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Comparison of 3 dimensional airway volume in class I patients, class II and class III skeletal deformities.

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ABSTRACT:
Background and objectives: The upper and lower airway has always been an area of interest because the oropharyngeal and nasopharyngeal structures play important roles in the growth and development of the craniofacial complex. Significant relationships between the pharyngeal structures and both dento-facial and craniofacial structures have been reported. The aim of the study were to evaluate Oropharyngeal and nasal passage volumes of patients with normal nasorespiratory functions having different dentofacial skeletal patterns using CBCT and the correlations between different variables and the airway

Material and Methods: The study consisted of 45 patients (23 males, 22 females), divided into 3 equal groups as Class I , Class II and Class III based on evaluation of facial profile and molar relation. After obtaining CBCT, the Oropharyngeal airway volume (OPV), Nasopharyngeal airway volume (NPV), vertical height of oropharynx (HOP), Constricted minimum axial area (CMinAx), and Constricted posterior airway space (CPAS) were measured. Differences between groups were determined by using the Tukey Post Hoc test. Correlations between the variables were tested with the Pearson's correlation coefficient.

Results: The mean OPV of the Class II subjects (6876.40 mm3) was significantly lower when compared with that of the Class I (8294.73 mm^3) and Class III subjects (10941.43 mm^3). The only statistically significant difference for NPV was observed between the Class I (9889.57 mm3) and Class II groups (7916.48 mm^3). The CMinAx had a high potential in explaining the OPV.

Conclusion: The results from this study indicate that mandibular growth deficiency patients had less airway volume, minimum axial area and constricted posterior airway space than the patients with good growth anteroposterior relationship between maxilla and mandible. The results of this research can be used as a guideline for subsequent works related to the airway study and presurgical assessment for orthognathic surgeries.
Keywords : Airway volume, Class I , Class II, Class III, CBCT, Oropharyngeal volume, Nasopharyngeal volume, Segmentation, Volumetric Analysis.

INTRODUCTION

The upper and lower airway has always been an area of interest because the oropharyngeal and nasopharyngeal structures play important roles in the growth and development of the craniofacial complex 1. Postural relationships of the head, jaws, and tongue are established in the first moments after birth as the airway is opened and stabilized, and are altered as necessary thereafter to maintain the airway 2 some authors reported associations of vertical growth pattern with obstruction of the upper and lower pharyngeal airways concurrently with mouth breathing 3-5. Normal respiratory activity influences the growth of maxillofacial structures, favoring their harmonious growth and development 6.Although some researchers have found no association between airway adequacy and dentofacial morphology, it seems to be a general belief that the oropharyngeal and nasopharyngeal structures play roles in the development of the dentofacial complex 7

The etiology of malocclusions is believed to be multifactorial. It could be considered erroneous to associate malocclusions only with breathing mode. Since the airway is assumed to play a role in dentofacial development, several studies tried to correlate patients with normal naso respiratory functions with different malocclusions and airway dimensions 2-4,11-14 .

Morphometric evaluation of the pharyngeal airway had been mostly performed on lateral cephalometric headfilms . The only drawback of these studies was that they were conducted with 2-dimensional (2D) cephalograms, which might misrepresent a 3-dimensional (3D) structure 7.

According to the medical literature, airway evaluation can be performed with magnetic resonance imaging (MRI), cineMRI, multi-detector CT(MDCT) , endoscopy and optical coherence tomography(OCT). Although CBCT is inferior to MDCT in discriminating between different soft-tissue structures, it defines the boundaries between soft tissues and empty spaces with high spatial resolution 16. Several studies have tested accuracy and reliability of CBCT and have confirmed its potential for the evaluation of the upper airway 16,17. As a result, better understanding of the upper airway anatomy and physiology is to be expected.

The purpose of this study were to evaluate Oropharyngeal and nasal passage volumes of patients with normal nasorespiratory functions having different dentofacial skeletal patterns using CBCT and the correlations between different variables and the airway .

