation indicating a tendency to overlap the labial surface of the maxillary incisors after operation (Table XV).

(5) Hyoid Movement during Deglutition:

Angle D represented the position of the hyoid bone in the

COMPARISON OF MEAN VALUES OF LENGTH h IN DEGLUTITION

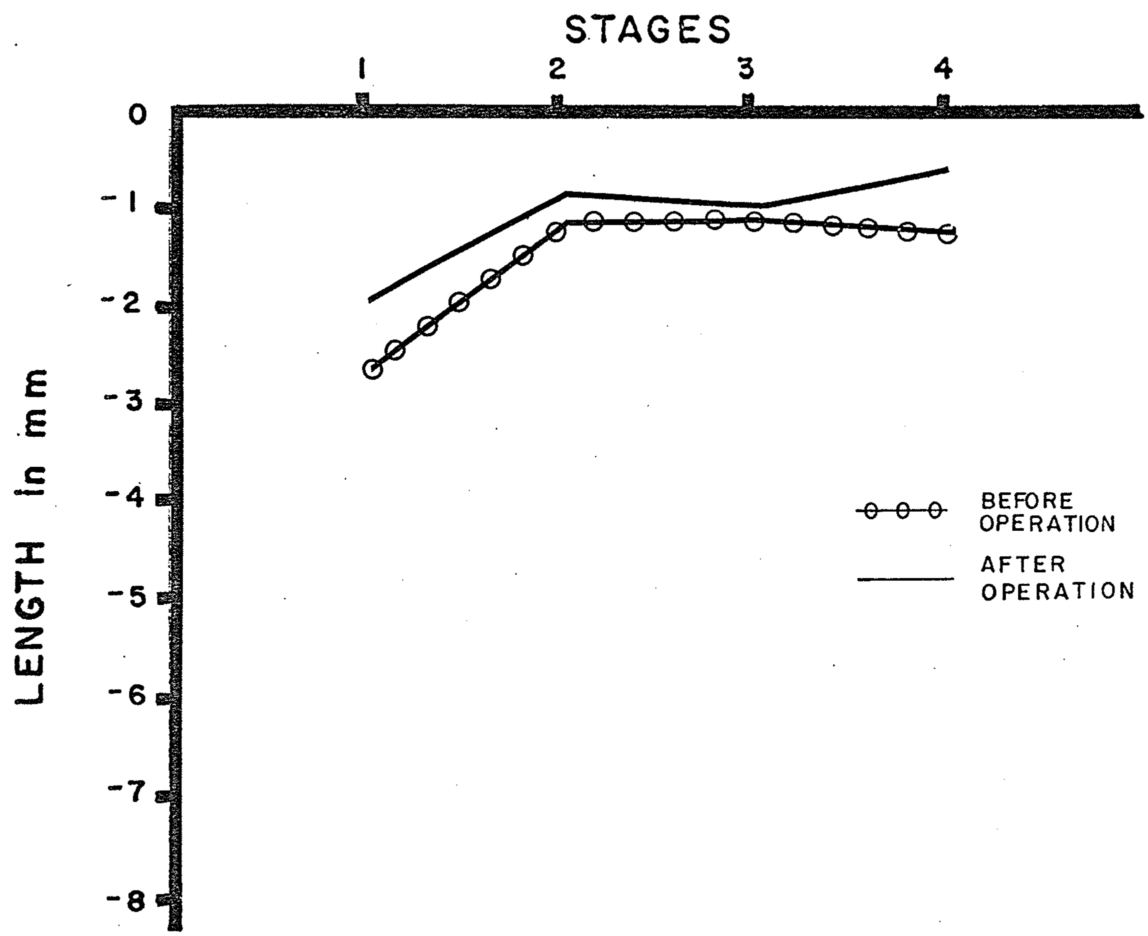

Figure 34. Graph showing the comparison of mean values of Length h in deglutition.

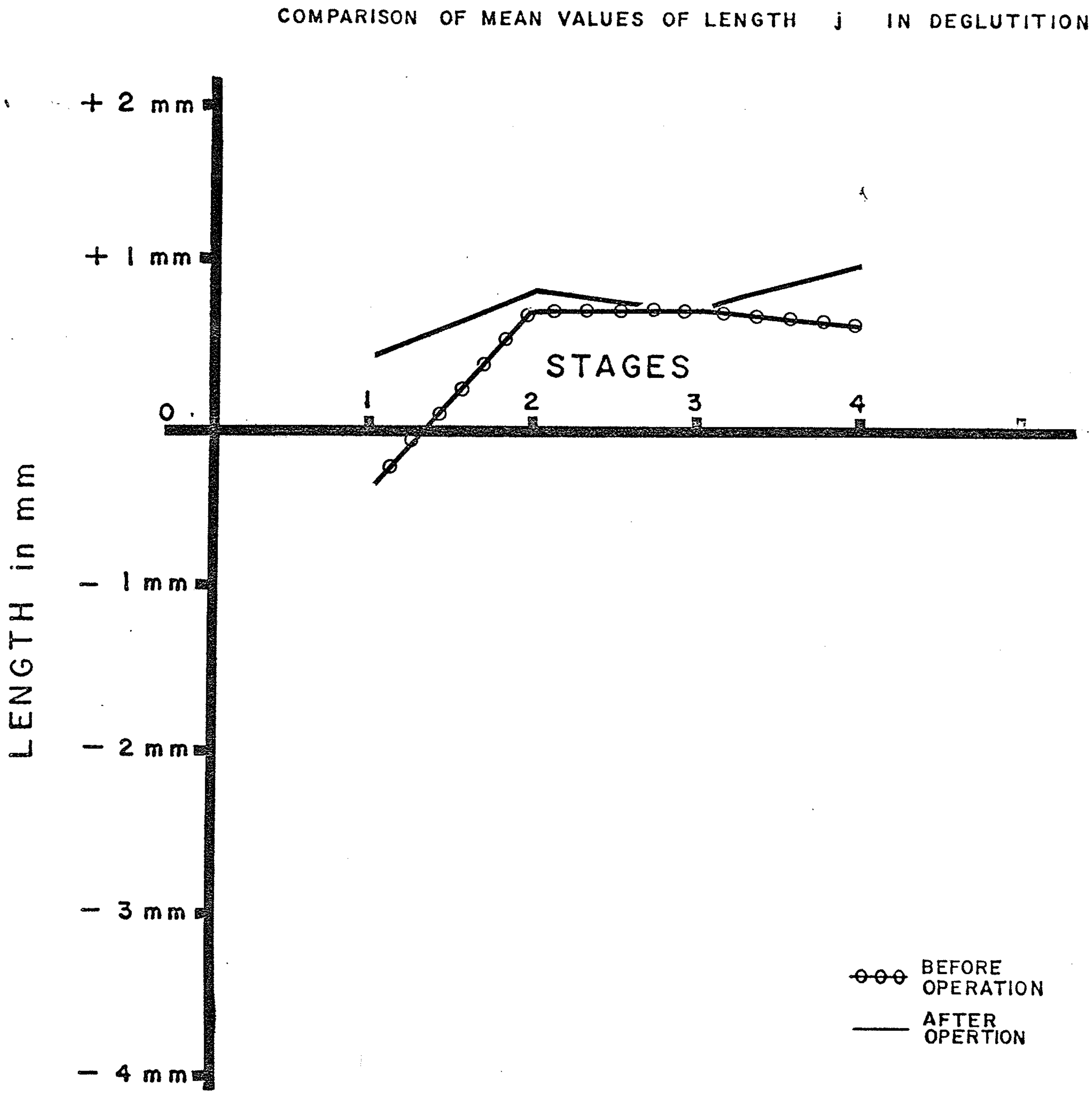

Figure 35. Graph showing the comparison of mean values of Length j in deglutition.

horizontal dimension. Its positional change during the act of swallowing before and after operation is shown in Figure 36. It is seen that after operation, the hyoid bone had occupied a more forward position. Its pattern of movement indicated that it tended to move slightly backward at Stage 3, before coming forward at Stage 4. At Stage 4, Angle D decreased significantly from its resting position at the 5 per cent level indicating that the hyoid bone had moved forward dramatically (Tables XII and XIII).

Length c represented the vertical position of the hyoid bone. Its length was found to have a tendency to decrease after operation in all stages of swallowing indicating that its functional position was closer to the palatal plane in the vertical dimension (Figure 37). At Stage 3 and Stage 4, Length c was found to be significantly smaller at the 5 per cent and 1 per cent level respectively when comparing it with the positions at rest (Tables XII and XIII). This means that the hyoid bone rose dramatically in the vertical dimension at Stage 3 reaching its highest level at Stage 4 of deglutition.

Composite diagrams comparing the rest position, various stages of deglutition and the production of "E" sound, before and after operation, are shown in Figures 38, 39 and 40.

