EVALUATION OF CHANGES IN HYOID BONE POSITION AND PHARYNGEAL AIRWAY DIMENSIONS FOLLOWING MANDIBULAR SETBACK SURGERY – A CEPHALOMETRIC STUDY

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THE TAMILNADU DR. M.G.R MEDICAL UNIVERSITY
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2012 – 2015

CERTIFICATE

This is to certify that **Dr. V. SENTHIL KUMAR**, Post graduate student **(2012 – 2015)** in the Department of Orthodontics and Dentofacial orthopaedics branch V, Tamil Nadu Government Dental College and Hospital, Chennai – 600 003 has done this dissertation titled ***"EVALUATION OF CHANGES IN HYOID BONE POSITION AND PHARYNGEAL AIRWAY DIMENSIONS FOLLOWING MANDIBULAR SETBACK SURGERY – A CEPHALOMETRIC STUDY"*** under my direct guidance and supervision for partial fulfillment of the M.D.S degree examination in April 2015 as per the regulations laid down by The Tamil Nadu Dr. M.G.R. Medical University, Chennai -600 032 for **M.D.S., Orthodontics and Dentofacial orthopaedics (Branch – V)** degree examination.

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DECLARATION

I, **Dr. V. SENTHIL KUMAR**, do hereby declare that the dissertation titled ***"EVALUATION OF CHANGES IN HYOID BONE POSITION AND PHARYNGEAL AIRWAY DIMENSIONS FOLLOWING MANDIBULAR SETBACK SURGERY – A CEPHALOMETRIC STUDY"*** was done in the Department of Orthodontics, Tamil Nadu Government Dental College & Hospital, Chennai 600 003. I have utilized the facilities provided in the Government Dental College for the study in partial fulfillment of the requirements for the degree of Master of Dental Surgery in the speciality of Orthodontics and Dentofacial Orthopaedics (Branch V) during the course period **2012-2015** under the conceptualization and guidance of my dissertation guide, **Professor Dr. G. VIMALA MDS.,**

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I seek the blessings of the Almighty without whose benevolence; the Study would not have been possible.

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And

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Principal **PG Student**

Witnesses **Student Guide**

1.

2.

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INTRODUCTION

Pharyngeal airway space and hyoid bone positions have been extensively studied in orthodontics. Numerous evidences from cephalometric studies support a link between airway dimensions, hyoid bone positions and maintenance of dentofacial harmony.

The pharynx is a 12–14 cm long musculomembranous tubular structure, shaped like an inverted cone[1]. It extends from the cranial base to the lower border of the cricoid cartilage (the level of the sixth cervical vertebra), where it becomes continuous with the oesophagus[2].

The pharynx communicates with the nasal, oral and laryngeal cavities via the nasopharynx, oropharynx and laryngopharynx respectively[3]. The nasopharynx and the oropharynx have significant locations and functions as they form a part of the unit in which respiration and deglutition are carried out. The nasopharynx forming the upper part of respiratory system is connected anteriorly with nasal cavity and posteriorly it extends as oropharynx. The oropharynx extends from the soft palate to the base of epiglottis (from second to fourth cervical vertebra). The laryngopharynx joins the oropharynx at the level of pharyngoepiglottic fold and the hyoid, and then it continues up to the level of the sixth cervical vertebra.

The pharynx is composed of three coats: mucous, fibrous, and muscular. The muscles of the pharynx are three circular constrictors and three longitudinal elevators. The constrictors may be thought of as three overlapping cones which arise from structures at the sides of the head and neck and pass posteriorly to insert into a midline fibrous band, the pharyngeal raphe[2]. Its lining mucosa is continuous with that lining the pharyngotympanic tubes, nasal cavity, mouth and larynx[1].

The hyoid bone is a horseshoe-shaped bone situated in the anterior midline of the neck between the chin and the thyroid cartilage. At rest, it lies at the level of the base of the mandible in the front and the third cervical vertebra behind[1, 3]. Unlike other bones of neck hyoid does not have any bony articulations. It provides attachments for ligaments, muscles, fascia of cranium and mandible. The two major group of muscles attached to hyoid bone are suprahyoid and infrahyoid muscles. Both suprahyoid and infrahyoid muscles have wide range of actions.

The hyoid bone plays an important and active part in accomplishing the delicate balance between anterior and posterior muscle tension relative to the occipital condyles, which in turn helps to balance the head as man assumed an upright posture. It is evident that there exists a mutual correlation between position of the hyoid bone, volume of pharyngeal airway and dentofacial structures

Mandibular prognathism or skeletal Class III malocclusion is one of the most severe maxillofacial deformities. The word prognathism is derived from Greek *pro* (forward) and *gnathos* (jaw). Mandibular prognathism is a skeletal deformity which is characterized by abnormal protrusion of mandible. Joffe defined mandibular prognathism as a disorder of craniofacial growth in which facial profile is impaired by excess prominence of mandible. It is genetic and manifests as familial.

Orthognathic surgery for mandibular prognathism is done for two major reasons. One reason is that orthodontic treatment alone cannot produce a satisfactory treatment result for prognathic mandible or skeletal class III malocclusion. The other reason is correction of functional problems like chewing and speaking[4].

Mandibular setback using bilateral sagittal split osteotomy (BSSO) is routinely done as an orthognathic surgical procedure to treat mandibular prognathism that results in both functional and aesthetic improvements. Mandibular setback surgery can improve the occlusion, masticatory function, and esthetics by markedly changing the position of the mandible[5].

The oropharyngeal complex is also affected by a posterior movement of the mandible. Mandibular setback surgery causes changes in the position of the hyoid bone and the tongue, and consequent narrowing of the pharyngeal airway space (PAS). Postoperative changes in the pharyngeal complex may influence clinical features such as skeletal relapse and the airway size[6]

Gu et al[7] postulated that the postoperative alteration in position of the hyoid bone may cause relaxation of the suprahyoidal musculature. The possible decreased tension of suprahyoidal musculature may change the balance within the head and neck musculature. This can result in an increased anteriorly directed force caused by the neck muscles, pulling the mandible forward again. If the oropharyngeal complex exerts such an influence over a prolonged period, the related changes in position of the hyoid bone and in the length of the suprahyoid muscles may contribute to skeletal relapse. Furthermore, the decrease in pharyngeal airway size could induce breathing problems[8].

Pharyngeal airway narrowing might be a reason for obstructive sleep apnea (OSA) [9]. OSA is considered a risk factor for systemic and pulmonary hypertension and cardiac arrhythmias and may increase morbidity and mortality[10].

Therefore it is relevant to evaluate the changes in nasopharyngeal airway and hyoid bone position in subjects with prognathic mandible, who had combined orthodontic and orthognathic surgery through mandibular setback.

This retrospective analytical cephalometric study has been undertaken to evaluate and compare the pharyngeal airway dimensions and hyoid bone positional changes in patients with prognathic mandible who underwent mandibular setback surgery through Bilateral Sagittal Split Osteotomy (BSSO).

AIMS AND OBJECTIVES

AIM OF THE STUDY

The Aim of this study is to evaluate the changes in hyoid bone and pharyngeal airway dimensions in patients with prognathic mandible who had undergone mandibular setback surgery

OBJECTIVES OF THE STUDY

- To evaluate the hyoid bone position and pharyngeal airway dimensions in skeletal class III patients who had undergone mandibular setback surgery at pretreatment (T1), postsurgical (T2) and post treatment (T3) stages.
- To evaluate the hyoid bone position and pharyngeal airway dimension in normal skeletal class I patients
- To compare the changes in hyoid bone position and pharyngeal airway in the above two groups

REVIEW OF LITERATURE

Numerous studies were found in literature with respect to the growth characteristics and developmental aspects of pharyngeal airway space, hyoid bone and tongue. The articles relating to methods of assessing their existent measurements, variations through the growth period and possible influence of various orthognathic surgeries over the hyoid and airway are plenty in literature. The most relevant studies are presented here.

Carmine Durzo et al (1962)[12] studied the growth behaviour of the hyoid bone in relation to other craniofacial structures in a series of five longitudinal cephalometric study. They concluded that the hyoid bone has a stable vertical position in normal individuals, at a level opposite the lower portion of third and upper portion of fourth cervical vertebra. During growth its relative position remains constant when it descends as the cervical vertebrae increase their length and the cranial base and mandible descend and move away from each other. In the mandibular deformity cases the hyoid movements followed closely those of mandibular growth movements and were restricted both anteroposteriorly and vertically. The hyoid movements were also modified as per the demands of maintaining a patent airway.

Ian Milne and John Cleall (1970)[13] conducted a cinefluorographic study on functional adaptation of oropharyngeal structures at three physiological developmental phases. The study showed that oropharyngeal structures showed marked ability to adapt to change in local dental environment. Changes in the hyoid position were statistically significant in rest position.

Lee W Graber (1978)[14] studied the changes in hyoid bone in 30 skeletal class III patients who were treated with chin cup orthopedic treatment for a period of three years between 6 and 9 years of age. The study with lateral cephalograms summarized that a clockwise rotation of mandible occurred with mandible being positioned in inferior and posterior direction. There was also a resultant slight posterior and more of an inferior position of hyoid bone. However neither such positional change of hyoid bring about any encroachment of pharyngeal space nor was the inferior positioning entirely attributed to growth changes. The author states that airway patency is the primary factor in determining hyoid position and the orthopedic treatment brought about both functional as well as morphologic adaptations to the hyoid bone.

James A McNamara Jr (1981)[15] tried to establish a possible relationship between upper airway obstruction and trend of craniofacial growth through four case reports consisting of an ideal long face, a case of adenoidectomy, a case of combined adenoidectomy and tonsillectomy and a case of late nasopharyngeal obstruction. All these cases were found to be having steep mandibular plane. Although the untreated ideal long face had very little changes during follow up period, those cases whish were treated with surgical removal of airway obstruction were found to have reduced mandibular plane to satisfactory extent. The author recommended for further randomized control trial to validate his observation.

Bibby, Preston (1981)[16] in their landmark article presented the novel method to determine the hyoid bone position referred to as the hyoid triangle which is formed by the joining of three cephalometric points namely retrognathion, hyoidale and C3. This method is different in a way that most of the previous articles which studied the hyoid position used cranium as the reference point of which the S-N plane was the most popular.

The authors related the hyoid bone to mandible and cervical vertebrae and they claimed that the mandible is at a more comparable level to the axis of rotation than cranium and hence head movement effect can be minimized and hyoid position can be more reliably determined. They applied the hyoid triangle in 54 normal class I patients and found a constant relationship between cervical vertebrae and antero posterior position of hyoid bone. They also indicated that hyoid bone serves as a bony anterior border to the pharynx and surprisingly no sexual dimorphism was noted.

W.J.B. Houston (1983)[11] presented an interesting article on errors in cephalometric measurements. He emphasized the importance of distinguishing between a measurement bias and random errors in sampling. He emphasizes that cephalometric studies are prone to error when the sampling method is not randomized and invariably leads to measurement bias. When evaluating individual radiographs, a highly error prone measurement relative to its total variability has very little value in clinical assessment. He says that such results should be interpreted with caution because it is difficult to specify limits of random errors in these studies. Also the sample number plays a part. He adds that adequate error calculation and control is lacking in many studies and may be grossly misleading.

Bibby (1984)[17] also used the same hyoid triangle to evaluate the hyoid bone position in mouth breathers and tongue thrusters. In this study 18 subjects comprising of mouth breathing and tongue thrusting group were evaluated with pre orthodontic lateral cephalograms. The study showed that any postural alterations caused by mouth breathing or tongue thrusting did not affect the position of hyoid and it was relatively stable.

S.C. Cole (1986)[18] described the difference between the terms natural head position and natural head posture. These words were synonymously being used in literature to describe spatial relationship between head and the true vertical or vertebral column or both. Such generalized assumption leading to confusion, the author considered the natural head position relating to true vertical and natural head posture to cervical column. After investigating five groups of people, he found that both these relationships are entirely different with statistical significance. Also of interest is that in those five analyzed groups the values obtained for saddle angle (N-S-Ar) showed no significant difference and altering the natural head position can itself produce class II or class III effects.

Ann Wenzel et al (1989)[19] illustrated the possibility of relationship between posture and airway size after mandibular osteotomy using cephalograms of 52 mandibular prognathic patients. 12 parameters were used to describe the sagittal and vertical changes. Significant correlations between posture and mandibular morphology before surgery and after surgery were present but the other parameter did not have such correlations with posture and hence concluded that mandibular morphology plays a vital role in head posture determination.

Greco et al (1990)[20] retrospectively evaluated the hypopharyngeal airway over long term after surgical correction of mandibular hyperplasia in 11 patients through cephalometry and concluded that hypopharyngeal airway space narrows after surgery and may lead to sleeping disorders in isolated cases.