MATERIALS AND METHOD:

This prospective comparative study was conducted on 45 patients (23 males, 22 females), divided into 3 equal groups as Class I , Class II , and Class III based on evaluation of facial profile and molar relation. Patients were selected after obtaining written informed consent on the basis of inclusion and exclusion criteria. Patients with Class I , Class II and Class III dentofacial skeletal pattern between 20 to 35 years of both sexes with their body-mass-index (BMI) ranging 18.5≤BMI≥29.9 were included in study. Patients with Transverse deficiencies, Severe hypodivergent growth pattern, Severe hyperdivergent growth pattern, Obese subjects according to their BMI i.e BMI≥30, Congenital craniofacial deformities, pharyngeal pathology, nasal obstruction if any,History of adenoidectomy and Scans showing incomplete imaging of airway were excluded from the study.

After obtaining ethical committee clearance from Institutional ethics comittee, The Oxford Dental College and Hospital, Bangalore, Karnataka .Forty-five patients who reported with various surgical problems and required Cone Beam Computed Tomographic images(CBCT) for diagnostic purpose were included in this study.

Particulars of patient , brief case history were noted in clinical proforma. All patients height, weight and Body Mass Index(BMI) were measured, and organized by using Excel software (Microsoft, Redmond, Wash). Patients with BMI ≥30 were excluded from the study.

The patients were divided into 3 groups according to their facial profile and molar relation as Class I, Class II, and class III (15 in each group).

All the patients were advised cone beam computerized tomographic imaging of Nasopharyngeal airway and oropharyngeal airway by obtaining full-skull CBCT. As a standard protocol, the patient was seated in the upright position with the Frankfort Horizontal plane parallel to the floor, with the teeth biting the mouth prop of CBCT machine and lips and tongue in position, filling the oral cavity. During the CBCT exposure time the patients were instructed not to swallow or move the head or tongue. All cone beam computed tomography images were taken with the CareStream 9300 as a routine part of initial diagnostic records for required patients from same diagnostic center. All images were taken at 10 mA, 90 kV, and a 12-in field of view setting. Each patient's image data consisted of 455 slices, with a slice thickness of 0.377 mm, a resolution of 1280

* 1024 pixels, and 16 bits per pixel (4096 gray scale). The images were taken in natural head posture . Scans showing incomplete imaging of the airway were excluded.

1) The volume of the pharynx between palatal plane (ANS-PNS) extending to the posterior wall of the pharynx(pp) and the plane parallel to palatal plane that passes from the most anterioinferior point of second cervical vertebrae(2cv) is taken as Oropharyngeal volume.

2) The inferior limit of the Nasopharyngeal airway was the superior limit of the Oropharyngeal airway and the superior limit was the last slice before the nasal septum fused with the posterior wall of the pharynx(PNP). To better view this fusion, the superior border of the Nasopharynx was defined on the axial slice first and then reflected to the sagittal plane.

For volumetric analysis of oropharynx(OP) and nasopharynx (NP) we used turtleseg software build 1.3.0.1777 (www.turtleseg.org) which was the latest build at the time of this study. And for linear measurements like OP length and minimum axial area we used the software MITK Workbench build 2015.05.2 (www.mitk.org) which was the latest build at the time of this study.

Using TurtleSeg build 1.3.0.1777 the Oropharynx and Nasopharynx was segmented. After opening the dicom images in software, using image intensity mapping the intensity of the images were adjusted so that airway area is clearly seen with its border. The oropharynx upper limit pp and lower limit 2cv were opened in axial slice and the boundaries were contoured using livewire method69,70. In same way oropharynx boundaries were contoured in saggital and coronal section. After that the software was allowed to make 3D segmentation. If there was any error software will suggest " spotlight " feature and guides in better segmentation.72,73 After segmentation process the software gives the volume of the segmented part as units of mm3 in statistical window. The value was noted as Oropharynx volume.

Using TurtleSeg software the nasopharynx was segmented with lower limit as pp and superior limit as PNP. Nasopharynx was also segmented in the same way how oropharynx was segmented previously. From the statistical report ,the nasopharynx volume was noted after segmentation process.