IV. <u>Coefficient of Correlation ("r"):</u>

The coefficient of correlation ("r") of the variables was considered only when the value of "r" was significant at or beyond the

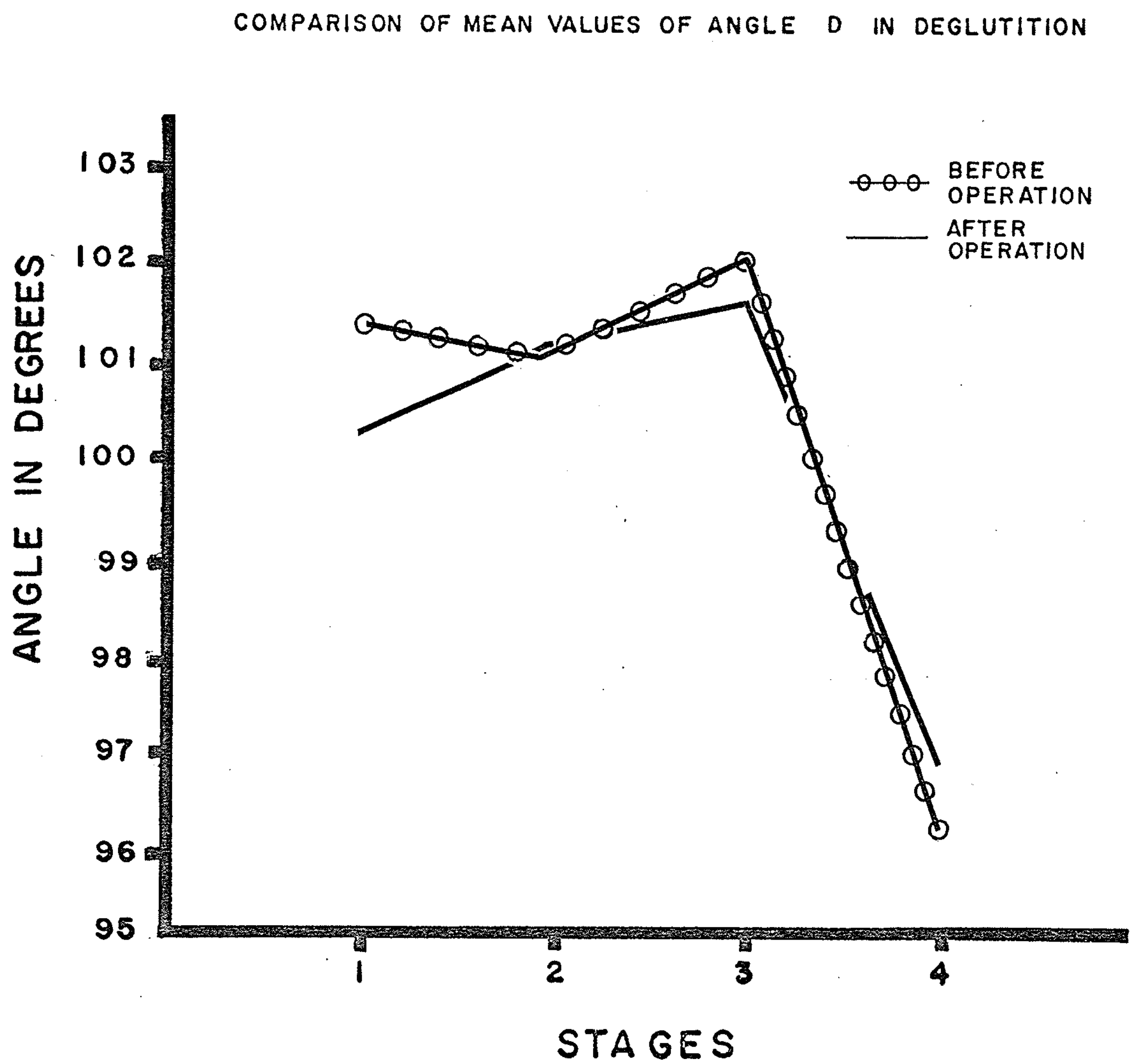

Figure 36. Graph showing the comparison of mean values of Angle D in deglutition.

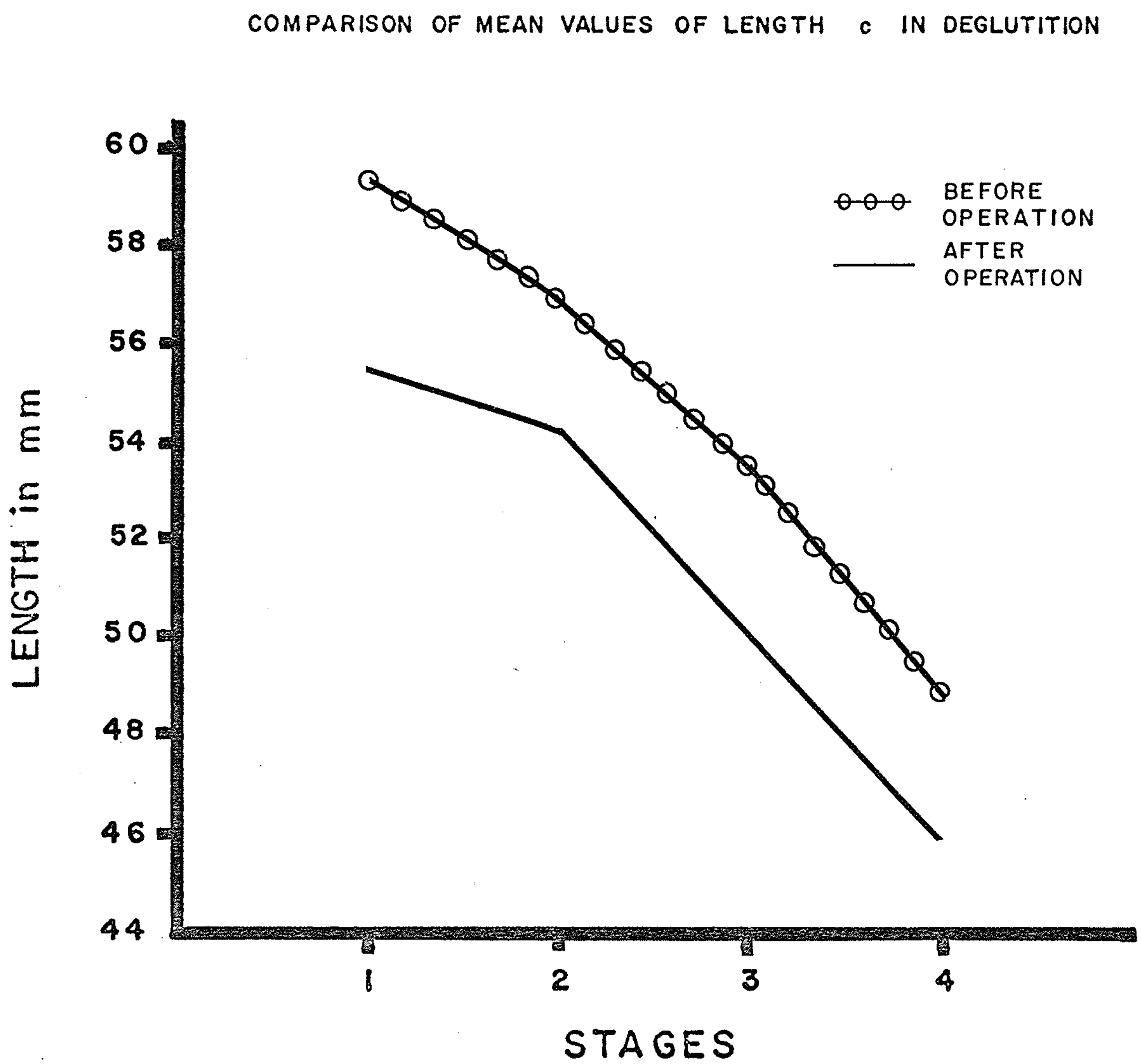

Figure 37. Graph showing the comparison of mean values of Length c in deglutition.

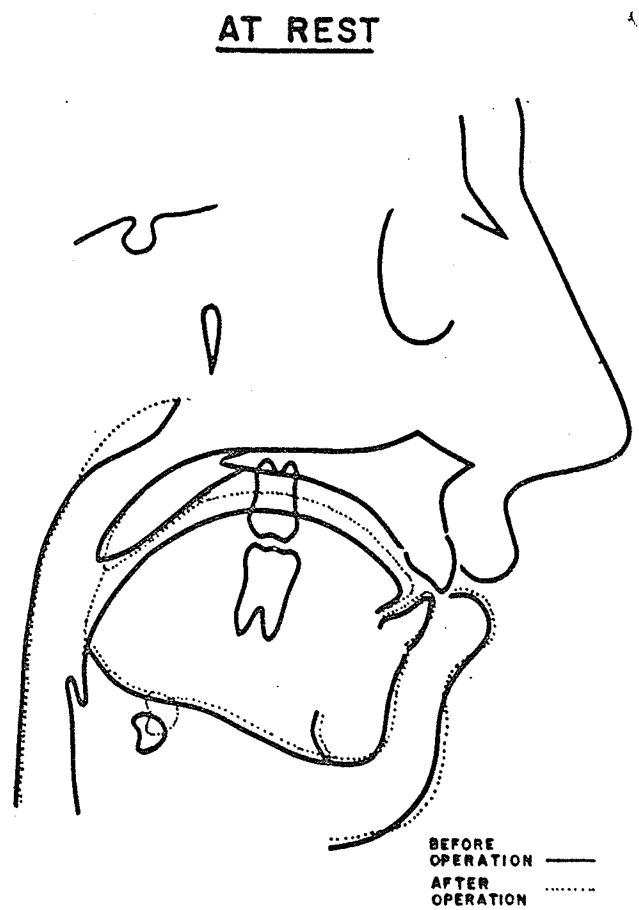

Figure 38. A composite diagram showing the rest position before and after operation.