Sorokolit, Nanda (1990)[21] evaluated the postsurgical changes following sagittal split ramus osteotomy (SSRO) stabilized with rigid fixation with lateral cephalograms of 25 individuals with mean age of 23.4 years at three time intervals. Average setback was 5.1 ± 3.0 mm was achieved. There was a relapse of 0.5 – 1.5 mm in these patients over long term post surgically. Though the relapse was statistically significant, it was small enough to be clinically insignificant. The authors claim that SSRO is a stable surgical procedure.

Athanasiou et al (1991)[22] studied the position of hyoid bone and pharyngeal depth in 52 adult mandibular prognathism patients who were treated with combined orthodontic and surgery treatment. Hyoid bone position and pharyngeal depth were analyzed at the level of second and fourth cervical vertebrae using lateral cephalograms. The results obtained showed only moderate correlations between the second and fourth cervical vertebrae to their respective reference coordinates. The study did not support their proposed hypothesis that surgery may reduce the airway and indicated that reflex alteration of pharyngeal, supra hyoid and infra hyoid muscles could take place.

Beni Solow et al (1993)[23] examined natural head position cephalograms of 50 males with severe obstructive sleep apnoea syndrome between 28-70 years of age confirmed with a polysomnographic diagnosis. They were compared with six groups of healthy samples as control. On evaluation the craniocervical angulation was found to be extremely large in study group exceeding by 1-2 standard deviation than control group. The authors suggested this feature to be physiological adaptation to maintain airway patency and proposed that obstructive sleep apnoea could cause increased craniocervical angle.

Lew (1993)[24] explained the postsurgical changes in hyoid, tongue and airway in patients with mandibular subapical osteotomy in 28 Chinese adults with lateral cephalograms taken pre and post operatively. The intermaxillary space decreased, tongue moved posteriorly and hyoid moved inferiorly at short term. Over long term the tongue and hyoid relapsed comparable to their preoperative position, demonstrating their ability to adapt to postoperative changes.

G.F.Shen et al (1994)[25] gave a detailed cephalometric analysis of upper airway in 116 normal Chinese population. The preliminary normal values for various hard and soft tissues of upper airway were established for both sexes. The study showed significant sexual dimorphism and predicted horizontal position of vallecula to be the best predictor of hypopharyngeal depth and suggested to use these values to investigate further airway abnormalities.

Eung – Pwon Pae et al (1994)[26] researched the upper airway in both upright and supine positions using a cephalometry and electromyography. 20 OSA patients and 10 symptom free patients were investigated. Decrease in oropharyngeal area and increase in tongue cross sectional area was noted when OSA patients changed from upright to supine position. They concluded that changes in airway size due to postural change from upright to supine should be considered while assessing the pathogenesis in airway.

Enacar et al (1994)[27] measured the changes in hyoid bone position, tongue and airway changes in 15 mandibular setback surgery patients with radiographs taken at 3 time intervals. A decrease in hypopharyngeal airway was noted which was statistically significant and sustained over long term follow up. The hyoid and tongue moved to an inferior position post surgically. The author enacts that narrowed hypopharyngeal space and posteroinferior positioning of hyoid and tongue could be permanent.

Miles, O`Reilly (1995)[28] conducted a study to determine the reliability of landmark identification for those structures most commonly reported in the obstructive sleep apnoea literature. Three judges were asked to identify specific landmarks on 20 randomly selected radiographs and 10 superior quality radiographs. The results indicated that the majority of the landmarks could be reliably identified, irrespective of the quality of the radiograph. However, the quality of the radiograph did affect identification of the horizontal position of the hyoid bone and the linear measure of posterior airway space although these were not clinically significant. The vertical position of the tip of the soft palate was highly unreliable, irrespective of the quality of the radiograph. This resulted in errors in the measurement of soft palate length.

Hochban et al (1996)[29] raised a question about the chances of mandibular setback causing sleep related breathing disorders by examining 16 consecutive patients who were analyzed by cephalograms at 1 week, 3 months and 1 year after surgery. The patients were also subjected to polysomnographic evaluation based on Marburg graded diagnostic protocol for sleep related breathing disorders. The study showed that in spite of pharyngeal narrowing noted at in all patients none of them had evidence of postoperative breathing disorder.

Taylor et al (1996)[30] studied the pattern of bony and soft tissue growth of oropharynx in 160 healthy orthodontically untreated children. The study showed that two periods of active growth (6 to 9 years and 12 to 15 years) and two periods of quiescence (9 to 12 years and 15 to 18 years) were found in the oropharyngeal soft tissues.

S.E.Martin et al (1997)[31] analyzed the effect of age, sex, obesity and posture on upper pharyngeal airway size in 60 men and 54 women with age range from 16 – 74 years, in both seated and supine position using acoustic reflection. The study found that, with increasing age all upper airway dimensions except oropharyngeal junction decreased in size in supine position. When compared to women, men had increased body mass indices and larger neck circumferences for any matched body mass index. Also men had greater changes in oropharyngeal junction while in supine position. The authors concluded that upper airway decreases with increasing age in both sex with men prone to greater upper airway collapsibility on lying down posture.

Nakagawa et al (1998)[32] investigated the upper airway changes in 25 patients (12 males and 13 females) after mandibular setback surgery by analyzing the lateral cephalograms taken at 3months, 6 months and 1 year postoperatively. The authors found great sexual dimorphism in their study as the pharyngeal airway space and hyoid bone which decreased and moved inferior respectively at short term continued to do so in males but relapsed to presurgical position in females.

Murat Ozbek et al (1998)[33] to prove the claim of prevailing studies that craniocervical extension occurs in obstructive sleep apnoea (OSA), conducted a cephalometric and polysomnographic evaluation of 252 adult males. They were divided into non apneic- snorers, mild, moderate and severe OSA groups based on apnoea + hypoapnoea index. The study confirmed the presence of craniocervical hyperextension in OSA groups which increased with severity.

Trenouth and Timms (1999)[34] studied the association between functional oropharyngeal airway and craniofacial morphology in 70 subjects in a cephalometric study. The study showed positive correlation of oropharyngeal airway with length of the mandible and cranial base angle.

Ayoub et al (2000)[35] conducted a retrospective study to evaluate the skeletal stability following mandibular setback surgery for correcting mandibular prognathism through two types of surgeries namely sagittal split osteotomy (SSO) and vertical subsigmoid osteotomy (VSO). Lateral cephalograms of 31 patients divided into two above said surgical groups were evaluated at three time points, before, immediately after and at least one year after surgery. The recordings included Euclidean distance matrix analysis apart from the linear and angular measurements along the x and y coordinates. The amount of setback was not statistically significant but the amount of relapse post surgery had statistical significance. There was posteriorly directed relapse of VSO group whereas the relapse occurred in anterior direction in SSO group. The author suggested that vertical subsigmoid osteotomy to be the better of the two surgeries in view of relapsing tendency occurring in posterior direction.

Turnbull, Battagel (2000)[36] beautifully analyzed the effects of orthognathic surgery on pharyngeal airway dimensions and quality of sleep on 32 orthognathic surgery cases. The digitized lateral cephalograms were prospectively analyzed from two surgical groups, one treated with mandibular setback and other with mandibular advancement. The daytime sleepiness changes were assessed using a questionnaire along with overnight domiciliary sleep monitoring. The authors deduced that retrolingual airway dimensions were greatly reduced in setback surgery patients, whereas the same has significantly increased in mandibular advancement patients. The sleep study and questionnaire revealed no significant changes in apnoeic events. Interesting point of this study was that, in patients with preexisting sleeping disorders, the mandibular advancement surgery has actually increased the quality of sleep.

Tselnik, Pogrel (2000)[37] retrospectively studied the changes in pharyngeal airway space following mandibular setback surgery in 14 adult patients taken at three time periods viz. preoperatively, immediately postoperatively and long term. The study showed a mean mandibular setback of 9.7mm. There was a 28% decrease in linear distance in hypopharynx with mean pharyngeal space getting reduced by 1.52 cm^2. A strong correlation was found between quantum of mandibular setback and airway decrease. The authors concluded that a permanent decrease in airway occurs over long term post surgery and can lead to sleep apnea syndrome in vulnerable individuals.

Athanasiou (2000)[38] in his discussion regarding the study by Tselnik and Pogrel (2000), stated that though two dimensional cephalometry has some limitations, meeting certain technical considerations like standardization of cephalograms and assessing methodological error can make them provide useful information for estimation of tongue and nasopharynx volume. Stating that sleep related disorders do not occur in sitting and standing posture, he advocated lateral cephalograms to be taken in supine position too. He recommends supine endoscopy as a promising choice since it is associated with apnea-hypopnea index and airway space.

Achilleos et al (2000)[39] described the effects of mandibular advancement surgery on hyoid position, soft palate, tongue and pharyngeal airway through lateral cephalograms taken at 3 time intervals. The hyoid and vallecula moved anterosuperiorly, the tongue increased in length transiently and the soft palate became more upright at short term. The pharyngeal airway increased in sagittal dimension both in short and long terms, making the authors indicate mandibular advancement as a treatment approach in sleep apnoea patients.

Karim Mobarak et al (2000)[40] described the long term stability of 80 consecutively treated bilateral sagittal split osteotomy cases through lateral cephalograms taken on 6 occasions. The results showed mandibular setback to be a fairly stable procedure over long term evaluation.

Pushkar Mehra et al (2001)[41] presented the study comparing pharyngeal airway space changes in two groups of high occlusal plane facial morphology patients whose correction included anticlockwise rotation of maxilla mandibular complex. One group (group 1)which underwent double jaw surgery comprising maxillary and mandibular advancement and another group (group 2) which underwent double jaw surgery comprising maxillary advancement and mandibular setback were evaluated with pre and postsurgical lateral cephalograms. The study concluded that group 1 had an increased pharyngeal airway space of 47% near soft palate and 76% near base of the tongue. Whereas in group 2, patients had a decreased airway space of 47% near soft palate and 65% near base of the tongue.

Hence either setback or advancement of mandible has a significant effect in altering pharyngeal airway dimensions.

Karim Mobarak et al (2001)[42] assessed the long term changes in soft tissue profile following mandibular setback osteotomy in 80 consecutive mandibular prognathic patients using lateral cephalograms taken at 6 occasions. The study found males having lesser ratios than women with significant changes in upper lip and chin and also the skeletal relapse in long term had a greater influence on soft tissue profile. The author recommended suitable modifications in prediction software database to allow more accurate treatment simulations.

Liukkonen et al (2002)[43] studied the long term effects of mandibular setback surgery on airway size through digitized pre and postoperative radiographs of 22 individuals with mean age of 30 years. The authors explained that effects of surgery could gradually increase upper airway resistance in individuals with insufficient neuromuscular adaptations and hence cases with larger sagittal discrepancies should be dealt with bimaxillary surgery.

T. Muto et al (2002)[44] measured the lateral cephalograms of 10 normal patients with head posture taken in five different positions (total 50 cephalograms) to obtain a regression equation and compared the relationship of craniocervical angle to the pharyngeal airway space. The authors found a strong correlation between OPT/NSL (craniocervical angle) and C3-Me (third vertebra to Menton distance), concluding that for every 10 degree increase in OPT/NSL or C3-Me, pharyngeal airway space increases by 4mm

Battagel et al (2002)[45] did a radiographic study of 100 Caucasian males of which 50 were non apnoeic snorers and 50 were diagnosed OSA patients. The lateral cephalograms with patients moving from upright to supine position were analyzed and the results showed no significant differences between the two groups. The airway behind soft palate showed maximum constriction of 40%, with area behind tongue showing 20% decrease, minor area increase in soft palate and hyoid dropping and moving anteriorly to maintain its relation with mandible.

Cakarne et al (2003)[46] estimated the values for pharyngeal airway sagittal dimensions in three levels- nasal, oral, and hypopharyngeal – for the young adult patients with class III dentofacial skeletal morphology in comparison with Class I patients with normal dentofacial morphology. Sample size of 32 patients with class III deformity were selected and cephalometric radiographs were taken before and after orthognathic surgery, a paired t test was used to evaluate the difference between class I and Class III pharyngeal airway Sagittal dimensions measurements and statistical analysis revealed a highly significant difference in naso and hypopharyngeal levels. Authors concluded that pre and post operative changes in pharyngeal airway dimensions after bimaxillary surgery showed statistically significant increase in nasopharyngeal airway space, without significant reduction in oral and hypopharyngeal level.

Saitoh (2004)[47] assessed the pharyngeal airway morphology changes over long term in patients who underwent combined orthodontic treatment and mandibular setback surgery through bilateral sagittal split ramus osteotomy. The assessment was done at three stages pretreatment (T1), after 3-6 months of surgery (T2) and after 2 or more years after surgery (T3). He concluded that significant constriction of pharyngeal airway occurred between T1 and T2 but between T2and T3 there was no significant change observed. He also said that there is a tendency for relapse at T3 and attributed it to the normal physiological adaptation of pharyngeal structures to the now stable and improved hard tissue relationships.