Using MITK Workbench build 2015-02 (www.mitk.org) the vertical length of the Oropharynx (HOP) and the constricted posterior airway space (CPAS) (the most constricted space behind the base of the tongue and limited by soft tissues) was measured on the midsagittal slice.74 The sagittal line corresponding to the CPAS region was opened on the axial slice, and the area of the most constricted region at the base of the tongue (CMinAx) was calculated. The dicom file was opened in MITK Workbench. Using the linear measurement scale provided in the software the HOP was measured from pp to 2cv in saggital section. The CPAS was measured in mid-sagittal section using linear measurement scale. The cross hair was moved to the CPAS region in saggital section and the corresponding axial section shows the CMinAx region slice. The image in axial section is zoomed in so that the borders were clearly seen. Using the polygon tool the boundaries of CMinAx was marked with multiple seed points. The software automatically shows the circumference (mm) and area (mm2). The area of the CMinAx was noted.

STATISTICAL ANALYSIS:

SPSS software (version 17.0, SPSS, Chicago, Ill) was used for all statistical analyses. In each group, means and standard deviations for age, skeletal variables, height, weight, BMI, and volumetric, area, and linear measurements for the OP and NP regions, were determined. The Shapiro-Wilk test was used to check the normality of the OP and NP volumes. Because of the nonnormality of the distribution of the OP volume data, nonparametric tests were used. Differences between groups were determined by using the ANOVA test. When the ANOVA test was found to be significant, further pair-wise comparisons were done with the Tukey post Hoc test. To check the correlations between the variables, the Pearson's correlation was performed.

RESULTS

In this study 45 patients were grouped in to 3 groups of 15 Class I patients (6 males, 9 females), 15 Class II patients (8 males, 7 females), and 15 Class III patients (9 males, 6 females). There were 39 normal weight (18.5 ≤BMI ≤24.9) and 6 overweight (24.9≤ BMI ≤ 29.9) subjects distributed homogeneously between the groups. OP variables (HOP (44.43 ± 4.10 mm), CPAS (10.01 ±4.94mm), CMinAx (249.91 ± 170.98 mm^2), and OPV (10941.43 ± 2863.22 mm^3) of the Class III subjects were higher compared with the other groups, and the Class I subjects had the largest NPV (9889.57 ± 2274.40mm^3).

Shapiro -Wilk test for normality is given in Table 1. In class I group the OPV, NPV, HOP, CMinAx and CPAS P values were 0.05, 0.75, 0.94, 0.23 and 0.29 respectively and were found to be insignificant. In class II group the OPV, NPV, HOP and CMinAx P values were 0.83, 0.81, 0.80, and 0.45 respectively and were found to be insignificant. In class II group the CPAS P value was 0.01 and found statistically significant. In class III group the OPV, NPV, HOP and CPAS P values were 0.17, 0.74, 0.56, and 0.14 respectively and were found to be insignificant. In class III group the CMinAx P value was 0.02 and found statistically significant. By Shapiro-Wilk test for normality, except Class II CPAS and class III CMinAx were found statistically significant values and found abnormal distribution.

ANOVA Test was done to find any correlation exist between the variables is given in Table 2. In class I group the mean OPV was 8294.73 ± 1786.59 mm^3.In class II group the mean OPV was 6876.4 ± 2433.72 mm^3.In class III group the mean OPV was 10941.43 ± 2863.22 mm^3. The OPV was found to be significant among 3 groups (P = 0.001).

In class I group the mean NPV was 9889.57 ± 2274.40 mm^3. In class II group the mean NPV was 7916.48 ± 2307.04 mm^3.In class III group the mean OPV was 8166.30 ± 1673.94 mm^3. The NPV was found to be significant among 3 groups (P= 0.03). In class I group the mean HOP was 41.08 ± 4.50 mm. In class II group the mean HOP was 43.05 ±3.25 mm. In class III group the mean HOP was 44.43 ± 4.10 mm. The HOP was found to be not significant among 3 groups (P = 0.08).In class I group the mean CMinAx was 152.15 ± 71.74 mm^2.In class II group the mean CMinAx was 122.75 ± 51.31 mm2.In class III group the mean CMinAx was 249.91 ± 170.98 mm^2. The CMinAx was found to be significant among 3 groups (P = 0.008). In class I group the mean CPAS was 6.83 ± 2.46 mm. In class II group the mean CPAS was 6.75 ±2.52 mm. In class III group the mean CPAS was 10.01 ± 4.94 mm. The CPAS was found to be signifcant among 3 groups (P = 0.02).

In ANOVA Test OPV, NPV, CMinAx, and CPAS were found to be statistically significant among 3 groups. Among the variables OPV (P= 0.001) was more positively significant followed by CminAx (P= 0.008), CPAS (P= 0.02) and (P= 0.03).