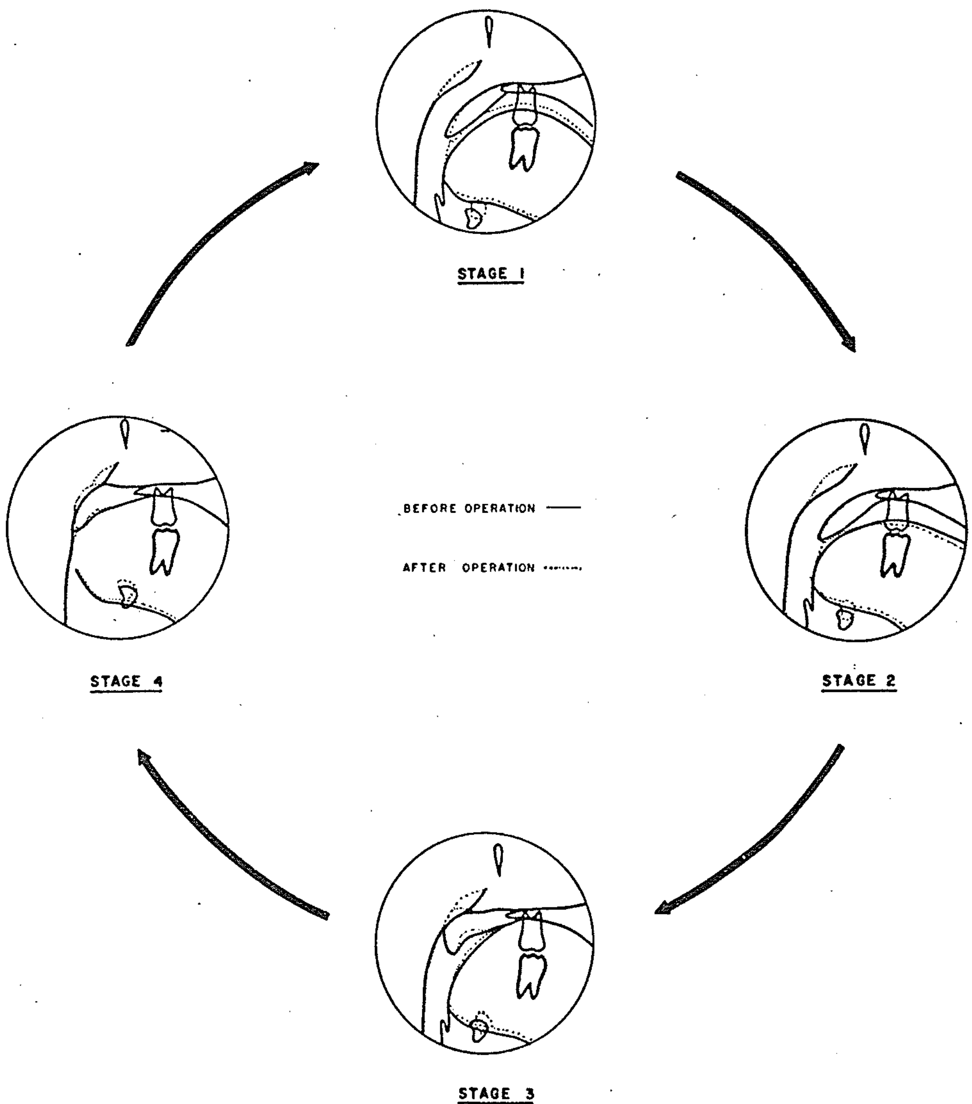

Figure 39. Composite diagrams showing the velopharyngeal area during the various stages of deglutition before and after operation.

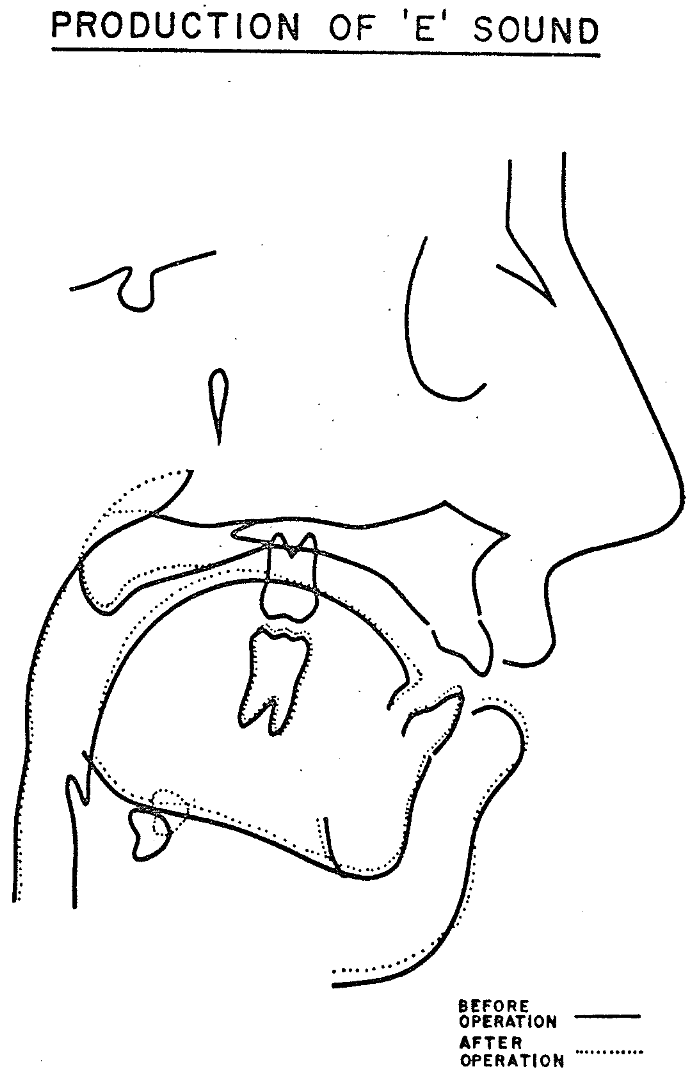

Figure 40. A composite diagram showing the production of "E" sound before and after operation.

5 per cent level of confidence. The coefficients of correlation for selected pairs of variables before and after operation were shown in Tables XXX and XXXI respectively.

At rest, a positive correlation was obtained between the angle of the soft palate with the hard palate (Angle E) and the antero-posterior dimensions of the oropharynx at three different levels. The findings indicate that a larger horizontal dimension of the pharyngeal area was often associated with a relatively more horizontally placed soft palate. When the correlation coefficient of the paired variables was compared, before and after operation, it was found that the values of "r" became relatively more significant after operation at the level of the palatal plane but relatively less significant at the level of the maxillary central incisors indicating that this positive correlation had become more important as it approaches the nasopharynx after operation. Similar positive correlations were found during the various stages of deglutition and in speech.

After operation positive correlation was found between the velar height (Length a) and the antero-posterior dimension of the nasopharynx (Length 1) in Stage 4 of deglutition and in the production of "E" sound, when velopharyngeal closure occurred. This indicates that as the horizontal dimension of the nasopharyngeal isthmus had increased following the removal of the adenoidal mass the Velum had the tendency to move to a higher position.

At rest, negative correlation was found only before operation between the vertical distance of the soft palate from the palatal plane (Length b) and the antero-posterior dimension of the nasopharyngeal isthmus (Length l). Such negative correlation was not found to be significant after operation. This finding points out that a narrowed nasopharyngeal isthmus tends to be compensated by a lowering of the soft palate to encourage a nasal airway, and substantiates the earlier findings of positive correlation between Angle E and Length l.

At rest, positive correlation was also found between the vertical dimension of the mandible (Angle C and Length d) and the antero-posterior dimension of the oropharynx at the level of the maxillary incisors (Length n). This indicates that as the mandible is further apart at rest, the horizontal dimension of the oropharynx increases, demonstrating the tendency that oral breathing requires a larger dimension in the oropharynx. A similar finding was noted between the lower lip line from the palatal plane (Length f) and the oropharyngeal dimension at the level of the maxillary incisors (Length n).

Correlation coefficient between the amount of lip separation (Length h) and the posterior oral seal (Length r) was not found to be significant at rest indicating that the lips apart posture has little relationship with the posterior oral incompetence in the present study.

Mandibular opening (Angles A and C) was found to be positively correlated to the antero-posterior position of the hyoid bone (Angle D) both at rest and during function. This was especially so before operation, when the hyoid bone had adjusted itself to the various functions when the movements of the structures in the pharyngeal areas had been altered by the presence of the enlarged tonsils and adenoids.

Both at rest and during most of the stages of deglutition, 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 antero-posterior dimensions of the oropharynx at various levels (Lengths l, m and n). These findings substantiate the fact that the hyoid bone had adjusted itself to the altered positions of the various structures in the pharynx both at rest and during function.