Fengshan Chen et al (2005)[48] proposed a mathematical model to predict the pharyngeal airway space changes by studying 23 female adult patients who were treated with combined orthodontic and mandibular setback surgery through BSSO. They analyzed the lateral cephalograms within 6 months before surgery (T1) and 1 to 1.5 years after surgery (T2)and gave the equation as

PAS narrowing = 0.386 - 0.541 ANB (T1 - T2) + 0.253 Co-Gn (T1 - T2) - 0.098 SN-GoGn (T1 - T2), Where,

ANB - Angle formed by point A, Nasion and point B.
Co - Condylion
Gn - Gnathion
SN-GoGn - Mandibular plane

He added that in patients with predisposing factors like obesity and short neck surgery can lead to sleep apnea syndrome.

Kawakami et al (2005)[49] diligently studied the tongue, hyoid and pharyngeal airway in 30 mandibular setback surgery cases, utilizing the digital lateral cephalograms taken at three time intervals (preoperative, one month later and more than one year post operatively). The study showed significant downward movement of hyoid 1 month after surgery but it returned to its original position in later stages thereby reducing the retro lingual airway dimension. The author concludes that pharyngeal airway relative to tongue and hyoid is maintained at short term but gets reduced over longer time period and careful observation is necessary.

Eggensperger et al (2005)[6] gave the treatise about long term changes in hyoid bone and pharyngeal airway size changes after mandibular setback surgery. 12 patients were chosen and reviewed through serial cephalograms taken at 1 week. 6 months, 14 months and after an average of 12 years post operatively. The hyoid bone moved postero inferiorly and ended up 1.6 mm posterior to the original position at long term. The suprahyoid muscles initially adapted to the skeletal changes due to surgery, shortening by 4mm but later correlated with the change in hyoid bone. The lower pharyngeal airway, after the initial decrease, remained almost constant over long term. The middle and upper airway continued to decrease over long term and finally settled at 3mm and 1.5mm lesser respectively.

Guven et al (2005)[50] analyzed the effects of two types of mandibular surgeries on pharyngeal airway and hyoid bone. 30 patients of which 15 treated by sagittal split ramus osteotomy (BSSO) and 15 treated by body osteotomy (BO), were analyzed using lateral cephalograms at early and long term postoperative periods. In both these groups a decrease in pharyngeal airway space was noted early and late. Though hyoid moved posteroinferiorly in early stages, it relapsed to the original anatomic position later. The decrease in airway was less in BO group when compared to BSSO group.

Malkoc et al (2005)[51] evaluated the reproducibility of tongue, hyoid and airway dimensions on standardized lateral cephalograms. The lateral cephalograms were taken for 30 patients, each three times at 30 minutes interval and were analyzed using twelve parameters and subjected it to statistical analysis. The study resulted in no statistically significant differences between these three sets of measurements and he concluded that natural – head - position cephalograms can very reliably used for measuring airway dimensions, tongue and hyoid bone positions.

Oscar Martin et al (2006)[52] assessed the nasopharyngeal soft tissue patterns in 91 patients of Complutense university dental school Madrid, who had ideal occlusion and no history of airway abnormalities or sleeping disorders. The analysis of digitized lateral cephalograms revealed a different nasopharyngeal soft tissue pattern in men and women with men having a larger nasal fossa and adenoidal tissue than women. The length of the nasal fossa significantly correlated with upper airway thickness. The changes in upper airway dimensions were mainly dictated by the upper airway thickness. Cranial base length was significantly related to the nasal fossa length and thickness of lower pharyngeal airway.

Korkmaz Sayinsu et al (2007)[53] aimed at evaluating the measurement error variability between a hand traced conventional lateral cephalogram and a computer traced, scanned and digitized cephalogram. 30 cephalograms for each method were deployed, the scan having a 300 dpi resolution and the software being Dolphin imaging version 9.0, with two operators performing both these processes twice. Statistics showed no appreciable inter or intra operator variability for 95% confidence limits. They concluded that computer software traced, scanned cephalograms does not increase the measurement errors when compared to traditional hand traced cephalograms.

Fengshan Chen et al (2007)[54] conducted a beautiful study of comparison on short and long term changes between skeletal class III patients treated by bilateral sagittal spit osteotomy only and patients treated by combined Lefort one osteotomy and mandibular setback. These patients were analysed at three intervals viz. 6 months before surgery, 3-6 months after surgery and at least 2 years after surgery. The mandibular setback group had significant constriction of oral and hypopharyngeal airway size at short term and long term follow up. Surprisingly the bimaxillary surgery group showed constriction only in short term follow up whereas in long term follow up no significant changes were noted. He suggests that bimaxillary surgery should be performed for skeletal class III patients whenever possible rather than single jaw surgery to prevent pharyngeal airway narrowing a possible predisposing factor for obstructive sleep apnoea.

Toshitaka Muto et al (2008)[55] gave another equation utilizing linear regression analysis for predicting airway space in mandibular setback surgery patients. The distance between third cervical vertebra and Menton (C3 – Me) was calculated in 29 female adults using lateral cephalograms before and 1 year after treatment. The equation used is $y = -21.105 + 0.402x$ (y: PAS; x: C3-Me; $r = 0.854$). Comparing the predicted value with conventionally measured value had more or less the same average with difference being ± 1.5mm.

Kitagawara et al (2008)[56] determined the pharyngeal morphology changes and respiratory function during sleep in 17 adult skeletal class III patients after bilateral sagittal split ramus osteotomy. Pharyngeal airway was analyzed using lateral cephalograms and pulse oximetry was used to measure the arterial oxygen saturation (SpO2) during sleep. No significant changes were noted in the oropharyngeal region but hyoid was found to be inferiorly positioned. Although decreased oxygen saturation was noted during sleep just after surgery, the patients improved 1 month after surgery. However the author warns that careful follow up is needed in potential sleep disorder patients.

T. Muto et al (2008)[57] evaluated the pharyngeal airway and soft palate changes in 49 women after bilateral sagittal split osteotomy through radiographs obtained at 2 intervals. The corrected data using regression equation showed cranial hyper flexion, decreased SNB angle by 3.9 degrees, decreased pharyngeal airway by 2.6 mm at retro palatal and 4.0mm at retro lingual region and increased soft palate thickness by 3.2mm. The study showed that setback surgery markedly decreases pharyngeal airway space soft palate morphology.

Marsan et al (2008)[58] examined the lateral cephalograms of 25 Turkish female mandibular prognathic patients treated with combined orthodontic and mandibular setback surgery through BSSO. Assessment was done before and 1.5 years after surgery. The pharyngeal airway reduced and soft palate length was increased with significant change in lower facial morphology. The author owes these changes to the normal physiological adaptation to the improved hard tissue relationships after surgery.

Chang-Min Sheng et al (2009)[59] conducted the research on developmental Changes in pharyngeal airway depth and hyoid bone position from childhood to young adulthood. They analyzed the lateral cephalograms of 239 normal Taiwanese who were divided into three groups based on age. In both the genders, the pharyngeal airway depth increased from mixed to permanent dentition stage. Sexual dimorphism was found in pharyngeal airway depth. The hyoid bone positions were different in permanent dentition with association to mandibular morphology in vertical plane.

Aboudara et al (2009)[60] compared the efficacy of airway space deduction between a conventional lateral cephalogram and a three dimensional cone beam computed tomography. Citing the previous articles which have questioned the reliability of lateral cephalograms, he conducted this study to validate their claim if it were true. The study resulted in a volumetric error range of 0% to 5% in cone beam computed tomography and a moderately high correlation between airway volume and area. However there was considerable variability in the airway volumes for similar airway in lateral cephalograms. He concluded that cone beam computed tomography to be more effective than lateral cephalograms.

Grauer et al (2009)[61] assessed the airway shape and volume in 62 non growing patients who belonged to different dentofacial skeletal pattern using computerized cone beam tomography. Instead of relying on linear measurements this study employed virtual three dimensional surface models to deduce the airway. The inferior component of airway had a significant relationship with sagittal jaw relation and so was between airway volume and size of the face. Incidentally there was no significant relationship to the vertical proportions. The class II patients had a forwardly inclined airway while the class III had a more vertically oriented one. He concluded that airway volume rather than shape differs with different vertical jaw relationships and for sagittal relationships they both vary.

Toru Kitahara et al (2009)[62] hypothetically tested the stability of hard and soft tissues after subjecting 45 female adult patients to either intraoral vertical osteotomy or sagittal split ramus osteotomy. The lateral cephalograms were analyzed at three standard time intervals. While the pretreatment evaluation showed no significant differences in these two groups, the post treatment evaluation showed the mandible being positioned more posteriorly in IVRO group. The soft tissue Menton was located more backward too. The authors concluded that patients treated with IVRO surgery had a more posterior relation of mandible compared to SSRO and advised to take this feature in consideration while planning treatment.

Degerliyurt et al (2009)[63] experimented the possibility of sexual dimorphism in orthognathic surgery patients treated through mandibular setback or bimaxillary surgery using computed tomography (CT). 34 women and 13 men with skeletal class III deformities were screened pre and post operatively with CT and the results showed decreased anteroposterior and cross sectional dimension of pharyngeal airway in setback group in both sexes. The bimaxillary group had only the mid sagittal dimension reduced. The statistical significance was lacking for both these groups in anteroposterior dimension. The author highlighted that no sexual dimorphism is present in airway relating to orthognathic surgery.

Toru Kitahara et al (2010)[64] had the purpose of examining 46 Japanese women having skeletal class III malocclusion for changes in pharyngeal airway space stability and positional change of hyoid bone. Of the 46 subjects, 25 underwent single jaw mandibular setback surgery through bilateral sagittal split ramus osteotomy (SSRO) and 21 underwent bilateral intraoral vertical ramus osteotomy (IVRO). The control group comprised of 30 women volunteers who had normal occlusion. The assessment was done at 3 stages; preoperative, immediately after surgery and after postsurgical orthodontic treatment. To begin with, all the class III subjects had a wider pharyngeal space compared to control group which was significantly reduced after setback surgery. In the SSRO group the hyoid moved in an upward and forward direction with lower border of pharyngeal airway following it. But in IVRO group, the hyoid bone and the anterior border of airway moved in backward direction. The authors concluded that narrowing of airway occurs post surgically in IVRO group but occurs during surgery in SSRO group. An added note is that the postsurgical airway of class III group is comparable to the pre-treatment airway of class I control group.

Ashok Kumar Jena, Satinder Pal Singh (2010)[65] studied the sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage in 91 patients classified into three groups as normal, prognathic and retrognathic mandible. Their study showed the length of the soft palate significantly smaller in mandibular prognathism subjects than in subjects with mandibular retrognathism. The thickness of the soft palate was significantly greater among subjects with mandibular prognathism than in subjects with normal and retrognathic mandibular development. The sagittal mandibular development had no effect on the dimensions of the nasopharyngeal and hypopharyngeal airway passage.

Zhe Zhong et al (2010)[66] evaluated the Upper Airway among different Skeletal Craniofacial Patterns in Non-snoring Chinese Children. Two groups of subjects were studied. A group of subjects with a normodivergent facial pattern was divided into three subgroups according to ANB angle (Class I, II, or III). A second group of subjects with a normal sagittal facial pattern was divided into three subgroups according to the FH-MP angle (low angle, normal angle, or high angle) In the group of subjects with a normodivergent facial pattern, a significant tendency for reduced upper airway dimension in the inferior part (palatopharyngeal and hypopharynx) was found in the Class III, Class I, and Class II subgroups, in that order. In the group of subjects with a normal sagittal facial pattern, the superior part of the airway (nasopharyngeal and palatopharyngeal) decreased with increasing mandibular plane angle.

Rodrigues et al (2010)[67] compared the validity of digitized cephalograms through indirect method with direct digital radiographs. They obtained the indirect digital radiographs through two digital cameras at a fixed distance of 25cm and 60 cm respectively and also through a scanner and compared them with the direct digital radiographs. The images from the scanner showed clinically insignificant differences. The images from camera placed at 60 cm were clinically acceptable while at 25cm the images were largely distorted.

Manish Valiathan (2010)[68] compared the changes in oropharyngeal volume after extraction vs non extraction treatment using cone beam computed tomography in twenty patients. The patients were matched for age, gender, body mass index and other variables. While the dental parameters showed significant changes from pretreatment to post treatment there were no significant changes in oropharyngeal airway volume in extraction and non-extraction patients.

Sooshin Hwang et al (2010)[69] deliberated the hyoid, tongue, pharyngeal airway and head posture changes in 60 class III patients treated with mandibular setback surgery through intraoral vertical ramus osteotomy (IVRO). Of these 45 patients had an additional Lefort I osteotomy performed. Lateral cephalograms were assessed at 4 time periods. The results showed hyoid moving inferoposteriorly and tongue moving posteriorly. The hyoid relapsed anterosuperiorly during observation. There was significant constriction of pharyngeal airway and remained so even during the observation period with Lefort I osteotomy having no significant effect on airway. Craniocervical hyperflexion was also noted. The author calls for close monitoring of airway space post surgery through IVRO.