Tukey post Hoc test was used for inter group correlations is given in Table 3. When the OPV of class I and class II were compared the P value was insignificant (P = 0.25). When the OPV of class I and class III were compared the the P value was significant (P = 0.01). When the OPV of class II and class III were compared the P value was significant (P <0.001).

When the NPV of class I and class II were compared the P value was significant (P = 0.04). When the NPV of class I and class III were compared the P value was insignificant (P = 0.07). When the NPV of class II and class III were compared the P value was insignificant (P = 0.94).

When the CMinAx of class I and class II were compared the P value was insignificant (P = 0.75). When the CMinAx of class I and class III were compared the P value was insignificant (P = 0.05). When the CMinAx of class II and class III were compared the P value was significant (P = 0.009).When the CPAS of class I and class II were compared the P value was insignificant (P = 0.99). When the CPAS of class I and class III were compared the P value was significant (P = 0.04). When the CPAS of class II and class III were compared the P value was significant (P = 0.03).

In Tukey post Hoc test, the OPV was statistically positively correlated between class I & class III and class II & class III groups. Among the two correlation, between class II & class III was more significant (P<0.001). The NPV was found positively significantly correlated between class I & class II groups (P= 0.04). The CMinAx was found positively more significant between class II & class III groups with a P value of 0.009. The CPAS was not much strongly correlated like OPV or CMinAx but positively statistically correlated between class I & class III groups (P= 0.04) and class II & class III groups (P=0.03).

Intra-group analysis was done with Pearson's correlation test results given in Tables 4.1, 4.2 & 4.3. In class I intragroup analysis OPV of class I was found to be positively significantly correlated with NPV and CMinAx with P value of 0.02 and 0.03 respectively. Class I CMinAx was positively significantly correlated with class I CPAS with P value of 0.005..

In class II intragroup analysis OPV of class II was found to be positively significantly correlated with CMinAx with P value of 0.006. Class II CMinAx was positively significantly correlated with class II CPAS with P value of 0.001.

In class III intragroup analysis OPV of class III was found to be positively significantly correlated with NPV, CMinAx and CPAS with P value of 0.01 for all. Class III HOP was positively significantly correlated with class III BMI with P value of 0.02. Class III CMinAx was positively significantly correlated with class III CPAS with P value of P< 0.001.

In intragroup analysis with pearson's coefficient, Class I CMinAx was positively strongly statistically correlated with CPAS (P=0.005) and Class I OPV was positively statistically correlated with NPV (P=0.02) and CMinAx (P=0.03). In class II intragroup analysis CMinAx was positively strongly statistically correlated with CPAS (P=0.001) than OPV (P=0.006). In class III intragroup analysis CMinAx was positively strongly statistically correlated with CPAS (P<0.001) and class III OPV was positively statistically equally correlated with NPV, CPAS and CMinAx (P=0.01) . In class III intragroup analysis BMI and HOP were statistically positively correlated.

DISSCUSSION

A mutual interaction is expected to occur between the pharyngeal structures and the dentofacial pattern, because of the close relationship between the pharynx and the dentofacial structures, and therefore justifies orthodontic interest. In many studies carried out on this subject, it has been demonstrated that there are statistically significant relationships between the pharyngeal structures and both dentofacial and craniofacial structures at varying degrees. According to the Balter's philosophy, Class II malocclusions are a consequence of a backward position of the tongue, disturbing the cervical region. The respiratory function is impeded in the region of larynx and there is thus a faulty deglutition and mouth breathing. Class III malocclusions are due to a more forward position of the tongue and to cervical over development. Thus, it might be considered to be useful that the assessment of the pharyngeal structures be included with the orthodontic diagnosis and treatment planning, as the functional, positional, and structural assessments of the dentofacial pattern.11

In this study, we added 3D and linear analyses of the airway volumes derived from CBCT to view possible alterations that could not be detected using the linear measurements of conventional lateral cephalograms. The linear accuracy of lateral cephalometric measurements from CBCT images has been studied and confirmed.75-7 In a study comparing the linear measurements of lateral cephalograms derived from CBCT with those of conventional cephalograms and direct measurements on a dry human skull, which was considered to represent the anatomic truth .78 For most linear measurements calculated in the sagittal plane, they found that the CBCT-derived 2D lateral cephalograms were more accurate than conventional lateral cephalograms .43