Coefficient correlation ("r") of the various pairs of variables representing the mandible, mandibular incisors and the tongue all indicate 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.

CHAPTER V

DISCUSSION

The effects of adverse muscle activity upon the growth and development of the jaws and the alignment of teeth has long been of interest to workers of various disciplines including those in the fields of orthodontics and speech therapy. Some believe that the skeletal pattern is the dominant hereditary factor with the soft tissues adapting to the bony framework. Others believe that the soft tissue postures and activities play an important role in the growth and development of the jaws and the alignment of teeth. It has been suggested that children with enlarged tonsils and adenoids exhibit abnormal changes in the pharyngeal areas which, during the period of rapid growth in childhood, 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, abnormal swallowing patterns, mouth breathing, and tongue thrusting could develop causing abnormal growth and development of the jaws along with malocclusion.

The present investigation has primarily attempted to determine the mechanism of velopharyngeal function in children with enlarged tonsils and adenoids and the changes that take place in the oral cavity during deglutition and in speech. Comparisons were also made to see if such changes could be altered as a result of surgical removal of both the tonsils and adenoids.

This study has shown objectively that the presence of enlarged tonsils and adenoids does alter the mechanism of velopharyngeal function both in deglutition and in speech. However, their effect upon the functions in the oral cavity was not found to be as dramatic as was suggested by previous clinical observations and some of the static radiographic studies.

Although the present study deals with children in their growing period, the dimensional change of the various structures because of growth should not be regarded as significant within a period of six weeks during which the pre-operative and post-operative films were taken. In addition, considerations regarding sex characteristics should not be weighed heavily since the sample size, age range, and skeletal pattern were not controlled in the present sample.

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 and deglutition. This is also found to a great extent in speech during velopharyngeal closure.

The present study supports the findings of James and Hastings (1932) that the urge of nasal breathing is strong and that oro-nasal breathing is more common in tonsils and adenoids cases than mouth breathing. It also supports the findings of Gwynne-Evans and Ballard (1957) that nasal breathing is resumed in the majority of cases as soon as the tonsils and adenoids are removed, since such operations do encourage nasal breathing 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 naso-pharynx 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 patients with enlarged adenoids attempt to lower the resting posture of the soft palate to encourage nasal breathing. Therefore, when the adenoids were removed, the soft palate resumed its normal resting postures by forming a larger angle with the hard palate. However, the number of these cases was not found to represent a large percentage of the present sample.

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 (1954). 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 the cases where both the tonsils and adenoids were unduly enlarged, lowering of the soft palate was not found to be the solution for nasal breathing since the enlarged tonsils prevented the lowering of the soft palate. Under such circumstances, oral breathing would require a fairly large drop of the mandible and changes of tongue position if mouth breathing were to take place. However, these cases were not found to be common. In fact, the best compromise appeared to have taken place by means of oro-nasal breathing with the mandible dropped to a varying degree depending on the oxygen requirement of the individual at that particular instance.

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 the cases did use the mouth to assist breathing when both the tonsils and adenoids were enlarged. However, after operation, only four of the fourteen cases continued to demonstrate a lack of both anterior and posterior oral seals indicating that the mouth was still used to assist breathing.

The present investigation has shown that enlarged tonsils and adenoids do alter the oropharyngeal mechanism in swallowing. This suggestion is supported by the findings that the time required for one complete swallowing cycle was not only found to be increased in tonsil and adenoid cases but also showed variations between stages of deglutition. Swallowing was found to be relatively "sluggish" and in addition, the oropharyngeal mechanism had adjusted itself to overcome the partial obstruction in the oropharynx. This is best seen when the bolus is passing through the oropharyngeal isthmus. In order to overcome the enlarged tonsils in the oropharyngeal isthmus, the muscular action has to either increase or become delayed. Whatever the case may be, the final outcome of the time required for such passage would be shortened. Since the passage of the bolus through the oropharyngeal isthmus is in the involuntary stage, it is likely that the passage might have been delayed by the enlarged tonsils and that as soon as the bolus has overcome the obstacle in the oropharyngeal isthmus, the time interval between Stage 3 and Stage 4 becomes shortened, with the bolus being overshot into the oropharynx.

After operation, the sluggishness in deglutition was found to have disappeared and comparable to that of the normal sample which was described by Cleall in 1965.

The mechanisms for velopharyngeal closure were found to be essentially the same in both deglutition and in speech with the soft palate rising upward and backward to come into contact with the posterior pharyngeal wall, thus shutting off the nasopharynx from the oropharynx. This is well shown in the later part of Stage 3 of deglutition when comparison is to be made with that of the production of "E" sound. 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". This supports the findings of Calnan (1953) who suggested that the soft palate had risen to a higher level in the production of "E" sound. After the removal of the enlarged adenoids, the antero-posterior dimension of the nasopharyngeal isthmus had increased with improvement of the nasopharyngeal airway. During velopharyngeal closure, the soft palate was found to be more posteriorly placed having a smaller area of contact with the posterior pharyngeal wall. These findings thus support those which were suggested by Subtelny in 1956. 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. None of the cases in the present study have demonstrated any inadequacy of velopharyngeal closure both in deglutition and in speech.

During the production of "E" sound, there was little or no movement of the posterior pharyngeal wall both before and after operation. The presence or absence of the "Passavant's Ridge" could not be demonstrated in the present technique because of lack of finer details in the cine film. However, the posterior pharyngeal wall was found to have come forward in Stage 4 of deglutition. Such forward movement was more noticeable after operation at the level of the palatal plane. It may be explained that the removal of the tonsils and adenoids has enabled the soft tissue environments to perform the vital functions more actively and smoothly.

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. 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 is, therefore, impossible at this stage to suggest if enlarged tonsils and adenoids are the cause of teeth apart swallow thus allowing the infantile type of swallow to be prolonged.

It has been suggested that enlarged tonsils are an important cause of forward positioning of the tongue both at rest and during deglutition. 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, 36 per cent of cases showed tongue thrust before operation. After operation, the percentage of cases showing tongue thrust decreased to only 28 per cent. This relatively small reduction of tongue thrust cases suggests that enlarged tonsils and adenoids are not important causes of tongue thrusting though they may have exaggerated the picture of tongue thrusting during the acute stages. Furthermore, tongue thrusting should be considered as characteristic of the individual's swallowing pattern rather than being caused by enlarged tonsils and adenoids.

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. The present study also supports the findings of Saunders and Davis (1951) and Bosma (1957) who suggest that the hyoid bone first moves upward and backward before coming upward and forward during the early stages of deglutition.

In view of the present investigation, it is clear that our present knowledge of the physiology of velopharyngeal function in children with enlarged tonsils and adenoids is by no means complete. Similar studies should be carried out on a longitudinal basis with children under the age of five years. It should be borne in mind that clinical observations may often give a gross picture which is misleading. Conclusions should not be drawn until conditions have been studied objectively by means of a standardized technique and carefully planned methods.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present study was to investigate from standardized cinefluorographic records, the resting posture and the pattern of movement of the oro-naso-pharyngeal structures before and after surgical removal of tonsils and adenoids. The sample consisted of twenty-eight Caucasian children between the ages of five and fourteen years. Seventeen of them were boys and eleven were girls.

All cinefluorographic records were obtained by a lateral plane projection, at a film speed of 30 frames per second. The movements of the oro-naso-pharyngeal structures during deglutition and speech were recorded on the cine films, using a standardized sequence. A similar sequence was obtained from each patient six weeks after surgery when normal function had resumed.

After the film had been examined repeatedly on a Tagarno movie projector suitable frames for the study of resting postures, swallowing and speech were selected and analysed on a 16 mm Vanguard Motion Analyzer. The analysis for each frame consisted of eight angular and eighteen linear measurements. The measurements were compared before and after operation and their differences tested for statistical significance. The findings from both statistical analysis and subjective evaluation of the results were concluded as follows:

1. The presence of enlarged tonsils and adenoids does alter the mechanism of velopharyngeal function both in deglutition and in speech. However, their effect upon the functions in the oral cavity was not found to be as dramatic as was suggested by previous studies.
2. 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 velopharyngeal closure in speech.
3. The findings support the hypothesis that the urge of nasal breathing is strong and that oro-nasal 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.
4. 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 naso-pharyngeal isthmus was common and might easily be blocked by excessive catarrh and swollen nasal mucosa in some cases.

5. The antero-posterior dimension of the nasopharyngeal isthmus at the level of the palatal plane had increased after surgery with improvement of the nasopharyngeal airway.
6. During velopharyngeal closure in deglutition and in speech the soft palate rises to contact the posterior pharyngeal wall. The area of contact between the soft palate and the posterior pharyngeal wall was wide, due to the presence of the enlarged adenoids before surgery, but was smaller and more posteriorly placed after operation.
7. The velar height was found to be higher in producing the word "Peter" when the "E" sound was preceded by the plosive "p". This elevation of the Velum in speech was found to be higher after the removal of both the tonsils and adenoids.
8. The movement of the soft palate in closing the nasopharyngeal isthmus during deglutition and in speech was found to be "sluggish" prior to surgery but became more active post-operatively.
9. The time required for one complete swallowing cycle was not only found to be increased in tonsil and adenoid cases, but also showed variations between stages of deglutition. The reason for such variations may be related to the physical size of the tonsils or the inflammatory state of the structures found in the oropharyngeal areas.