Austin Phoenix et al (2011)[70] examined the hyoid bone changes in adolescents treated with rapid maxillary expansion by measuring the hyoid bone to mandibular plane distance using lateral and frontal cephalograms. The sample consisted of 138 subjects treated with RME and 148 control subjects treated without RME. The RME groups had decreased lateronasal width, inter premolar width and increased hyoid to mandibular plane distance when compared to non RME group to begin with. However there were statistically significant changes in those parameters after treatment. The tongue length did not show any significant changes through treatment in all these patients.

Kyung-Min Oh et al (2011)[71] studied the form and size of the pharyngeal airways in Preadolescents among various skeletal patterns, using cone-beam computed tomography. The inclination and the volume of the pharyngeal airway were measured and compared with craniocervical angles and cephalometric variables. The study concluded that Children with Class II malocclusion have more backward orientation and smaller volume of the pharyngeal airway than do children with Class I and III malocclusion. Inclination of the oropharyngeal airway might be a key factor in determining the form of the entire pharyngeal airway and is related to head posture

Yoshihiko Takemoto et al (2011)[72] analysed the pharyngeal airway in 25 prognathic girls and compared it with 15 girls with normal occlusion using lateral cephalograms. The study showed that prognathic girls had a significantly wider lower pharyngeal airway when compared with control group. The mandible in prognathic girls tends to be positioned more anteriorly, resulting in a wider lower pharyngeal airway.

Sara M. Wolfe et al (2011)[73] conducted a serial cephalometric study on Craniofacial growth of Class III subjects six to sixteen years of age at three time points ,6–8, 10–12, and 14–16 years of age. She compared the Class I subjects with the Class III subjects and found that class III subjects had significantly larger mandibular plane angles, gonial angles, mandibular ramus heights and corpus length, and SNB angles. Maxillary lengths and ANB angles were significantly smaller and remained smaller in Class III subjects Lower face height, maxillary-mandibular differential, and mandibular body length were also significantly larger and increased significantly more between 6 and 16 years of age in Class III subjects. She concluded that AP maxillomandibular relationship of Class III subjects worsens over time. AP discrepancies are primarily due to excessive mandibular growth, which produces a protrusive, hyperdivergent phenotype.

Ashok Kumar Jena, Ritu Duggal (2011)[74] analysed the hyoid bone position in subjects with different vertical jaw dysplasias 79 north Indian adults with age range of 15 to 25 years were selected and were divided into three groups based on their FMA. The cephalometric study concluded that anteroposterior position of hyoid bone was significantly forward in subjects with low FMA and also the axial inclination of hyoid bone closely followed the axial inclination of mandible.

Hakan, Palamo (2011)[75] evaluated the nasal passage and oropharyngeal volumes for different dentofacial patterns by dividing 140 patients into class I class II and class III groups who were further subdivided based on SNA and SNB angles. The study deduced that class II patients had a significantly reduced oropharyngeal volume when compared to the class I and class III groups and attributed this to the retruded mandibular position.

Kirsi Pirila¨-Parkkinen et al (2011)[76] tested the capability of two-dimensional lateral cephalogram in recognizing pharyngeal obstruction when compared with the three-dimensional magnetic resonance imaging (MRI) and clinical observation of tonsillar size. The study participants were 36 prepubertal children (19 male, 17 female) with sleep-disordered breathing diagnosed by nocturnal polygraphy. Nasopharyngeal and retropalatal cephalometric variables had a significant positive correlation with the MRI findings. The findings confirm that the lateral cephalogram is a valid method for measuring dimensions of the nasopharyngeal and retropalatal region

Jakobsone et al (2011)[77] studied the upper airway changes in skeletal class III patients who were treated with combined maxillary advancement and mandibular setback. The lateral cephalogram study of 76 patients at three different time intervals were analyzed to conclude that clinically significant maxillary advancement (≥ 2mm) showed significant increase in airway at the level of nasopharynx. When the maxilla was not advanced to the significant level a decrease of airway at oropharyngel level was noted. He added that significant maxillary advancement increases airway at nasopharyngeal level which to some extent compensate for the decrease in airway caused by mandibular setback

Halise Ayedemir et al (2012)[78] determined the effects of different surgical techniques on the pharyngeal airway in 48 adult class III patients of which 32 were treated with bimaxillary surgery, 7 with mandibular setback and 9 with maxillary advancement. Cephalometric records were taken at three time intervals before treatment, after surgery and at the end of treatment. There were no differences in hyoid position or craniocervical posture. They concluded that mandibular setback surgery caused the most narrowing effect on pharyngeal airway and maxillary advancement and bimaxillary surgery negated this effect by providing widening of nasopharyngeal airway.

Claudino et al (2013)[79] studied the possibility of a relation between facial skeletal pattern and pharyngeal airway volume using cone beam computerized tomography. The study concluded that class II group had significantly reduced lower pharyngeal areas when compared to the class I and class III group. Also with increased ANB angle the tendency for decreased airway volume was noted. However the upper airway volume did not show any correlation to the facial skeletal pattern.

MATERIALS AND METHODS

The samples for this study were chosen from the record archives of the Department of Orthodontics and Dentofacial Orthopaedics, Tamilnadu Government Dental College and Hospital, Chennai. Standardized lateral cephalograms of 20 patients diagnosed with Class III malocclusion due to prognathic mandible who underwent combined orthodontic and orthognathic surgical procedures between years 2009 and 2012 were analyzed. All these patients underwent presurgical orthodontics followed by mandibular setback surgery through Bilateral Sagittal Split ramus Osteotomy (BSSO) to correct mandibular prognathism and postsurgical orthodontics for final settling of occlusion.

Standardized lateral cephalograms of 20 patients diagnosed with class I malocclusion were taken as control group and analyzed. A good visibility of hyoid bone was ensured in all these lateral cephalograms. The age range was between 18 and 25 years. Inclusion and exclusion criteria were analyzed from clinical records of these patients.

The study has been undertaken after obtaining permission from the Institutional Ethical Committee to use the treatment records.

METHODOLOGY

All the lateral cephalograms used in this study had been taken in the Department Of Oral Medicine Diagnosis and Radiology, Tamilnadu Government Dental College and Hospital, Chennai, with the same cephalostat machine (PLANMECA PM 2002 CC PROLINE) with parameters of 70kvp, 30mA, from a fixed distance of 60 inches from the X ray source to the patients' midsagittal plane, where the usual standard protocol of positioning the patients in Natural head position, teeth in occlusion, lips relaxed and Frankfurt Horizontal plane parallel to the floor is followed.

Three cephalograms taken at the start of presurgical orthodontic treatment (T1), immediately after surgery (T2) and after completion of postsurgical orthodontic treatment (T3) were used for the study.

All the cephalograms were standardized using transparent grid of 1mm accuracy and using the software Adobe

Photoshop elements version 13 (Adobe systems, San Jose, CA, US). All the cephalograms were scanned with HP 3545 (Hewlett – Packard, Palo Alto, CA, US) 24 bit flatbed scanner with 1200 dpi resolution and digitized.

The scanned images were analyzed using the cephalomeric software program AX CEPH Version 2.3.0.74 (Audax d.o.o. Ljubljana, Slovenia). The process of digitization, land mark identification and cephalometric analysis were done by the same investigator to eliminate inter examiner variability. The measurements of the coordinates were completed twice on two separate occasions, three weeks apart by the same investigator.

INCLUSION CRITERIA FOR CLASS III GROUP

1. Patients with skeletal class III malocclusion attributable to prognathic mandible with or without mild maxillary retrognathism
2. ANB Angle of 0 to – 14 degrees
3. Patients treated for mandibular prognathism through Bilateral Sagittal Split ramus Osteotomy (BSSO)
4. No obvious hyperplasia of tonsils or adenoids on cephalograms

5. Good soft and hard tissue outlines with good visibility of the hyoid bone and teeth in full occlusion, lips resting in natural position in the radiographs.

INCLUSION CRITERIA FOR CONTROL GROUP

1. Patients with skeletal class I malocclusion attributable to orthognathic maxilla and mandible.
2. ANB angle of 2 to 4 degrees
3. Average BMI and growth pattern
4. No obvious hyperplasia of tonsils or adenoids on cephalograms
5. Good soft and hard tissue outlines with good visibility of the hyoid bone and teeth in full occlusion, lips resting in natural position in the radiographs.

EXCLUSION CRITERIA

1. Skeletal class III patients with moderate to severe maxillary retrognathism
2. Patients treated for mandibular prognathism through bijaw surgery
3. Mandibular setback by Intra oral Vertical Ramus Osteotomy (IVRO) or Extra oral Vertical Ramus Osteotomy (EVRO) surgeries

4. Patients with craniofacial anomalies
5. Patients with previous history of trauma
6. Patients with previous history of orthodontic treatment or orthognathic surgery
7. History of abnormal oral habits
8. History of nasal or respiratory obstructions, diseases and allergic conditions.

CEPHALOMETRIC EVALUATION

The pharynx is analyzed at three segments namely nasopharynx, oropharynx and hypopharynx. Sella was used as the origin, and a horizontal line passing through Sella parallel to the Frankfurt horizontal plane was used as the x-coordinate in the analysis. A line perpendicular to the x-axis passing through Sella was defined as the y-coordinate. Four variables, three linear and one angular for pharynx and three linear variables for hyoid bone were selected and analyzed.

TABLE 1: CEPHALOMETRIC LANDMARKS USED IN THIS STUDY:

N	Nasion
S	Sella
Po	Porion
Or	Orbitale
ANS	Anterior Nasal Spine
PNS	Posterior Nasal Spine
PNSp	Point of intersection of ANS-PNS line with a line from H perpendicular to ANS-PNS line
A	Point A
B	Point B
UV	The most adjacent point on the soft palate to the posterior pharyngeal wall
UT	The lowest point on the soft palate
PP1	The point of intersection of the line joining ANS and PNS and the posterior pharyngeal wall
PP2	The most adjacent point from the uvula to the posterior pharyngeal Wall
PP3	The most adjacent point from the back of the tongue to the posterior pharyngeal wall
Tb	The most posterior point of the back of the tongue;

H	The most superior and anterior point of the hyoid bone
Cv2ip	The inferoposterior point of the second cervical vertebrae
Cv2tg	The tangent point of the superoposterior extremity of the second cervical vertebrae
RGN	The most protrusive point of retrognathion
Cv3ia	The most anteroinferior point of the third vertebra

CEPHALOMETRIC MEASUREMENTS USED:

TABLE 2: MEASUREMENTS FOR PHARYNGEAL AIRWAY PARAMETERS:

OPT/NSL, degrees	Craniocervical angulation at the uppermost part of the cervical spine
PP1 – PNS, mm	The distance from PNS to PP1, representing the nasopharyngeal airway space
PP2 – UV, mm	The distance from UV to PP2, representing the oropharyngeal airway space
PP3 – Tb, mm	The shortest distance between the base of the tongue and the posterior pharyngeal wall

TABLE 3: MEASUREMENTS FOR HYOID BONE PARAMETERS:

PNSp – H, mm	The vertical distance from the palatal plane to the anterosuperior tip of the Hyoid bone.
H – RGN, mm	Distance between H and RGN, representing the horizontal distance from anterosuperior tip of the Hyoid bone to the most posterior point on the mandibular symphysis.
Cv3ia – H, mm	Distance between C3 and H, representing the horizontal distance from inferoanterior point of the third cervical vertebrae to the anterosuperior tip of the hyoid bone.

TABLE 4: MEASUREMENTS FOR DENTOFACIAL PARAMETERS:

ANB, degrees	Angle between point A and B at Nasion
FMA, degrees	Angle between the mandibular plane and the FH plane

STATISTICAL ANALYSIS

The data gathered was computed using the software Microsoft™ Office Excel spreadsheet. The computed data was subjected to statistical analysis using the software IBM™ Statistical Package for Social Sciences (SPSS) Version 22. Intra group differences between T1, T2 and T3 of the class III group were analyzed using paired Students *t* test. Inter group differences between the control group and class III group were analyzed using Independent Samples Test.

The mean values measured on each occasion were compared by using paired t tests to detect any systematic errors. The error variance was calculated according to Dahlberg's formula[11].