All cone beam computed tomography images were taken with the CareStream 9300 as a routine part of initial diagnostic records for required patients. To eliminate the bias of variance in CBCT image acquisition all CBCT were taken from same diagnostic center and same operating technician. All images were taken at 10 mA, 90 kV, and a 12-in field of view setting. Each patient's image data consisted of 455 slices, with a slice thickness of 0.377 mm, a resolution of 1280 * 1024 pixels, and 16 bits per pixel (4096 gray scale). The images were taken in natural head posture. Scans showing incomplete imaging of the airway were excluded.

Numerous software packages are dedicated to manage and analyse DICOM records. Many of them have incorporated tools to segment and measure the airway. In our study we used turtleseg build 1.3.0.1777 software (www.turtleseg.org) which was latest version of the software available at the time of study for segmentation of oropharynx airway volume(OPV) and nasopharynx airway volume(NPV), and MITK Workbench build 2015-02 software (www.mitk.org) which was latest version of the software available at the time of study for linear measurements like constricted posterior airway space (CPAS), constricted minimum axial area(CMinAx) and vertical height of oropharynx (HOP).72-4

It has been reported in the literature that the pharyngeal structures continue to grow rapidly until 13 years of age; between 14 and 18 years, a quiescent period for pharyngeal structures has been reported. In long-term follow-up studies, it has been established that, between 20 and 50 years of age, the soft palate becomes longer and thicker, and the pharyngeal region gets narrower and predispose OSA.7,9,24,52 According to these data, the most stable time period to evaluate mature OPV and NPV seems to be between 20 and 35 years of age. The mean age of our sample was 25.27 ± 4.37 years.

There is no difference in oropharyngeal length between men and women, after normalizing body's height.24. In our study, the pharyngeal dimensions were not affected by sex in any group as in other literature.11,86-8

Obesity, as measured by BMI, is a well-known factor for upper airway narrowing in both children and adults. Therefore, obese patients (BMI .30) were not included in our study to eliminate bias. There were 39 normal weight (18.5 ≤BMI ≤24.9) and 6 overweight (24.9≤ BMI ≤ 29.9)subjects distributed homogeneously between the groups. The mean BMI was 23.2 kg/m2 which is considered as normal weight individual. This might explain why no significant correlation was found between BMI and OPV. The only significant correlations was observed for the BMI and HOP in class III patients.

In this study we found that Class I subjects had larger NPV than did the Class II group and class III group. The mean class I NPV was 9889.57 mm^3 where as mean NPV of class II and class III were 7916.48 mm^3 and 8166.30mm^3 respectively. Kerr stated that Class II malocclusion subjects showed smaller nasopharyngeal and adenoid areas.5 In a 3D study, Kim et al found

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that the nasal airway volumes of the Class I subjects were greater than in the Class II subjects, but it was not significant.8 A constricted nasopharyngeal airway is associated with detruded mandible and maxilla.97 Alves et al concluded that patients with growth mandibular deficiency had less airway volume than the patients with good growth anteroposterior relationship between maxilla and mandible.37,43,85

In our study there was positive correlation between the OPV and NPV. The positive correlation might be the result of using healthy subjects with no airway pathology because situations such as nasal congestion, craniofacial anomalies, hypertrophic adenoids, and nasopharyngeal diminished airway space are known to cause structural narrowing of the pharynx.7,52 Kim et al also found a significant positive correlation between the nasal airway and the superior pharyngeal airway.8

The highest correlation found was between OPV and CMinAx (P= 0.006) in class II group. Tso et al also mentioned a high correlation between the most constricted cross-sectional area of the airway and the total airway volume.27 Subjects with skeletal Class III malocclusions had significantly increased cross-sectional areas of the lower part of the pharyngeal airway in the axial plane.36 In our study mean CMinAx for class III group was 249.91 mm^2 where as class I and class II mean constricted minimum axial area were 152.15mm^2 and 122.75mm^2 . Some studies have demonstrated that the parameters used to determine pharyngeal airway dimensions, such as volume, minimum cross-sectional area, length, and form, are correlated with obstructive sleep apnea syndrome and its gravity 98-101. When the results of this study are taken into account, detection of the sites of restriction of the upper airway are of particular clinical importance in understanding the size and volume of the pharyngeal airway and planning therapy. Although CPAS was also significantly correlated with the OPV in our study (P= 0.01), the correlation was lower compared with that obtained with CMinAx.