10. Enlarged tonsils and adenoids were not found to be important causes of teeth apart swallow and tongue thrusting both at rest and during deglutition.

11. The position of the tongue tip was not found to have protruded beyond the incisal edge of the mandibular incisors at rest in tonsil and adenoid cases. In fact, the position of the tongue tip was found to be more lingually placed in the oral cavity before operation but had taken a more upward and forward position after operation with possible re-establishment of the anterior oral seal.

12. The present knowledge of the physiology of velopharyngeal function in children with enlarged tonsils and adenoids is not complete and similar studies should be carried out on a longitudinal basis with children under the age of five years.

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APPENDIX

TABLE III

ANALYSIS OF VARIANCE OF EIGHT ANGULAR MEASUREMENTS

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARES							
		Angle A	Angle B	Angle C	Angle D	Angle E	Angle G	Angle H	Angle I
Sex	1	533.6	789.4	353.6**	530.8	357.7	3,054.7**	743.3*	3,720.3**
Error (1)	26	138.3	210.3	17.0	339.9	285.4	309.3	182.7	461.5
Total between Subjects	27	152.9	231.7	235.9	347.0	288.8	411.0	203.5	582.2
Operation	1	36.4*	207.2**	19.4	20.6	28.3	0.0	36.6*	258.1**
Sex v Operation	1	16.9	36.4	6.4	76.4	10.7	10.2	9.8	19.4
Stages	4	76.3**	613.7**	31.1**	250.1**	1,335.8**	28.5*	23.1**	1,539.4**
Sex v Stage	4	4.4	31.1	1.3	34.2	23.9	0.8	1.2	134.4**
Operation v Stage	4	1.6	5.6	2.5	21.5	20.6	7.6	6.1	25.6
Sex v Operation v Stage	4	1.8	2.2	0.4	19.2	8.5	5.3	0.2	23.4
Error (2)	234	7.8	13.6	5.9	33.1	27.0	8.3	5.5	32.7
Total within Subjects	252	8.7	23.4	6.1	37.1	48.3	8.4	5.7	56.6
Total:	279	-	-	-	-	-	-	-	-

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

TABLE IV

ANALYSIS OF VARIANCE OF ELEVEN VERTICAL MEASUREMENTS

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARES Length a	Length b	Length c	Length d	Length e	Length f	Length g	Length h	Length i	Length j	Length k
Sex	1	9.5	60.7	220.9	30.1	37.9	12.9	35.4	180.3*	164.6	1.0	0.0
Error (1)	26	6.7	75.4	599.0	651.1	149.2	152.1	61.8	36.8	83.9	35.7	17.9
Total between Subjects	27	6.8	74.9	585.0	628.1	145.1	146.9	60.8	42.1	86.9	34.4	17.2
Operation	1	16.9**	9.8	792.7**	287.0**	22.2*	71.0**	73.2**	11.9	37.2**	3.1	19.2**
Sex v Operation	1	0.2	7.8	0.6	3.3	4.4	15.7	13.2	5.8	0.0	12.8	0.1
Stages	4	253.7**	332.9**	1,138.4**	56.9**	137.6**	295.4**	295.9**	329.7**	147.9**	415.6**	37.5**
Sex v Stage	4	1.5	9.6	7.4	5.8	10.5	5.2	2.5	10.7	21.8	12.6	3.0
Operation v Stage	4	2.5	7.2	5.4	3.3	4.8	4.2	2.3	1.2	1.1	2.3	0.5
Sex v Operation v Stage	4	0.3	9.4	14.9	0.2	0.8	1.3	2.7	1.5	5.6	4.6	2.1
Error (2)	234	2.2	8.6	17.7	12.0	5.7	5.7	10.5	4.6	4.3	5.9	1.8
Total within Subjects	252	6.1	13.9	37.7	13.3	7.6	10.3	14.8	9.4	6.6	12.0	2.3
Total:	279	-	-	-	-	-	-	-	-	-	-	-

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

TABLE V

ANALYSIS OF VARIANCE OF SIX HORIZONTAL MEASUREMENTS

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARES Length l	Length m	Length n	Length p	Length q	Length r
Sex	1	428.2	1.5	213.7	5.9	44.1	16.0
Error (1)	26	184.6	162.6	299.5	81.1	124.3	16.1
Total between Subjects	27	193.6	156.6	296.4	78.3	121.3	16.1
Operation	1	341.6**	4.8	12.3	76.9**	125.5**	222.4**
Sex v Operation	1	25.3	8.7	24.7	11.5	14.7	4.1
Stages	4	47.5**	41.5**	29.6**	448.3**	394.1**	461.1**
Sex v Stage	4	9.4	0.8	4.0	24.4*	21.2*	4.3
Operation v Stage	4	11.7	5.8	1.9	1.6	3.5	18.9*
Sex v Operation v Stage	4	1.5	2.6	5.4	8.3	5.4	15.8
Error (2)	234	12.3	7.7	8.1	8.3	8.4	6.9
Total within Subjects	252	14.3	7.9	8.3	15.2	14.7	15.0
Total:	279	-	-	-	-	-	-

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

TABLE VI

CINEFLUOROGRAPHIC ANALYSIS OF DEGLUTITION IN MALE SAMPLE

VARIABLE	STAGE 1		STAGE 2		STAGE 3		STAGE 4	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
Angle A	32.4	3.6	31.6	3.6	31.6	3.8	31.4	4.7
Angle B	33.2	7.3	29.6	6.1	30.7	6.4	30.1	5.8
Angle C	64.0	4.8	63.5	4.8	63.9	5.2	63.5	5.9
Angle D	101.7	5.9	102.2	5.4	103.0	6.5	96.7	8.4
Angle E	135.8	7.3	138.4	5.7	145.0	7.3	148.1	6.9
Angle G	-8.5	5.3	-7.4	5.2	-8.7	5.4	-8.7	5.8
Angle H	-12.5	4.6	-12.2	4.2	-13.1	4.5	-13.0	4.8
Angle I	-16.7	8.3	-13.4	8.3	-13.1	9.5	-12.7	9.1
Length a	0.0	0.0	0.2	0.5	2.4	2.3	3.5	2.0
Length b	20.2	4.2	18.6	4.6	15.1	3.6	13.8	4.1
Length c	57.2	8.1	55.3	9.1	51.3	9.1	47.1	9.6
Length d	62.2	8.5	62.1	8.7	61.6	8.7	61.2	8.9
Length e	26.4	4.2	24.0	4.1	24.3	4.4	24.3	5.2
Length f	25.5	3.8	24.9	4.4	25.1	4.2	24.5	4.3
Length g	9.6	3.3	10.8	4.6	6.4	3.1	5.6	2.9
Length h	-1.7	1.6	-0.5	1.0	-0.4	1.3	-0.5	1.3
Length i	-2.8	3.5	-2.5	3.6	-1.7	3.6	-1.8	3.6
Length j	-0.2	3.0	0.6	2.6	0.7	2.7	0.7	2.5
Length k	-2.6	2.2	-2.3	1.9	-2.1	1.9	-1.9	1.9
Length l	21.0	5.8	20.4	6.1	19.7	6.4	17.6	6.3
Length m	27.4	4.7	27.0	4.3	26.4	4.9	25.1	4.6
Length n	33.7	6.9	33.6	6.2	34.1	6.6	32.9	6.3
Length p	8.3	4.6	6.3	4.4	5.9	5.1	5.9	4.2
Length q	4.0	5.9	2.3	5.0	1.8	5.5	1.7	4.9
Length r	2.8	2.9	3.4	3.2	4.5	2.2	0.5	1.6

TABLE VII

CINEFLUOROGRAPHIC ANALYSIS OF DEGLUTITION IN FEMALE SAMPLE

VARIABLE	STAGE 1 MEAN	STAGE 1 S.D.	STAGE 2 MEAN	STAGE 2 S.D.	STAGE 3 MEAN	STAGE 3 S.D.	STAGE 4 MEAN	STAGE 4 S.D.
Angle A	29.3	5.3	28.1	5.6	28.7	5.2	28.6	5.4
Angle B	32.0	5.4	25.5	3.9	25.7	3.9	25.8	4.8
Angle C	61.6	5.3	61.0	5.7	61.5	4.9	61.7	5.9
Angle D	99.2	7.5	99.4	8.2	99.9	7.1	96.1	8.4
Angle E	134.7	8.4	137.3	9.7	141.5	7.5	144.1	4.9
Angle G	-1.6	7.2	-0.8	7.8	-1.9	6.7	-1.6	8.2
Angle H	-9.5	4.9	-8.7	5.2	-9.8	4.9	-9.9	5.5
Angle I	-14.2	9.7	-4.6	8.8	-3.8	9.6	-2.2	9.6
Length a	0.0	0.0	0.2	1.2	3.1	2.3	3.8	2.2
Length b	20.8	4.1	18.7	4.2	17.2	3.6	15.4	2.9
Length c	58.4	9.6	56.9	8.6	52.9	9.7	48.4	6.9
Length d	62.5	8.1	62.5	8.3	61.8	8.0	61.8	7.9
Length e	25.6	4.7	22.9	4.0	23.1	3.9	22.7	3.7
Length f	24.8	4.7	23.9	4.4	24.4	4.9	24.1	4.8
Length g	9.1	4.0	10.6	4.9	5.4	2.8	4.8	1.4
Length h	-3.2	4.1	-1.5	3.1	-1.8	3.8	-1.6	3.3
Length i	-0.4	4.2	-0.1	3.5	-0.1	3.9	-0.2	3.8
Length j	0.5	2.4	1.3	2.4	1.0	3.3	1.3	2.6
Length k	2.5	1.6	1.9	1.8	1.9	2.0	1.8	1.9
Length l	22.5	4.6	22.6	5.3	22.7	4.4	21.3	3.7
Length m	27.4	4.6	27.2	5.9	26.9	5.3	25.4	4.6
Length n	32.5	4.9	32.3	5.7	31.7	5.2	30.7	5.0
Length p	9.9	3.6	5.4	3.3	4.6	2.8	4.5	2.2
Length q	5.0	3.8	1.3	3.1	0.1	3.3	-0.5	3.3
Length r	2.7	2.5	2.1	3.4	5.7	2.2	0.6	1.8