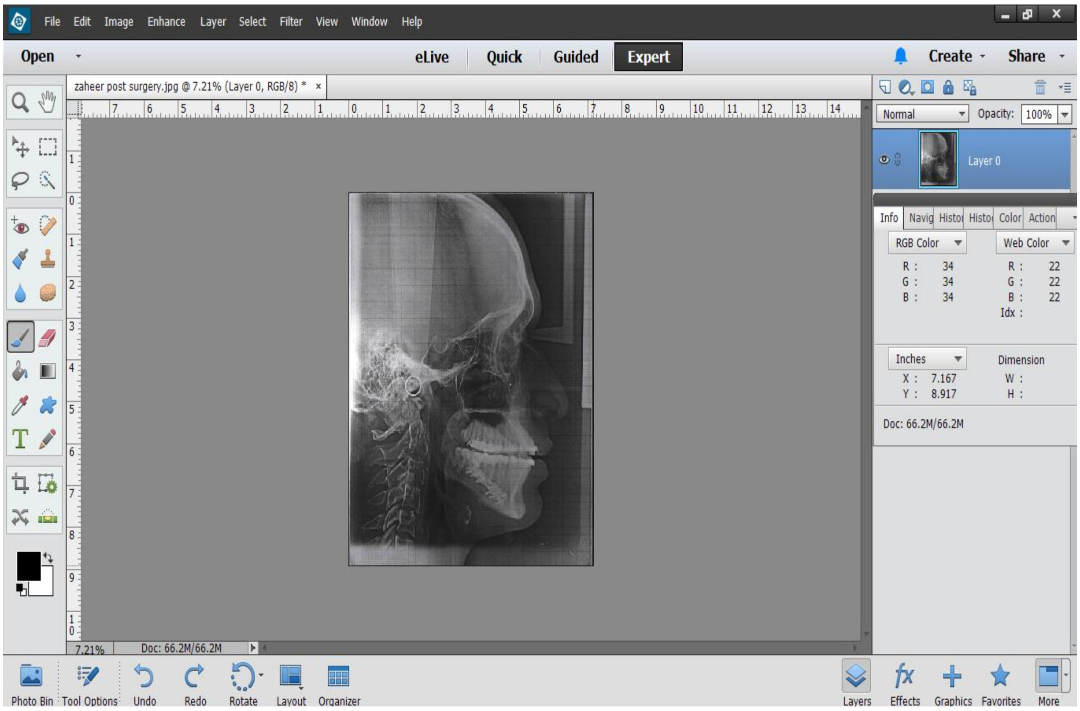
P values less than 0.05 were considered statistically significant.

1. CEPHALOSTAT

2. HP 3545 MFP SCANNER

3. STANDARDIZATION WITH TRANSPARENT GRID

4. STANDARDIZATION WITH ADOBE PHOTOSHOP



zaheer post surgery.jpg @ 7.21% (Layer 0, RGB/8) *

Normal

Opacity: 100%

Layer 0

RGB Color: R: 34 G: 34 B: 34

Web Color: R: 22 G: 22 B: 22 Idx:

Inches: X: 7.167 Y: 8.917

Dimension: W: H:

Doc: 66.2M/66.2M

7.21%

5. CEPHALOMETRIC SOFTWARE

Ax.CEPH
Cephalometric X-ray Analysis Software
Ver 2.3.0.74

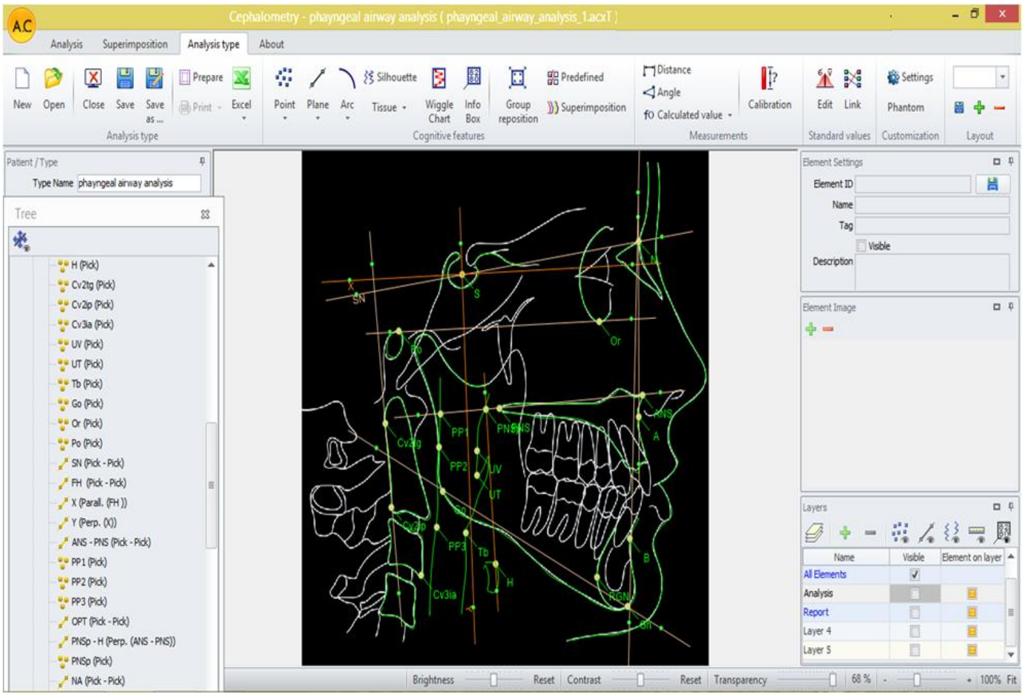
AUDAX d.o.o., Tehnološki park 18
SI-1000, Ljubljana, Slovenia

www.axceph.com

According to 93/42/EEC

Main GUI initialization

6. CEPHALOMETRIC ANALYSIS – LANDMARKS AND PARAMETERS

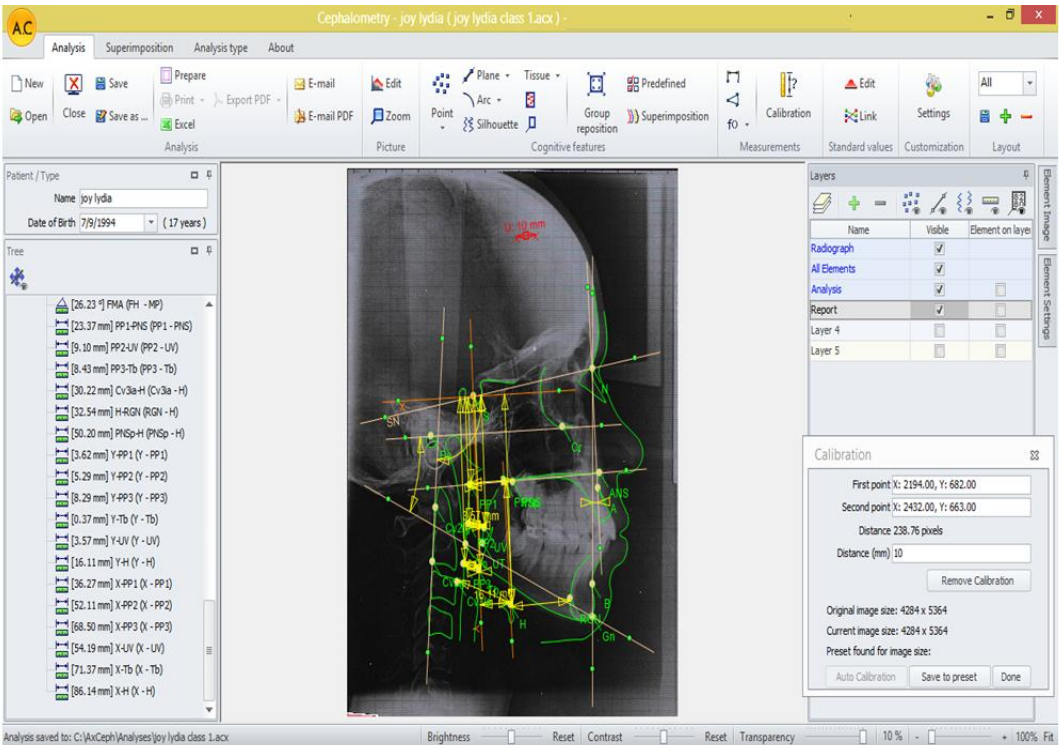


Cephalometry - phayngeal airway analysis (phayngeal_airway_analysis_1.acxT)

Patient / Type
Type Name: phayngeal airway analysis

Tree
- H (Pick)
- Cv2tg (Pick)
- Cv2ip (Pick)
- Cv3ia (Pick)
- UV (Pick)
- UT (Pick)
- Tb (Pick)
- Go (Pick)
- Or (Pick)
- Po (Pick)
- SN (Pick - Pick)
- FH (Pick - Pick)
- X (Parall. (FH))
- Y (Perp. (X))
- ANS - PNS (Pick - Pick)
- PP1 (Pick)
- PP2 (Pick)
- PP3 (Pick)
- OPT (Pick - Pick)
- PNSp - H (Perp. (ANS - PNS))
- PNSp (Pick)
- NA (Pick - Pick)

7. DIGITIZED CEPHALOMETRIC TRACING CLASS I – CONTROL GROUP



Patient / Type
Name: joy lydia
Date of Birth: 7/9/1994 (17 years)

Tree
[26.23 °] FMA (FH - MP)
[23.37 mm] PP1-PNS (PP1 - PNS)
[9.10 mm] PP2-UV (PP2 - UV)
[8.43 mm] PP3-Tb (PP3 - Tb)
[30.22 mm] Cv3ia-H (Cv3ia - H)
[32.54 mm] H-RGN (RGN - H)
[50.20 mm] PNSp-H (PNSp - H)
[3.62 mm] Y-PP1 (Y - PP1)
[5.29 mm] Y-PP2 (Y - PP2)
[8.29 mm] Y-PP3 (Y - PP3)
[0.37 mm] Y-Tb (Y - Tb)
[3.57 mm] Y-UV (Y - UV)
[16.11 mm] Y-H (Y - H)
[36.27 mm] X-PP1 (X - PP1)
[52.11 mm] X-PP2 (X - PP2)
[68.50 mm] X-PP3 (X - PP3)
[54.19 mm] X-UV (X - UV)
[71.37 mm] X-Tb (X - Tb)
[86.14 mm] X-H (X - H)

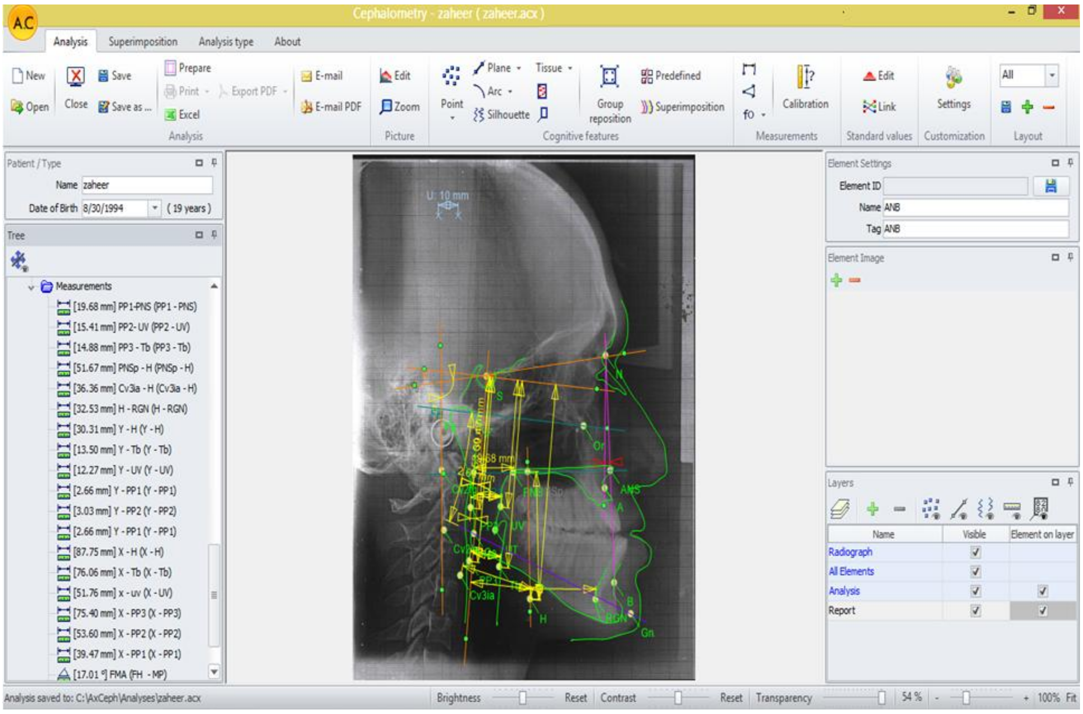
Layers

Name	Visible	Element on layer
Radiograph	☑	
All Elements	☑	
Analysis	☑	☐
Report	☑	☐
Layer 4	☐	☐
Layer 5	☐	☐

Calibration
First point: X: 2194.00, Y: 682.00
Second point: X: 2432.00, Y: 663.00
Distance 238.76 pixels
Distance (mm): 10
Remove Calibration
Original image size: 4284 x 5364
Current image size: 4284 x 5364
Preset found for image size:
Auto Calibration | Save to preset | Done

Analysis saved to: C:\AxCeph\Analyses\joy lydia class 1.acx

8. DIGITIZED CEPHALOMETRIC TRACING – CLASS III PRETREATMENT (T1)



Patient / Type
Name: zaheer
Date of Birth: 8/30/1994 (19 years)