In our study the mean constricted posterior airway space (CPAS) of class III individuals was 10.01mm and largest than class I and class II group. The anteroposterior skeletal pattern showed weak, but significant correlation with inferior posterior airway space.22 Studies had concluded that the posterior airway space and the skeletal pattern have a close relationship, and therefore a mutual interaction can be expected to occur between them.1,43,85 Pharyngeal airway width shows lowest values in the high-angle group. Another explanation for the airway differences among the groups might be the retruded mandible in the high-angle group.59 Narrow posterior airway space, elongated tongue, enlarged soft palate, and an inferiorly located hyoid may be variables that can be significant determinants of apnea severity.11

There was a positive correlation between CMinAx and OP V for all separate groups. It was observed that CMinAx and CPAS also contributed to the NPV. Volumetric studies provide a new perspective on the airway, and possible constrictions might be a precipitating factor for different dentofacial skeletal patterns.

The Cone Beam Computerized Tomograph (CBCT) system provides a low-radiation rapid scan capability to assess patients’ airway using highly correlative linear, cross-sectional area, and volumetric measurements that include assessing the morphometry of the airway in three dimensional view .

The Oropharyngeal airway volumes of Class II patients were smaller when compared with Class I and Class III patients. The only significant difference for the Nasopharyngeal volume was between the Class I and Class II groups, with a smaller volume observed for the Class II group. The constricted minimum axial area was the predictor variable that best explained the

Oropharyngeal airway volume. Since the orpharngeal and nasopharyngeal volumes of class II patients were smaller compared to other two groups we conclude that class II patients undergoing orthognathic surgeries might experience post operative complications of pharyngeal airway like snoring, obstructive sleep apnea.

CONCLUSIONS

This study concludes that patients with mandibular growth deficiency had less airway volume, airway area, minimum axial area and constricted posterior airway space than the patients with good growth anteroposterior relationship between maxilla and mandible.The results of this research can be used as a guideline for subsequent works related to the airway study and presurgical assesment for orthognathic surgeries.

REFERENCE

1.Kumar AV, Kumar A, Subbiah S, Senkutvan RS. Pharyngeal airway dimension in different types of malocclusion. Int J Dent Sci Res 2014;2:7-11.

2.Shelton RL Jr, Bosma JF. Maintenance of the pharyngeal airway. J Appl Physiol 1962;17:209– 214.

3.Mergen DC, Jacobs RM. The size of nasopharynx associated with normal occlusion and Class II malocclusion. Angle Orthod 1970;40:342-6.

4.Freitas MR, Alcazar NMPV, Janson G. Upper and lower pharyngeal airways in subjects with Class I and Class II malocclusions and different growth patterns. Am J Orthod Dentofac Orthop 2006;130:742-5.

5.Kerr WJ. The nasopharynx, face height, and overbite. Angle Orthod 1985;55:31-6.

6.Cooper BC. Nasorespiratory function and orofacial development. Otolaryngol Clin North Am 1989;22:413-41.

7.El H, Palomo JM. Airway volume for different dentofacial skeletal patterns. Am J Orthod Dentofac Orthop 2011;139:511- 21.

8.Ceylan I, Oktay H. A study on the pharyngeal size in different skeletal patterns. Am J Orthod Dentofac Orthop 1995;108:69-75.

9.Trenouth MJ, Timms DJ. Relationship of the functional oropharynx to craniofacial morphology. Angle Orthod 1999;69:419-23.

10.Martin O, Muelas L, Vinas MJ. Nasopharyngeal cephalometric study of ideal occlusions. Am J Orthod Dentofacial Orthop 2006;130:e431-9.

11.Martin O, Muelas L, Viñas MJ: Comparative study of nasopharyngeal soft-tissue characteristics in patients with Class III malocclusion. Am J Orthod Dentofacial Orthop 2011 ;139:242-251.

12.Guijarro-Martinez R, Swennen GRJ. Cone-Beam computerized tomography imaging and analysis of the upper airway: a systematic review of the literature. Int J Oral Maxillofac Surg 2011:40:1227-37.