TABLE VIII

COMPARISON OF MEAN VALUES SHOWING SIGNIFICANT DIFFERENCE BETWEEN THE MALE AND FEMALE SAMPLES IN STAGE 1 OF DEGLUTITION

VARIABLE	MALE MEAN	MALE S.D.	FEMALE MEAN	FEMALE S.D.	DIFFERENCE
Angle A	32.4	3.6	29.3	5.3	3.1*
Angle B	33.2	7.3	32.0	5.4	1.2
Angle E	135.8	7.3	134.7	8.4	1.1
Angle G	-8.5	5.3	-1.6	7.2	6.9**
Angle H	-12.5	4.6	-9.5	4.9	3.0*
Angle I	-16.7	8.3	-14.2	9.7	2.5
Length b	20.2	4.2	20.8	4.1	0.6
Length h	-1.7	1.6	-3.2	4.1	1.5*
Length i	-2.8	3.5	-0.4	4.2	2.4*
Length l	21.0	5.8	22.5	4.6	1.5
Length q	4.0	5.9	5.0	3.8	1.0

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

TABLE IX

COMPARISON OF MEAN VALUES SHOWING SIGNIFICANT DIFFERENCE BETWEEN THE MALE AND FEMALE SAMPLES IN STAGE 2 OF DEGLUTITION

VARIABLE	MALE MEAN	MALE S.D.	FEMALE MEAN	FEMALE S.D.	DIFFERENCE
Angle A	31.6	3.6	28.1	5.6	3.5**
Angle B	29.6	6.1	25.5	3.9	4.1**
Angle E	138.4	5.7	137.3	9.7	1.1
Angle G	-7.4	5.2	-0.8	7.8	6.6**
Angle H	-12.2	4.2	-8.7	5.2	3.5**
Angle I	-13.4	8.3	-4.6	8.8	8.8**
Length b	18.6	4.6	18.7	4.2	0.1
Length h	-0.5	1.0	-1.5	3.1	1.0
Length i	-2.5	3.6	-0.1	3.5	2.4*
Length l	20.4	6.1	22.6	5.3	2.2
Length q	2.3	5.0	1.3	3.1	1.0

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

TABLE X

COMPARISON OF MEAN VALUES SHOWING SIGNIFICANT DIFFERENCE BETWEEN THE MALE AND FEMALE SAMPLES IN STAGE 3 OF DEGLUTITION

VARIABLE	MALE MEAN	MALE S.D.	FEMALE MEAN	FEMALE S.D.	DIFFERENCE
Angle A	31.6	3.8	28.7	5.2	2.9*
Angle B	30.7	6.4	25.7	3.9	5.0**
Angle E	145.0	7.3	141.5	7.5	3.5
Angle G	-8.7	5.4	-1.9	6.7	6.8**
Angle H	-13.1	4.5	-9.8	4.9	3.3*
Angle I	-13.1	9.5	-3.8	9.6	9.3**
Length b	15.1	3.6	17.2	3.6	2.1*
Length h	-0.4	1.3	-1.8	3.8	1.4
Length i	-1.7	3.6	-0.1	3.9	1.6
Length l	19.7	6.4	22.7	4.4	3.0*
Length q	1.8	5.5	0.1	3.3	1.7

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

TABLE XI

COMPARISON OF MEAN VALUES SHOWING SIGNIFICANT DIFFERENCE BETWEEN THE MALE AND FEMALE SAMPLES IN STAGE 4 OF DEGLUTITION

VARIABLE	MALE MEAN	MALE S.D.	FEMALE MEAN	FEMALE S.D.	DIFFERENCE
Angle A	31.4	4.7	28.6	5.4	2.8*
Angle B	30.1	5.8	25.8	4.8	4.3**
Angle E	148.1	6.9	144.1	4.9	4.0*
Angle G	-8.7	5.8	-1.6	8.2	7.1**
Angle H	-13.0	4.8	-9.9	5.5	3.2*
Angle I	-12.7	9.1	-2.2	9.6	10.5**
Length b	13.8	4.1	15.4	2.9	1.6
Length h	-0.5	1.3	-1.6	3.3	1.1
Length i	-1.8	3.6	-0.2	3.8	1.6
Length l	17.6	6.3	21.3	3.7	3.7*
Length q	1.7	4.9	-0.5	3.3	2.2*

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

TABLE XII

CINEFLUOROGRAPHIC ANALYSIS OF DEGLUTITION BEFORE OPERATION

VARIABLE	STAGE 1 MEAN	STAGE 1 S.D.	STAGE 2 MEAN	STAGE 2 S.D.	STAGE 3 MEAN	STAGE 3 S.D.	STAGE 4 MEAN	STAGE 4 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 f	25.8	4.2	24.7	4.4	25.3	4.2	24.9	4.6
Length g	10.1	4.2	11.2	4.9	6.5	3.2	5.7	2.9
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 j	-0.3	2.9	0.8	2.7	0.8	2.9	0.7	2.6
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 XIII

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 f	24.6	4.0	24.3	4.4	24.4	4.8	23.8	4.4
Length g	8.7	2.8	10.2	4.5	5.6	2.8	4.9	1.8
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 j	0.5	2.6	0.9	2.3	0.8	3.1	1.1	2.6
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

TABLE XIV

COMPARISON OF MEAN VALUES FOR STAGE 1 OF DEGLUTITION ANGULAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	S.D.	AFTER OPERATION MEAN	S.D.	DIFFERENCE
Angle A	31.7	4.1	30.7	5.0	1.0
Angle B	34.2	7.7	31.2	5.1	3.0 *
Angle C	63.5	4.7	62.6	5.6	0.9
Angle D	101.3	6.1	100.1	7.2	1.2
Angle E	136.4	7.2	134.3	8.2	2.1
Angle G	-6.4	6.4	-5.2	7.5	1.2
Angle H	-11.6	4.5	-11.0	5.4	0.6
Angle I	-17.2	9.6	-14.2	8.1	3.0

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

TABLE XV

COMPARISON OF MEAN VALUES FOR STAGE 1 OF DEGLUTITION
LINEAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	BEFORE OPERATION S.D.	AFTER OPERATION MEAN	AFTER OPERATION S.D.	DIFFERENCE
Length a	0.0	0.0	0.0	0.0	0.0
Length b	20.3	4.0	20.5	4.3	0.2
Length c	59.7	8.3	55.8	8.6	3.9
Length d	63.3	7.5	61.3	8.9	2.0
Length e	26.4	3.8	25.7	4.9	0.7
Length f	25.8	4.2	24.6	4.0	1.2
Length g	10.1	4.2	8.7	2.8	1.4
Length h	-2.6	3.0	-1.9	2.9	0.7
Length i	-2.3	3.7	-1.4	4.2	0.9
Length j	-0.3	2.9	0.5	2.6	0.8
Length k	-2.9	2.0	-2.2	1.9	0.7
Length l	19.9	5.7	23.3	4.5	3.4*
Length m	27.2	4.8	27.5	4.5	0.3
Length n	33.3	6.3	33.1	6.2	0.2
Length p	9.4	5.2	8.4	3.1	1.0
Length q	5.2	6.5	3.7	3.3	1.5
Length r	4.3	2.7	1.3	1.9	3.0**

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

TABLE XVI

COMPARISON OF MEAN VALUES FOR STAGE 2 OF DEGLUTITION
ANGULAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	S.D.	AFTER OPERATION MEAN	S.D.	DIFFERENCE
Angle A	30.4	4.9	30.1	4.6	0.3
Angle B	28.5	6.8	27.5	4.4	1.0
Angle C	62.5	5.3	62.6	5.3	0.1
Angle D	101.0	6.4	101.1	7.2	0.1
Angle E	138.6	6.1	137.3	8.7	1.3
Angle G	-4.9	6.6	-4.8	7.7	0.1
Angle H	-10.2	4.4	-11.4	5.3	1.2
Angle I	-11.4	9.6	-8.6	9.3	2.8