Tree
Measurements
[19.68 mm] PP1-PNS (PP1 - PNS)
[15.41 mm] PP2- UV (PP2 - UV)
[14.88 mm] PP3 - Tb (PP3 - Tb)
[51.67 mm] PNSp - H (PNSp - H)
[36.36 mm] Cv3ia - H (Cv3ia - H)
[32.53 mm] H - RGN (H - RGN)
[30.31 mm] Y - H (Y - H)
[13.50 mm] Y - Tb (Y - Tb)
[12.27 mm] Y - UV (Y - UV)
[2.66 mm] Y - PP1 (Y - PP1)
[3.03 mm] Y - PP2 (Y - PP2)
[2.66 mm] Y - PP1 (Y - PP1)
[87.75 mm] X - H (X - H)
[76.06 mm] X - Tb (X - Tb)
[51.76 mm] x - uv (X - UV)
[75.40 mm] X - PP3 (X - PP3)
[53.60 mm] X - PP2 (X - PP2)
[39.47 mm] X - PP1 (X - PP1)
[17.01 °] FMA (FH - MP)

Element Settings
Element ID:
Name: ANB
Tag: ANB

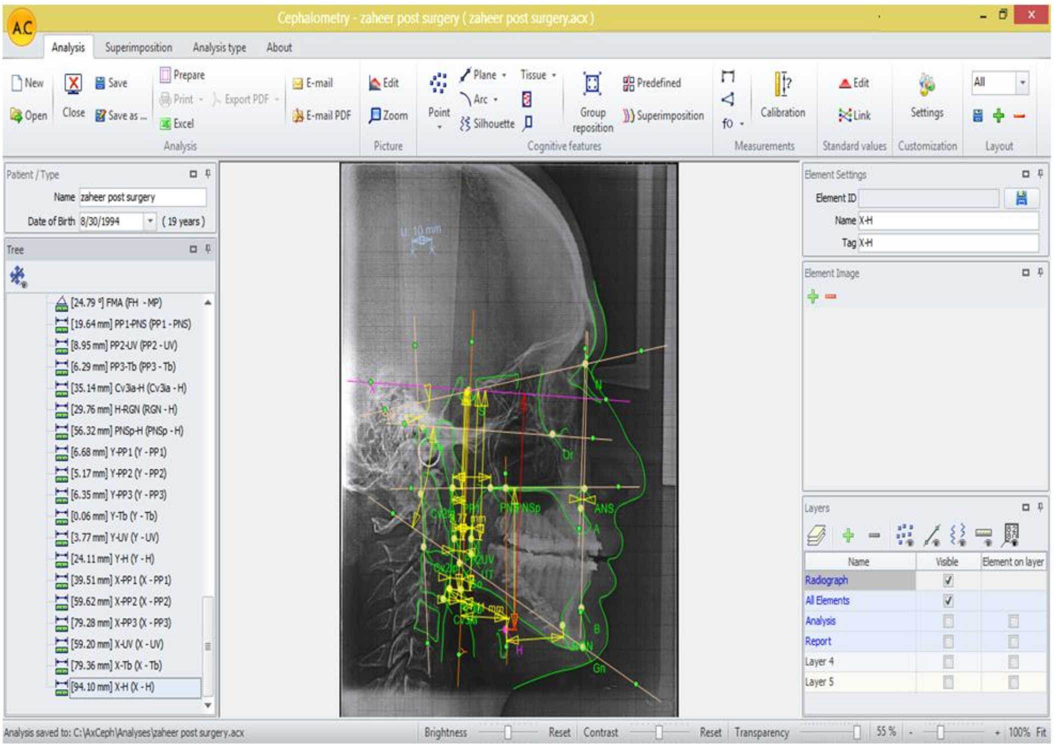
Element Image

Layers

Name	Visible	Element on layer
Radiograph	☑	
All Elements	☑	
Analysis	☑	☑
Report	☑	☑

Analysis saved to: C:\AxCeph\Analyses\zaheer.acx

9. DIGITIZED CEPHALOMETRIC TRACING - CLASS III POST SURGERY (T2)



Patient / Type

Name: zaheer post surgery

Date of Birth: 8/30/1994 (19 years)

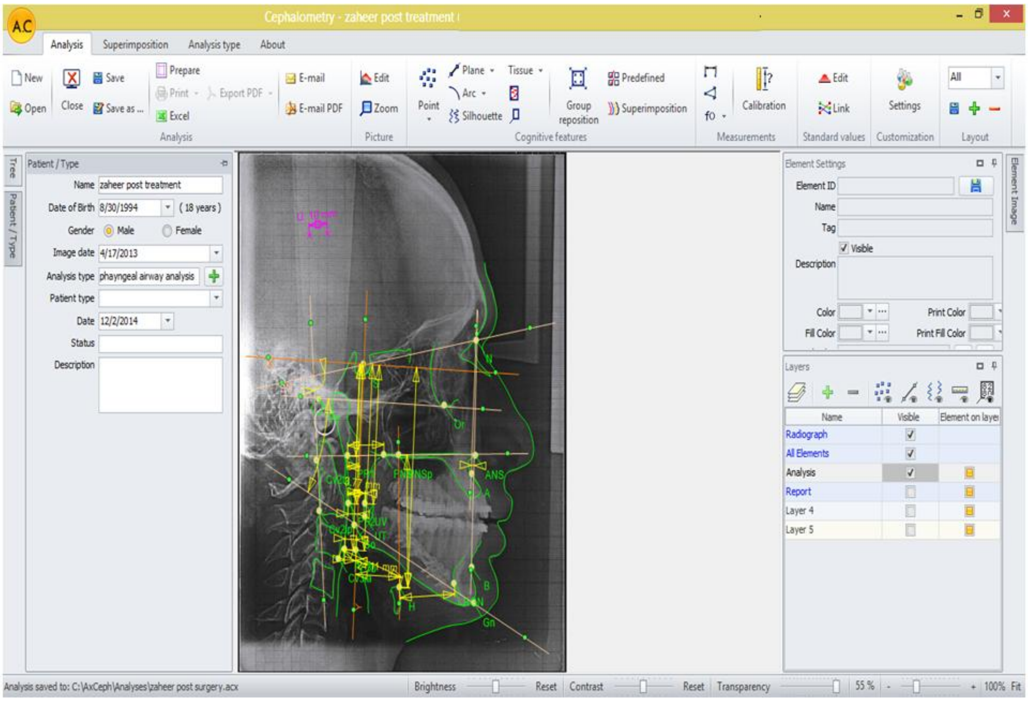
[24.79 °] FMA (FH - MP)
[19.64 mm] PP1-PNS (PP1 - PNS)
[8.95 mm] PP2-UV (PP2 - UV)
[6.29 mm] PP3-Tb (PP3 - Tb)
[35.14 mm] Cv3ia-H (Cv3ia - H)
[29.76 mm] H-RGN (RGN - H)
[56.32 mm] PNSp-H (PNSp - H)
[6.68 mm] Y-PP1 (Y - PP1)
[5.17 mm] Y-PP2 (Y - PP2)
[6.35 mm] Y-PP3 (Y - PP3)
[0.06 mm] Y-Tb (Y - Tb)
[3.77 mm] Y-UV (Y - UV)
[24.11 mm] Y-H (Y - H)
[39.51 mm] X-PP1 (X - PP1)
[59.62 mm] X-PP2 (X - PP2)
[79.28 mm] X-PP3 (X - PP3)
[59.20 mm] X-UV (X - UV)
[79.36 mm] X-Tb (X - Tb)
[94.10 mm] X-H (X - H)

Element Settings: Name X-H, Tag X-H

Name	Visible	Element on layer
Radiograph	☑	
All Elements	☑	
Analysis	☐	☐
Report	☐	☐
Layer 4	☐	☐
Layer 5	☐	☐

Analysis saved to: C:\AxCeph\Analyses\zaheer post surgery.acx

10. DIGITIZED CEPHALOMETRIC TRACING - CLASS III POST TREATMENT (T3)



Patient / Type

Name: zaheer post treatment

Date of Birth: 8/30/1994 (18 years)

Gender: ● Male ○ Female

Image date: 4/17/2013

Analysis type: phayngeal airway analysis

Patient type:

Date: 12/2/2014

Status:

Description:

Element Settings: ☑ Visible

Name	Visible	Element on layer
Radiograph	☑	
All Elements	☑	
Analysis	☑	☐
Report	☐	☐
Layer 4	☐	☐
Layer 5	☐	☐

Analysis saved to: C:\AxCeph\Analyses\zaheer post surgery.acx

TABLE 5: DISTRIBUTION OF STUDY SUBJECTS BASED ON GENDER

GENDER	CONTROL GROUP (n=20)	CLASS III GROUP (n=20)
MALE	9	11
FEMALE	8	12
Fisher`s Exact Test	P Value: 1.000	