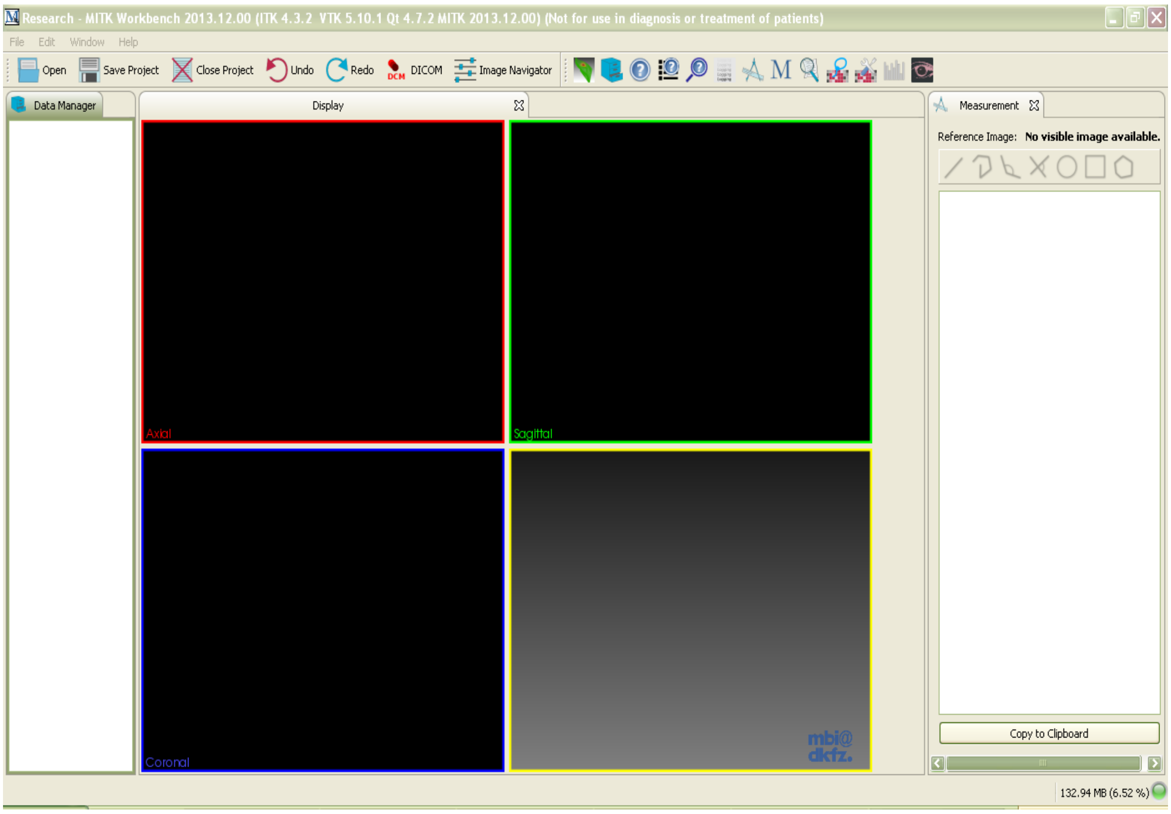
13.Lenza MG, de O. Lenza MM, Dalstra M, Melsen B, Cattaneo PM. An analysis of different approaches to the assessment of upper airway morphology: A CBCT study. Orthod Craniofac Res 2010; 13: 96–105.

14.Brown AA, Scarfe WC, Scheetz JP, Silveira AM, Farman AG. Linear accuracy of cone beam CT derived 3D images. Angle Orthod 2009;79:150–7.