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

TABLE XVII

COMPARISON OF MEAN VALUES FOR STAGE 2 OF DEGLUTITION
LINEAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	BEFORE OPERATION S.D.	AFTER OPERATION MEAN	AFTER OPERATION S.D.	DIFFERENCE
Length a	0.1	0.3	0.3	1.1	0.2
Length b	18.6	3.9	18.7	4.9	0.1
Length c	57.3	9.1	54.6	8.6	2.7
Length d	62.9	8.1	61.5	8.9	1.4
Length e	23.7	4.3	23.4	3.9	0.3
Length f	24.7	4.4	24.3	4.4	0.4
Length g	11.2	4.9	10.2	4.5	1.0
Length h	-1.1	2.4	-0.8	1.8	0.3
Length i	-1.9	3.7	-1.2	3.8	0.7
Length j	0.8	2.7	0.9	2.3	0.1
Length k	-2.3	2.0	-1.9	1.7	0.4
Length l	19.7	6.2	22.8	5.1	3.1*
Length m	26.7	4.8	27.5	5.2	0.8
Length n	33.2	6.2	32.9	5.9	0.3
Length p	6.5	4.7	5.4	3.1	1.1
Length p	2.8	5.5	1.0	2.7	1.8
Length r	4.9	3.6	2.4	2.4	2.5**

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

TABLE XVIII

COMPARISON OF MEAN VALUES FOR STAGE 3 OF DEGLUTITION
ANGULAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	BEFORE OPERATION S.D.	AFTER OPERATION MEAN	AFTER OPERATION S.D.	DIFFERENCE
Angle A	30.9	4.6	30.0	4.6	0.9
Angle B	29.7	7.3	27.8	4.3	1.9
Angle C	63.4	4.8	62.5	5.6	0.9
Angle D	102.0	6.7	101.5	7.1	0.5
Angle E	143.9	7.6	143.3	7.6	0.6
Angle G	-6.0	6.3	-6.0	7.2	0.0
Angle H	-11.4	4.6	-12.2	5.2	0.8
Angle I	-10.8	10.5	-8.0	10.5	2.8

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

TABLE XIX

COMPARISON OF MEAN VALUES FOR STAGE 3 OF DEGLUTITION
LINEAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	S.D.	AFTER OPERATION MEAN	S.D.	DIFFERENCE
Length a	2.4	2.2	2.9	2.3	0.5
Length b	16.3	3.6	15.6	3.8	0.7
Length c	53.8	9.4	50.1	8.9	3.7
Length d	62.7	7.7	60.7	9.0	2.0
Length e	24.1	4.4	23.6	4.2	0.5
Length f	25.3	4.2	24.4	4.8	0.9
Length g	6.5	3.2	5.6	2.8	0.9
Length h	-1.1	2.6	-0.9	2.7	0.2
Length i	-1.3	3.6	-0.9	4.0	0.4
Length j	0.8	2.9	0.8	3.1	0.0
Length k	-2.3	1.9	-1.8	1.9	0.5
Length l	19.6	6.6	22.0	4.9	2.4
Length m	26.6	4.9	26.6	5.2	0.0
Length n	33.5	6.1	32.9	6.3	0.6
Length p	6.3	5.3	4.6	2.9	1.7
Length q	2.1	5.8	0.1	3.3	2.0*
Length r	5.9	2.4	4.1	1.8	1.8*

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

TABLE XX

COMPARISON OF MEAN VALUES FOR STAGE 4 OF DEGLUTITION
ANGULAR MEASUREMENTS

VARIABLE	BEFORE OPERATION MEAN	S.D.	AFTER OPERATION MEAN	S.D.	DIFFERENCE
Angle A	30.9	5.0	29.8	5.3	1.1
Angle B	29.4	6.5	27.5	4.9	1.9
Angle C	63.1	5.7	62.5	6.3	0.6
Angle D	96.1	7.5	96.8	9.3	0.7
Angle E	146.3	6.6	146.8	6.5	0.5
Angle G	-5.6	7.2	-6.1	8.2	0.5
Angle H	-11.4	4.9	-12.1	5.6	0.7
Angle I	-9.5	11.1	-7.6	10.1	1.9

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

TABLE XXI

COMPARISON OF MEAN VALUES FOR STAGE 4 OF DEGLUTITION
LINEAR MEASUREMENTS

	BEFORE OPERATION		AFTER OPERATION		
VARIABLE	MEAN	S.D.	MEAN	S.D.	DIFFERENCE
Length a	3.3	1.9	3.9	2.2	0.6
Length b	14.9	3.3	14.1	4.2	0.8
Length c	49.1	8.1	46.1	8.9	3.0
Length d	62.5	7.9	60.2	8.9	2.3
Length e	23.8	4.7	23.7	4.8	0.1
Length f	24.9	4.6	23.8	4.4	1.1
Length g	5.7	2.9	4.9	1.8	0.8
Length h	-1.2	2.6	-0.6	1.9	0.6
Length i	-1.4	3.7	-0.6	3.9	0.8
Length j	0.7	2.6	1.1	2.6	0.4
Length k	-2.1	2.0	-1.6	1.7	0.5
Length l	18.1	6.6	19.9	4.5	1.8
Length m	24.9	5.1	25.5	4.0	0.7
Length n	32.4	6.6	31.7	5.2	0.7
Length p	5.9	4.1	4.8	2.9	1.1
Length q	1.6	5.5	0.2	3.2	1.4
Length r	0.6	1.7	0.5	1.6	0.1

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

TABLE XXII

COMPARISON OF MEAN VALUES BETWEEN THE MALE AND FEMALE SAMPLES IN THE PRODUCTION OF "E" SOUND - ANGULAR MEASUREMENTS

VARIABLE	MALE MEAN	MALE S.D.	FEMALE MEAN	FEMALE S.D.	DIFFERENCE
Angle A	33.6	3.9	31.7	4.8	1.9
Angle B	36.2	6.1	33.6	4.9	2.6
Angle C	65.4	5.1	63.1	4.9	2.3
Angle D	103.9	12.4	98.8	6.1	5.1*
Angle E	146.9	6.5	144.7	7.3	2.2
Angle G	-9.4	4.0	-2.9	6.6	6.5**
Angle H	-14.0	4.3	-10.3	5.3	3.7**
Angle I	-22.6	6.2	-16.4	7.2	6.2**

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

TABLE XXIII

COMPARISON OF MEAN VALUES BETWEEN THE MALE AND FEMALE SAMPLES IN THE PRODUCTION OF "E" SOUND - LINEAR MEASUREMENTS

VARIABLE	MALE MEAN	MALE S.D.	FEMALE MEAN	FEMALE S.D.	DIFFERENCE
Length a	4.5	1.8	5.2	1.7	0.7
Length b	15.2	3.4	15.5	3.3	0.3
Length c	56.9	7.8	60.0	8.5	3.1
Length d	63.1	10.4	64.9	7.1	1.8
Length e	26.4	4.9	27.2	4.1	0.8
Length f	29.4	5.4	30.1	3.6	0.7
Length g	8.1	6.3	6.8	2.9	1.3
Length h	-5.1	3.8	-8.3	3.6	3.2**
Length i	-4.4	2.4	-5.1	2.2	0.7
Length j	-4.6	2.9	-6.1	4.8	1.5*
Length k	-3.4	1.6	-4.3	1.2	0.9
Length l	20.1	5.9	22.3	3.6	2.2
Length m	27.3	4.5	27.0	4.2	0.3
Length n	34.8	6.5	32.9	4.8	1.9
Length p	11.3	3.0	11.8	4.2	0.5
Length q	6.9	3.7	6.7	2.9	0.2
Length r	7.9	3.0	8.6	5.7	0.7

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

TABLE XXIV

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

VARIABLE	BEFORE OPERATION MEAN	S.D.	AFTER OPERATION MEAN	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

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

TABLE XXV

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

VARIABLE	BEFORE OPERATION MEAN	S.D.	AFTER OPERATION MEAN	S.D.	DIFFERENCE
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 f	30.6	4.6	28.7	4.8	1.9
Length g	8.4	6.9	6.8	2.8	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 j	-5.3	2.9	-5.0	4.7	0.3
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

TABLE XXVI

COMPARISON OF MEAN VALUES AT REST AND THE PRODUCTION OF "E" SOUND BEFORE OPERATION - ANGULAR MEASUREMENTS

VARIABLE	AT REST MEAN	S.D.	"E" SOUND MEAN	S.D.	DIFFERENCE
Angle A	31.7	4.1	33.3	4.5	1.6
Angle B	34.2	7.7	36.0	6.0	1.8
Angle C	63.5	4.7	64.8	5.0	1.3
Angle D	101.3	6.1	103.3	13.7	2.0
Angle E	136.4	7.2	146.1	6.6	9.7**
Angle G	-6.4	6.4	-6.7	6.6	0.3
Angle H	-11.6	4.5	-12.1	5.1	0.5
Angle I	-17.2	9.6	-20.0	7.6	2.8