DISTRIBUTION OF STUDY SUBJECTS BASED ON GENDER

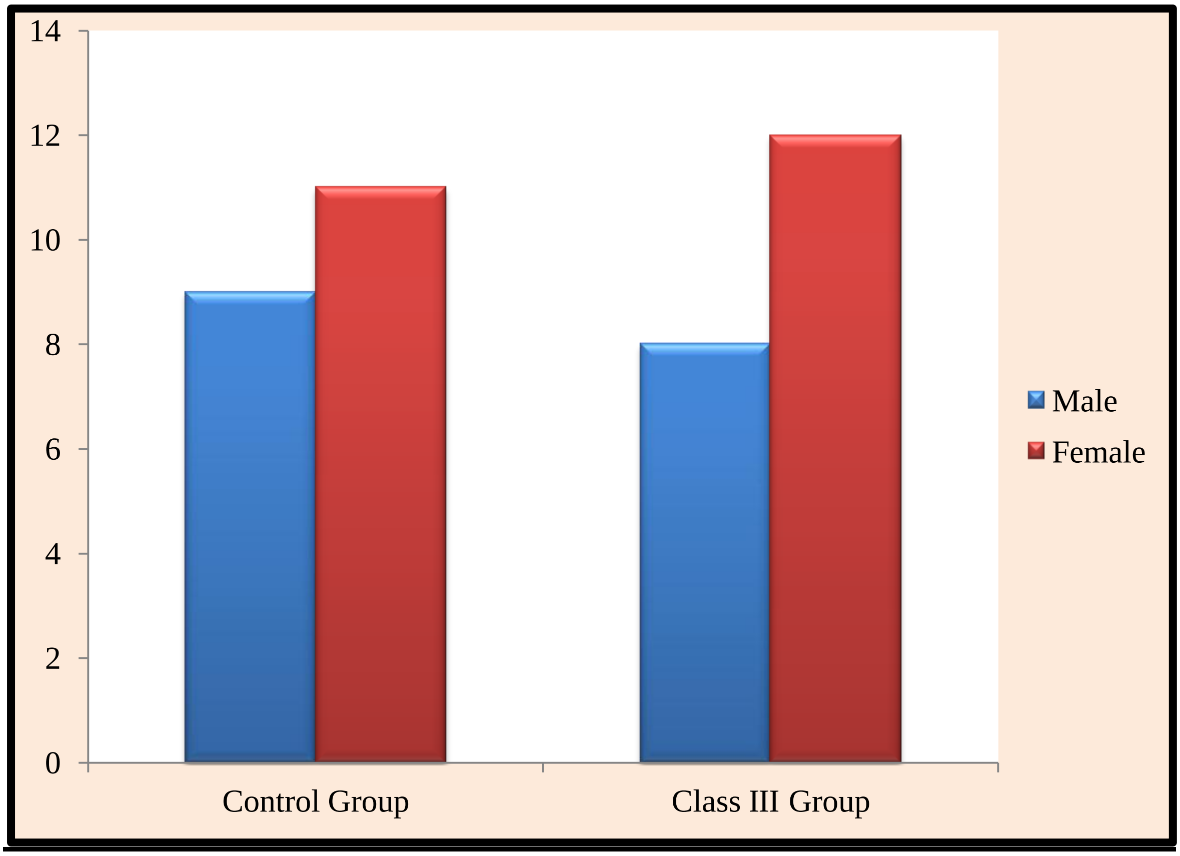


TABLE 6: DISTRIBUTION OF STUDY SUBJECTS BASED ON AGE

GROUP	MEAN AGE	SD	F VALUE	P VALUE
CONTROL (n=20)	22.0900	1.89011	.299	.740
CLASS III (n=20)	22.2950	1.99195		

TABLE 7: DISTRIBUTION OF STUDY SUBJECTS BASED ON BODY MASS INDEX

GROUP	MEAN BMI	SD	F VALUE	P VALUE
CONTROL (n=20)	21.0050	.97951	1.867	**.834**
CLASS III (n=20)	21.0815	1.28909		

DISTRIBUTION OF STUDY SUBJECTS BASED ON AGE & BODY MASS INDEX

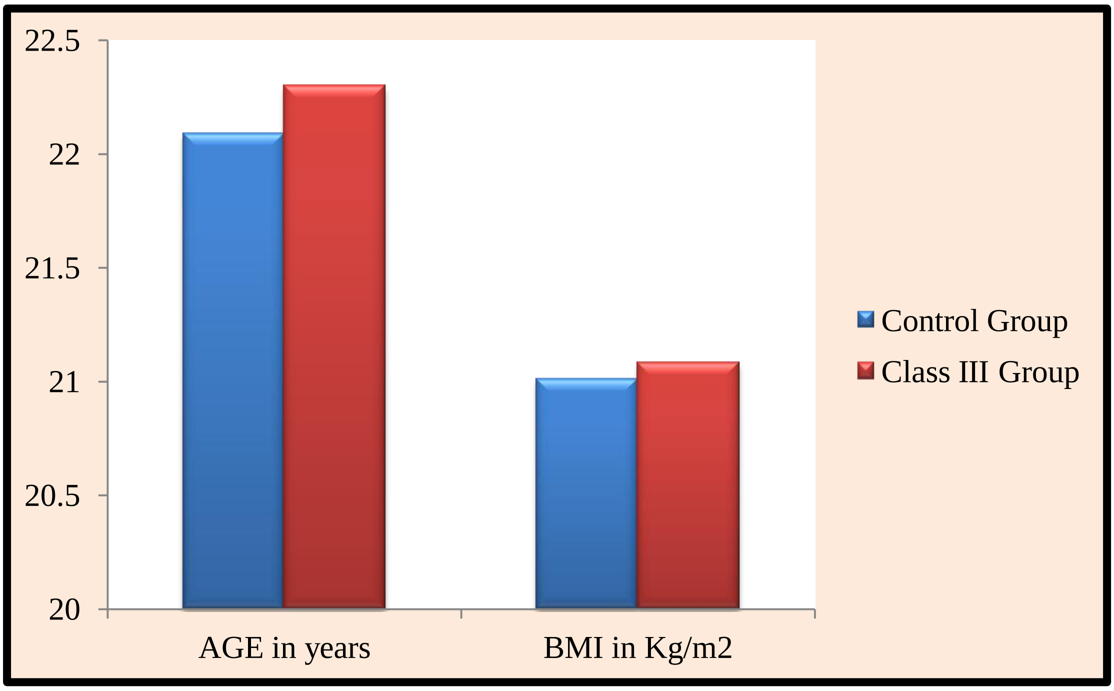


TABLE 8: SUMMARY OF CLASS III TREATMENT

TREATMENT PHASES	CLASS III (n=20)	
	MEAN	SD
Duration of presurgical orthodontic treatment, months	15.9600	1.30562
Average age at surgery, years	20.3450	.69090
Average amount of mandibular setback at T2, mm	7.3250	1.16749
Average amount of mandibular setback at T3, mm	6.8000	.98995
Duration of maxillomandibular fixation, days	14.4050	1.15233
Duration of postsurgical orthodontic treatment, months	12.3400	1.23519
Duration of overall orthodontic treatment, months	27.1200	1.46381

TABLE 9: ASSESSMENT OF METHOD ERROR IN X COORDINATE

LANDMARK	DAHLBERG AGREEMENT	PAIRED T TEST (P VALUE)
H	0.750	0.288
PP1	0.635	0.268
PP2	0.895	0.352
PP3	0.770	0.299
Tb	0.997	0.247
UV	0.587	0.151
UT	0.526	0.197
Cv2ip	0.674	0.143
Cv2tg	0.526	0.309
Cv3ia	0.684	0.122

TABLE 10: ASSESSMENT OF METHOD ERROR IN Y COORDINATE

LANDMARK	DAHLBERG AGREEMENT	PAIRED T TEST (P VALUE)
H	0.295	0.270
PP1	0.630	0.665
PP2	0.427	0.141
PP3	0.630	0.192
Tb	0.850	0.193
UV	0.671	0.242
UT	0.538	0.291
Cv2ip	0.580	0.272
Cv2tg	0.947	0.263
Cv3ia	0.540	0.154

TABLE 11: COMPARISON OF DENTOFACIAL PARAMETERS AT THREE STAGES OF TREATMENT IN CLASS III

PAIRED *t* TEST

PARAMETER (n=20)	T1		T2		T1-T2 P value	T3		T2-T3 P value
	MEAN	SD	MEAN	SD		MEAN	SD	
SNB°	85.7000	1.37075	80.8950	1.60081	.0001	81.1300	1.53695	.0001
FMA°	29.0500	1.21547	30.1450	1.13855	.0001	29.8400	1.09275	.0001

TABLE 12: COMPARISON OF PHARYNGEAL AIRWAY PARAMETERS AT THREE STAGES OF TREATMENT IN CLASS III

PAIRED *t* TEST

PARAMETER (n=20)	T1		T2		T1-T2 P value	T3		T2-T3 P value
	MEAN	SD	MEAN	SD		MEAN	SD	
OPT/NSL°	98.4100	1.07942	99.4900	1.18539	.0001	99.4900	1.18539	1.000
PP1-PNS, mm	26.3050	1.84404	26.5550	3.88211	0.112	26.6300	1.56881	1.000
PP2-UV, mm	12.1600	1.31245	10.4500	.90699	.0001	10.3800	.85987	.9621
PP3-Tb, mm	11.4800	1.88864	12.0900	1.79088	.0001	10.6800	2.77563	.0001

TABLE 13: COMPARISON OF HYOID BONE PARAMETERS AT THREE STAGES OF TREATMENT IN CLASS III

PAIRED *t* TEST

PARAMETER (n=20)	T1		T2		T1-T2 P value	T3		T2-T3 P value
	MEAN	SD	MEAN	SD		MEAN	SD	
PNSp-H, mm	61.2500	3.95241	65.0100	2.86079	.0001	63.5900	2.77563	.009
H-RGN, mm	34.6000	1.05731	31.0100	1.54201	.0001	31.5300	1.50861	.0001
Cv3ia-H, mm	35.5100	1.25022	32.1600	1.51914	.0001	32.5300	1.49247	.009

TABLE 14: COMPARISON OF DENTOFACIAL PARAMETERS BETWEEN CONTROL AND CLASS III

INDEPENDENT SAMPLES TEST

PARAMETER (n=20)	CONTROL		T1		P value	T2		P value	T3		P value
	MEAN	SD	MEAN	SD		MEAN	SD		MEAN	SD	
SNB°	80.87	1.6	85.7	1.4	0.0001	80.89	1.6	0.962	81.13	1.5	0.605
FMA°	26.46	2	29.05	1.2	0.0001	30.14	1.1	0.0001	29.84	1.1	0.0001

TABLE 15: COMPARISON OF PHARYNGEAL AIRWAY PARAMETERS BETWEEN CONTROL AND CLASS III

INDEPENDENT SAMPLES TEST

PARAMETER (n=20)	CONTROL		T1		P value	T2		P value	T3		P value
	MEAN	SD	MEAN	SD		MEAN	SD		MEAN	SD	
OPT/NSL°	99.36	3.56	98.41	1.07	.264	99.49	1.18	.878	99.49	1.18	.878
PP1-PNS, mm	27.18	1.49	26.55	1.84	.108	26.63	1.61	.801	27.63	1.56	.359
PP2-UV, mm	9.51	1.12	12.16	1.31	.001	10.45	.90	.006	10.38	.85	.046
PP3-Tb, mm	10.03	1.35	11.48	1.88	.008	12.09	1.79	.0001	10.68	2.77	.163

TABLE 16: COMPARISON OF HYOID BONE PARAMETERS BETWEEN CONTROL AND CLASS II

INDEPENDENT SAMPLES TEST

PARAMETER (n=20)	CONTROL		T1		P value	T2		P value	T3		P value
	MEAN	SD	MEAN	SD		MEAN	SD		MEAN	SD	
PNSp-H, mm	60.4	3.7	61.25	4	.488	65.01	2.9	.0001	63.59	2.8	.001
H-RGN, mm	30.15	1.4	34.6	1.1	.0001	31.01	1.5	.072	31.53	1.5	.005
Cv3ia-H, mm	30.15	1.4	35.51	1.3	.0001	32.16	1.5	.072	32.53	1.5	.005

TABLE 17: COMPARISON OF HORIZONTAL CHANGES (mm) OF LANDMARKS IN AIRWAY AND HYOID BONE AT THREE TIMES IN CLASS III GROUPS

PAIRED *t* TEST

LANDMARK (n=20)	T1		T2		T1-T2	T3		T2-T3
	MEAN	SD	MEAN	SD	P Value	MEAN	SD	P Value
H	17.41	3.32	12.76	4.01	.0001	14.42	3.10	.021
PP1	-7.24	2.01	-7.47	1.82	.319	-7.59	2.37	.511
PP2	-11.71	2.11	-11.99	1.99	.224	-12.31	2.05	.117
PP3	-13.27	3.40	-16.50	3.57	.0001	-15.40	3.19	.138
UV	0.54	2.66	-2.64	3.18	.0001	-2.82	3.22	.982
Tb	-1.87	3.74	-5.55	3.75	.0001	-5.68	3.47	.078

TABLE 18: COMPARISON OF VERTICAL CHANGES (mm) OF LANDMARKS IN AIRWAY AND HYOID BONE AT THREE TIMES IN CLASS III GROUPS

PAIRED *t* TEST

LANDMARK (n=20)	T1		T2		T1-T2	T3		T2-T3
	MEAN	SD	MEAN	SD	P Value	MEAN	SD	P Value
H	-107.5	3.92	-115.2	3.97	.0001	-110.2	3.46	.0001
PP1	-45.50	2.34	-45.48	2.22	.933	-45.69	2.60	.511
PP2	-66.02	3.41	-65.60	3.25	.342	-66.13	3.55	.795
PP3	-91.80	3.87	-95.09	4.95	.0001	-91.43	4.50	.0001
UV	-68.24	2.97	-68.56	3.24	.086	-68.98	3.07	.216
Tb	-92.64	3.31	-96.36	4.56	.0001	-92.52	3.80	.0001

TABLE 19: COMPARISON OF HORIZONTAL CHANGES (mm) OF LANDMARKS IN AIRWAY AND HYOID BONE IN CONTROL AND CLASS III GROUPS

INDEPENDENT SAMPLES TEST

LANDMARK (n=20)	CONTROL		T1		P Value	T2		P Value	T3		P Value
	MEAN	SD	MEAN	SD		MEAN	SD		MEAN	SD	
H	10.64	3.37	17.41	3.32	.0001	12.76	4.01	.079	14.42	3.10	.001
PP1	-7.43	1.88	-7.24	2.01	.760	-7.47	1.82	.967	-7.59	2.37	.813
PP2	-12.58	1.98	-11.71	2.11	.188	-11.99	1.99	.848	-12.31	2.05	.905
PP3	-16.06	2.91	-13.27	3.40	.008	-16.50	3.57	.672	-15.40	3.19	.499
UV	-3.46	1.84	0.54	2.66	.0001	-2.64	3.18	.134	-2.82	3.22	.654
Tb	-6.11	3.39	-1.87	3.74	.0001	-5.55	3.75	.219	-5.68	3.47	.196

TABLE 20: COMPARISON OF VERTICAL CHANGES (mm) OF LANDMARKS IN AIRWAY AND HYOID BONE IN CONTROL AND CLASS III GROUPS

INDEPENDENT SAMPLES TEST

LANDMARK (n=20)	CONTROL		T1		P Value	T2		P Value	T3		P Value
	MEAN	SD	MEAN	SD		MEAN	SD		MEAN	SD	
H	-105.6	4.51	-107.5	3.92	.230	-115.2	3.97	.0001	-110.2	3.46	.001
PP1	-45.24	1.87	-45.50	2.34	.701	-45.48	2.22	.714	-45.69	2.60	.534
PP2	-65.66	2.89	-66.02	3.41	.721	-65.60	3.25	.994	-66.13	3.55	.660
PP3	-87.51	3.45	-91.80	3.87	.002	-95.09	4.95	.0001	-91.43	4.50	.004
UV	-67.52	2.69	-68.24	2.97	.427	-68.56	3.24	.594	-68.98	3.07	.119
Tb	-88.40	2.99	-92.64	3.31	.0001	-96.36	4.56	.0001	-92.52	3.80	.001

RESULTS

1. No statistically significant differences were found in comparisons of two groups based on age (Fisher`s exact test – TABLE 5), gender and BMI (Independent samples test - TABLE 6 & 7).
2. The method error assessment for horizontal and vertical landmarks using Dahlberg`s formula and paired *t* tests showed insignificant differences and accidental errors smaller than 1.0mm (TABLE 9 & 10)
3. Comparison of mean values and standard deviations of dentofacial parameters showed that SNB angle was significantly increased ($P< 0.0001$)in class III group when compared to control at T1 (TABLE 14) and also significantly decreased ($P<0.0001$) after surgery (T2) when compared to pretreatment (T1) (TABLE 11). But the SNB angle showed significant increase ($P<0.0001$) post treatment (T3) which may be attributed to relapse after surgery.
4. The FMA angle was significantly increased ($P<0.0001$) in class III group when compared to control at T1 (TABLE 14). There was also a significant increase ($P<0.0001$) in FMA angle after surgery (T2) indicating a clockwise rotation of mandible (TABLE 11). However the angle was found to be decreased significantly ($P<0.0001$) post treatment (T3) in class III group.

5. Analysis of the pharyngeal airway parameters between T1, T2 and T3 of class III group (TABLE 12) showed significant differences ($P<0.0001$) for the parameters OPT/NSL, PP1-PNS, PP2-UV and PP3-Tb between T1 and T2, whereas only PP3-Tb showed significant difference between T2 and T3, indicating increased craniocervical angulation and decrease in oropharyngeal airway dimension after surgery (T3).
6. Comparison between control and class III group (TABLE 15) for pharyngeal airway parameters showed insignificant differences for OPT/NSL and PP1-PNS at T1, T2 & T3. PP2-UV showed significant differences at all three stages (T1- $P<0.001$, T2- $P<0.01$, T3- $P<0.05$). PP3-Tb was significant in T1 ($P<0.01$) and T2 ($P< 0.0001$). The results showed that class III group had increased oropharyngeal and hypopharyngeal dimensions when compared to control at pretreatment (T1).
7. Analysis of the hyoid bone parameters between T1, T2 and T3 of class III group showed significant differences ($P<0.0001$) for PNSp –H, H-RGN and Cv3ia-H at T1-T2, indicating a definite posterior and inferior movement of hyoid bone after surgery (TABLE 13). However there seems to be a relapse of hyoid bone in anterior and superior direction at T3 stage indicated by the significant

difference in parameters PNSp –H (P< 0.01), H-RGN (P<0.0001) and Cv3ia-H (P< 0.01).

8. Comparison of hyoid bone parameters between control and class III group showed significantly increased (P<0.0001) measurements for PNSp –H, H-RGN and Cv3ia-H at T1. At T2, only PNSp-H showed significance (P<0.0001) while other parameters didn’t. At T3, PNSp –H (P< 0.001), H-RGN (P< 0.01) and Cv3ia-H (P< 0.01) showed statistical significance (TABLE 16). It was inferred from the results that class III group had a more anterior position of hyoid bone when compared to control at pretreatment (T1). Though the hyoid bone moves posteroinferiorly after surgery (T2), it relapses at a later stage. The study showed that the final position of hyoid in class III group at T3 is still anterior when compared to that of control group at T1.
9. Analysis of the horizontal changes of the airway and hyoid landmarks between class III group at T1, T2 & T3 showed significant (P<0.0001) decrease for H, PP3, UV, Tb at T2, indicating the posterior movements of landmarks after surgery (T2). At T3 only H point showed significant decrease (P<0.05).
10. Comparison of the horizontal changes of the airway and hyoid landmarks of class III group with the control group revealed significant differences for H, PP3, UV and Tb at

pretreatment (T1) with $P < 0.0001$ for H, UV and Tb and $P<0.01$ for PP3. However at post treatment (T3) only H point has significance ($P<0.01$). The results indicated more anteriorly positioned hyoid and airway landmarks for class III group when compared to the controls at pretreatment stage (T1).

11. Comparison of vertical changes of the airway and hyoid landmarks between class III group at T1, T2 & T3 showed significant ($P<0.0001$) increase for H, UV, Tb at T2, indicating the inferior movements of landmarks after surgery. At T3 only H point showed significant decrease ($P<0.0001$).
12. Comparison of the vertical changes of the airway and hyoid landmarks of class III group with the control group revealed a significant inferior positioning for PP3 ($P<0.05$) and Tb ($P<0.0001$) at pretreatment (T1). After surgery (T2) H, PP3 and Tb points of class III group showed significant ($P<0.0001$) inferior positioning when compared to control group. These points were significantly increased at post treatment (T3) also with $P<0.05$ for PP3 and $P<0.001$ for H and Tb.

DISCUSSION

Narrowing of Pharyngeal Airway Space (PAS) after a mandibular setback surgery has gained interest in the past decades. One of the main reasons for such interest is that PAS narrowing could be a predisposing factor of Obstructive Sleep Apnoea (OSA) [25, 80, 81]. The present study evaluates the degree of pharyngeal airway narrowing in mandibular prognathism patients after mandibular setback surgery.

Nasopharyngeal airway area increases rapidly until 13 years of age and after this the growth slows down. An inactive period of growth in pharyngeal structures has been reported beyond 15 years of age[30, 82-85] Chang min et al[59] reported the developmental changes on pharynx and hyoid position. By 3 years of age the hyoid lies at a level between 3rd and 4th cervical vertebrae and descends to the level of the 4th vertebrae at adulthood. Later during growth the relative position of the hyoid remains constant[12, 86]. Literature findings indicate that growth may have little effect if any on the sagittal depth of the pharyngeal airway[82-85].

It was important that the selected subjects had completed the maxillomandibular growth to evaluate the morphological changes due to surgery treatment. The Class III group and the control group selected for this study had a mean age of 22.29 (SD ± 1.99) and 22.09 (SD ± 1.89) years respectively. Hence the subjects were appropriate for morphological comparison.

Body mass index is one of the key factors in pharyngeal airway evaluation because obesity may play a role in compromising upper airway patency[96]. Studies suggest that fat deposition adjacent to pharyngeal airway plays a role in pathogenesis of Obstructive Sleep Apnoea[97]. In our study the mean body mass index (BMI) of the class III and control group were 21.08 (SD ±1.28) and 21.005 (SD±0.97) kg/m^2 respectively. The BMI of the two groups were statistically insignificant and were within the normal range.

As this analytical study was retrospective in nature, direct assessment of the respiratory pattern for individual patient was not possible. The medical history and dental history recorded in the clinical orthodontic records were analyzed for the criteria for selection of the subjects. Prior history about tonsillectomy and respiratory infections were considered.

All these patients had been diagnosed with skeletal class III malocclusion attributed to prognathic mandible and the treatment plan involved presurgical orthodontic treatment, orthognathic surgery and postsurgical orthodontic treatment. Fixed appliance used was MBT 0.22” Prescription and the surgical technique was single jaw mandibular setback surgery through Bilateral Sagittal Split ramus Osteotomy (BSSO) using Obwegeser – Dal Pont method. The bone fragments were fixed using three positioning screws (2mm diameter) at each osteotomy site. No splints were used for stabilization of mandible. Rigid intermaxillary fixation was maintained for approximately 2 weeks (TABLE 8).

Several studies in literature have used lateral cephalograms to assess the PAS in patients treated with orthognathic surgery[19,22,87]. Computed tomography and magnetic resonance imaging has also been used[88, 89]. Although two dimensional, cephalometric measurements of the PAS are reliable in diagnosing pharyngeal volume[90]. Riley and Powell[91] reported that cephalometric measurements of PAS highly correlated with measurements using a three dimensional computed tomography scan with considerably high accuracy in predictability. We have used lateral cephalograms in our study to assess the morphologic changes in the PAS because they are simple, less expensive, easily achieved with reduced radiation and ease of comparison with extensive normative data and other studies[23,28,54,92.]

The process of converting the analogue information into digital form is called digitization. Quantitative, systematic, and objective measurements based on hard and soft tissue landmarks determined on cephalometric films are used in orthodontics as a valuable tool in orthodontics. Korkmaz Sayinsu et al[53] and Cleomar Donizeth Rodrigues et al[67] confirmed that there was no statistically as well as clinically significant difference in the tracings between digitized cephalograms, direct digital and conventional methods. In the present study lateral cephalograms were digitized using HP 3545 MFP scanner and analyzed using Ax Ceph version 2.3.0.74 software.

Morphologic changes in the pharyngeal airway after mandibular setback surgery have been previously studied. A study by Riley and Powell[80] suggested that mandibular setback might contribute to further development of Obstructive Sleep Apnoea Syndrome (OSAS) after orthognathic surgery.

Numerous studies have been reported in literature that mandibular setback surgery primarily affects the oropharyngeal level which is also the main level reported to be narrowed in OSAS patients[47, 93, 94.]

The class III patients in this study had a wider dimension of pharyngeal airway at the level of PP2-UV and PP3-Tb representing oropharynx and hypopharynx respectively when compared with the control subjects prior to orthognathic surgery (T1). The results obtained in this study were similar to previous studies[29,57,92] showing that pharyngeal airway space is larger in mandibular prognathism patients before surgery when compared to control class I subjects.

However a study by Liukkonen et al[43] did not support these findings and they said the values were within normal limits and showed no obvious difference between the two groups. This variation could have been caused due to differences in sample subjects. The subjects of our study had large mandibles and underwent single jaw surgery, whereas the subjects of the other study could have been patients with small or backward positioned maxilla.

Various studies done in other populations have reported constriction of pharyngeal airway after mandibular setback surgery[29, 37]. In our study the pharyngeal parameters PP2-UV and PP3-Tb showed statistically significant ($P<0.0001$) decrease after orthognathic surgery. This study confirms the study by Muto et al[57] Craniocervical hyperflexion due to orthognathic surgery has also been reported in literature[69]. In our study statistically significant ($P<0.0001$) increase in craniocervical angle was noted.

During the postsurgical stage the PP3-Tb continued to remain in the posterior position with statistical significance when compared with T2. Kitahara et al[64] reported that movement of proximal and distal segments of mandible during surgical procedure correlates with the position of the tongue. During BSSO surgery both proximal and distal segments move backward and after the release of Intermaxillary fixation there might be a tendency to move forward. In our study the tongue moved backwards along with the proximal segments and continued to remain there postsurgically thereby causing narrowing of the oropharyngeal airway. The pharyngeal airway dimensions after post treatment correlated with that of the control groups. This result is similar to the one obtained by Achilleos et al and Saitoh[39, 47.]

The horizontal and vertical changes of the pharyngeal airway and hyoid bone in relation to the reference planes showed significant consistencies with the dimensional changes of pharyngeal airway and hyoid bone positions between control group and class III group. They were also consistent with the changes noted in the three treatment phases of class III group.

After mandibular setback surgery the hyoid bone moves in an inferior and posterior direction. This is said to be a physiological adaptation of soft tissue structures to maintain airway patency and equilibrium of adjoining structures[49]. Various studies have postulated that hyoid bone moves in a posteroinferior direction after surgery but returns to its previous anatomic posture over long term[24, 95]. Enacar et al[27] in their study reported that though hyoid returns to its pre anatomic position over long term, the postsurgical decrease in hypopharyngeal airway space is maintained as such.

In our study we found that the hyoid bone moved in a posterior as well as inferior direction in immediate postsurgical period given by the significant increase in PNSp-H parameter which increased significantly after surgery. This fact is in acceptance to the various studies conducted previously[24, 95]. During the post treatment period an upward and forward movement of hyoid bone was noted, indicated by the significant decrease in PNSp-H value.

The findings in our study suggest that the pharyngeal airway dimensions decreases and the hyoid bone position significantly changes after mandibular setback surgery. These changes can either lead to a dentoskeletal morphological adaptation or can relapse and become worse over long term.

LIMITATIONS OF THE STUDY

Although we utilized lateral cephalograms for evaluation in this study owing to is various advantages cited earlier, it is still a two dimensional representation of a three dimensional structure. Three dimensional cone beam computed tomography may provide a better evaluation of the oropharyngeal airway morphology.

Long term observation of the subjects is important to accurately determine the post-surgical morphological adaptation and position of the oropharyngeal structures to the improved lower facial morphology.

Future studies could be conducted to improve the validity of our prediction by increasing the sample size and involving patients with various types of orthognathic surgeries

SUMMARY AND CONCLUSION

Pharyngeal airway dimension plays an important role in dentofacial development. Although mandibular setback surgeries like Bilateral Sagittal Split ramus Osteotomy (BSSO) could improve the occlusion, function and esthetics by changing the position of prognathic mandible in patients, it is likely to cause narrowing of pharyngeal airway space and changes in hyoid bone position[5]. Narrowing of pharyngeal airway through setback surgery may contribute to treatment relapse apart from inducing the development of Obstructive Sleep Apnoea Syndrome (OSAS) [80]. Hence it is essential to estimate and understand the changes in airway dimensions and hyoid bone positions following the mandibular set back surgeries.

This study was therefore performed to evaluate the changes if any in hyoid bone position and pharyngeal airway dimensions following mandibular setback surgery in patients with prognathic mandible, at immediate post-operative stage and at the end of the whole orthodontic treatment.

Following conclusions were derived from this study

1. Skeletal Class III patients with prognathic mandible exhibited significantly larger pharyngeal airway space than the skeletal Class I individuals at pretreatment stage.
2. Significant narrowing of pharyngeal airway space occurred in Skeletal Class III patients with prognathic mandible immediately after surgery.
3. The post treatment pharyngeal airway parameters of the Skeletal Class III patients with prognathic mandible corresponded to the pretreatment parameters of skeletal Class I individuals.
4. Although some surgical relapse following BSSO occurred in the said Skeletal Class III patients at post treatment stage, the pharyngeal airway parameters which were narrowed immediately after surgery, did not subsequently increase and was still maintained in the same narrowed dimension as found at postsurgical time.
5. The hyoid bone moved inferiorly and posteriorly immediately after surgery probably due to the attached soft tissue structures.
6. However the hyoid bone returned to its presurgical position at the time of treatment completion.

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