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

TABLE XXVII

COMPARISON OF MEAN VALUES AT REST AND THE PRODUCTION OF "E" SOUND BEFORE OPERATION - LINEAR MEASUREMENTS

VARIABLE	AT REST MEAN	AT REST S.D.	"E" SOUND MEAN	"E" SOUND S.D.	DIFFERENCE
Length a	0.0	0.0	4.2	1.4	4.2**
Length b	20.3	4.0	15.9	3.2	4.4**
Length c	59.7	8.3	59.9	7.5	0.2
Length d	63.3	7.5	65.2	8.9	1.9
Length e	26.4	3.8	27.5	4.6	1.1
Length f	25.8	4.2	30.6	4.6	4.8**
Length g	10.1	4.2	8.4	6.9	1.7
Length h	-2.6	3.0	-6.6	4.3	4.0**
Length i	-2.3	3.7	-4.9	2.3	2.6**
Length j	-0.3	2.9	-5.3	2.9	5.0**
Length k	-2.9	2.0	-3.9	1.4	1.0*
Length l	19.9	5.7	20.5	5.5	0.6
Length m	27.2	4.8	27.6	4.9	0.4
Length n	33.3	6.3	34.5	6.1	1.2
Length p	9.4	5.2	11.9	3.7	2.5*
Length q	5.2	6.5	7.1	4.0	1.9*
Length r	4.3	2.7	8.9	3.6	4.6**

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

TABLE XXVIII

COMPARISON OF MEAN VALUES AT REST AND THE PRODUCTION OF "E" SOUND AFTER OPERATION - ANGULAR MEASUREMENTS

VARIABLE	AT REST MEAN	AT REST S.D.	"E" SOUND MEAN	"E" SOUND S.D.	DIFFERENCE
Angle A	30.7	5.0	32.5	4.3	1.8
Angle B	31.2	5.1	34.4	5.6	3.2*
Angle C	62.6	5.6	64.1	5.2	1.5
Angle D	100.1	7.2	100.4	6.2	0.3
Angle E	134.3	8.2	146.0	7.3	11.7**
Angle G	-5.2	7.5	-7.0	5.5	1.8
Angle H	-11.0	5.4	-13.0	4.9	2.0
Angle I	-14.2	8.1	-20.3	7.0	6.1**

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

TABLE XXIX

COMPARISON OF MEAN VALUES AT REST AND THE PRODUCTION OF "E" SOUND AFTER OPERATION - LINEAR MEASUREMENTS

VARIABLE	AT REST MEAN	AT REST S.D.	"E" SOUND MEAN	"E" SOUND S.D.	DIFFERENCE
Length a	0.0	0.0	5.3	1.9	5.3**
Length b	20.5	4.3	14.8	3.5	5.7**
Length c	55.8	8.6	56.4	8.5	0.6
Length d	61.3	8.9	62.4	9.5	1.1
Length e	25.7	4.9	25.9	4.5	0.2
Length f	24.6	4.0	28.7	4.8	4.1**
Length g	8.7	2.8	6.8	2.8	1.9*
Length h	-1.9	2.9	-6.1	3.8	4.2**
Length i	-1.4	4.2	-4.3	2.4	2.9**
Length j	0.5	2.6	-5.0	4.7	4.5**
Length k	-2.2	1.9	-3.6	1.6	1.4**
Length l	23.3	4.5	21.4	5.0	1.9
Length m	27.5	4.5	26.8	3.7	0.7
Length n	33.1	6.2	33.6	5.7	0.5
Length p	8.4	3.1	11.1	3.4	2.7**
Length q	3.7	3.3	6.5	2.8	2.8*
Length r	1.3	1.9	7.5	4.7	6.2**

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

TABLE XXX

THE COEFFICIENTS OF CORRELATION ("r") FOR SELECTED PAIRS OF VARIABLES BEFORE OPERATION

VARIABLE	DEGLUTITION STAGE 1	STAGE 2	STAGE 3	STAGE 4	SPEECH "E" SOUND
Angle A: Angle B	+0.39*	+0.70**	+0.67**	+0.81**	+0.89**
Angle A: Angle D	+0.47‡	+0.64**	+0.55**	+0.64**	+0.49**
Angle B: Angle C	+0.29	+0.63**	+0.63**	+0.74**	+0.83**
Angle C: Angle D	+0.47‡	+0.71**	+0.70**	+0.68**	+0.53**
Angle C: length n	+0.47‡	+0.48‡	+0.46‡	+0.47‡	+0.46‡
Angle D: Angle E	+0.63**	+0.52**	+0.63**	+0.44*	+0.17
Angle D: length 1	+0.37	+0.13	+0.29	+0.22	-0.27
Angle D: length m	+0.66**	+0.57**	+0.64**	+0.53**	+0.14
Angle D: length n	+0.57**	+0.75**	+0.73**	+0.58**	+0.22
Angle E: length a	+0.00	+0.21	+0.23	+0.27	-0.03
Angle E: length b	-0.62**	-0.39*	-0.50**	-0.59**	-0.33
Angle E: length 1	+0.44*	+0.38*	+0.33	+0.21	+0.23
Angle E: length m	+0.64**	+0.50**	+0.54**	+0.47‡	+0.23
Angle E: length n	+0.55**	+0.54**	+0.75**	+0.69**	+0.42*
Angle G: Angle I	+0.20	+0.21	+0.28	+0.62**	+0.62**
Angle H: Angle I	+0.14	+0.32	+0.28	+0.56**	+0.59**
Length a: length 1	+0.00	-0.27	+0.09	+0.25	+0.30
Length b: length 1	-0.45*	-0.10	-0.01	-0.06	+0.03
Length d: length e	+0.84**	+0.90**	+0.83**	+0.78**	+0.83**
Length d: length f	+0.73**	+0.80**	+0.69**	+0.82**	+0.75**
Length f: length n	+0.52**	+0.50**	+0.69**	+0.51**	+0.38
Length h: length r	-0.34	-0.13	+0.02	-0.26	-0.06

** = Significant at the 0.01 level of confidence
‡ = Significant at the 0.02 level of confidence
* = Significant at the 0.05 level of confidence

TABLE XXXI

THE COEFFICIENTS OF CORRELATION ("r") FOR SELECTED PAIRS OF VARIABLES AFTER OPERATION

VARIABLE	DEGLUTITION STAGE 1	STAGE 2	STAGE 3	STAGE 4	SPEECH "E" SOUND
Angle A: Angle B	+0.78**	+0.70**	+0.71**	+0.83**	+0.73**
Angle A: Angle D	+0.49**	+0.38*	+0.40*	+0.15	+0.49**
Angle B: Angle C	+0.77**	+0.72**	+0.71**	+0.81**	+0.70**
Angle C: Angle D	+0.65**	+0.59**	+0.59**	+0.43*	+0.59**
Angle C: length n	+0.47‡	+0.42*	+0.45‡	+0.52**	+0.51**
Angle D: Angle E	+0.81**	+0.79**	+0.49**	+0.59**	+0.38*
Angle D: length l	+0.45‡	+0.51**	+0.39*	+0.42*	+0.01
Angle D: length m	+0.62**	+0.70**	+0.53**	+0.74**	+0.41*
Angle D: length n	+0.62**	+0.68**	+0.65**	+0.47‡	+0.53**
Angle E: length a	+0.00	+0.61**	+0.49**	+0.41*	+0.48‡
Angle E: length b	-0.66**	-0.68**	-0.51**	-0.29	-0.72**
Angle E: length l	+0.48‡	+0.61**	+0.62**	+0.53**	+0.60**
Angle E: length m	+0.59**	+0.68**	+0.63**	+0.49**	+0.57**
Angle E: length n	+0.40*	+0.47‡	+0.66**	+0.47‡	+0.47‡
Angle G: Angle I	+0.52**	+0.67**	+0.67**	+0.62**	+0.61**
Angle H: Angle I	+0.60**	+0.70**	+0.71**	+0.67**	+0.65**
Length a: length l	+0.00	+0.36	+0.25	+0.55**	+0.60**
Length b: length l	-0.03	-0.12	-0.16	-0.31	-0.41*
Length d: length e	+0.93**	+0.86**	+0.93**	+0.89**	+0.85**
Length d: length f	+0.84**	+0.84**	+0.81**	+0.85**	+0.78**
Length f: length n	+0.67**	+0.69**	+0.62**	+0.51**	+0.31
Length h: length r	+0.10	+0.02	-0.12	-0.05	+0.01

** = Significant at the 0.01 level of confidence
‡ = Significant at the 0.02 level of confidence
* = Significant at the 0.05 level of confidence

GLOSSARY

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Anterior Nasal Spine (ANS)

The median, sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

Menton (M)

The lowest point of the symphysis menti of the mandible.

Palatal Plane

This is not a true plane but a line joining the anterior nasal spine and the posterior nasal spine.

Pogonion (P)

The most prominent or most anterior point of the bony chin.

Point A (A)

The deepest point on the midline contour at the alveolar process between the anterior nasal spine and the alveolar crest of the maxillary central incisor.

Posterior Nasal Spine (PNS)

The process formed by the united projecting ends of the posterior borders of the palatal processes of the palatal bones.

Pterygo-maxillary fissure (PTM)

The projected contour of the fissure formed by the anterior curvature of the pterygoid process and the posterior wall of the tuberosity of the maxilla.

Registration Point R (R)

The point of intersection between the palatal plane and the vertical projection of Pterygo-maxillary fissure.

Registration Point R' (R')

The point of intersection between the palatal plane and the vertical projection of Point A.