15.Hassan B, van der Stelt P, Sanderink G. Accuracy of three-dimensional measurements obtained from cone beam computed tomography surface-rendered images for cephalometric analysis: influence of patient scanning position. Eur J Orthod 2009;31:129–34.
16.Kumar V, Ludlow J, Soares Cevidanes LH, Mol A. In vivo comparison of conventional and cone beam CT synthesized cephalograms. Angle Orthod 2008;78:873–9.
17.Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Silveira AM, Farman AG. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2007;132:550–60.
18.Alves M Jr, Franzotti ES, Baratieri C, Nunes LK, Nojima LI, Ruellas AC. Evaluation of pharyngeal airway space amongst different skeletal patterns. Int J Oral Maxillofac Surg. 2012;41:814–819.
19.Top A, Hamarneh G, Abugharbieh R. Spotlight: Automated Confidence-based User Guidance for Increasing Efficiency in Interactive 3D Image Segmentation. In Medical Image Computing and Computer-Assisted Intervention Workshop on Medical Computer Vision (MICCAI MCV),2010 204-13,
20.Top A, Hamarneh G, Abugharbieh R. Active Learning for Interactive 3D Image Segmentation.In Medical Image Computing and Computer-Assisted Intervention (MICCAI) 2011;6893:603-10
21.Wolf I, Nolden M, Böttger T, Wegner I, Schöbinger M, Hastenteufel M, Heimann T, Meinzer H, Vetter M. The Medical Imaging Interaction Toolkit. Medical Image Analysis. 2005; 9(6) : 594 – 604
22. Grauer D, Cevidanes LSH, Styner MA, Ackerman JL, Proffit WR. Pharyngeal airway volume and shape from cone-beam computed tomography: Relationship to facial morphology. Am J Orthod Dentofacial Orthop 2009;136:805–14.
23. Shigeta Y, Ogawa T, Venturin J, Nguyen M, Clark GT, Enciso R. Gender- and age-based differences in computerized tomographic measurements of the orophaynx. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:563-70.
24. El H, Palomo JM. An airway study of different maxillary and mandibular sagittal positions. Eur J Orthod. 2013;35:262–270
25. Shigeta Y, Ogawa T, Venturin J, Nguyen M, Clark GT, Enciso R. Gender- and age-based differences in computerized tomographic measurements of the orophaynx. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:563-70.
26.Solow B, Siersbaek-Nielsen S, Greve E. Airway adequacy, head posture, and craniofacial morphology. Am J Orthod 1984;86:214-23.
27.Linder-Aronson S, Woodside DG. The growth in the sagittal depth of the bony nasopharynx in relation to some other facial variables. Trans Eur Orthod Soc 1977;69-83.
28.Handelman CS, Osborne G. Growth of the nasopharynx and adenoid development from one to eighteen years. Angle Orthod 1976;46:243-59.
29. Kim YJ, Hong JS, Hwang YI, Park YH. Three-dimensional analysis of pharyngeal airway in preadolescent children with different anteroposterior skeletal patterns. Am J Orthod Dentofac Orthop 2010;137:306-11.
30. Hwang YI, Lee KH, Lee KJ, Kim SC, Cho HJ, Cheon SH, et al. Effect of airway and tongue in facial morphology of prepubertal Class I, II children. Korean J Orthod 2008;38:74–82.

31. Alves M Jr, Baratieri C, Nojima LI, Nojima MC, Ruellas AC. Three-dimensional assessment of pharyngeal airway in nasal- and mouth-breathing children. Int J Pediatr Otorhinolaryngol 2011;75:1195-9.
32. Alves PV, Zhao L, O'Gara M, Patel PK, Bolognese AM. Three-dimensional cephalometric study of upper airway space in skeletal Class II and III healthy patients. J Craniofac Surg 2008;19:1497-507.
33. Hong J S, Oh K M, Kim B R, Kim Y J, Parkb Y H. Three-dimensional analysis of pharyngeal airway volume in adults with anterior position of the mandible. Am J Orthod Dentofacial Orthop 2011;140:e161-e169
34. Enciso R, Nguyen M, Shigeta Y, Ogawa T, Clark GT. Comparison of cone-beam CT parameters and sleep questionnaires in sleep apnea patients and control subjects. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:285-93.
35.Abramson Z, Susarla S, August M, Troulis M, Kaban L. Three-dimensional computed tomographic analysis of airway anatomy in patients with obstructive sleep apnea. J Oral Maxillofac Surg 2010;68:354-62.
36. Walsh JH, Leigh MS, Paduch A, Maddison KJ, Philippe DL, Armstrong JJ, et al.Evaluation of pharyngeal shape and size using anatomical optical coherence tomography in individuals with and without obstructive sleep apnoea. J Sleep Res 2008;17:230-8.
37.Vos W, De Backer J, Devolder A, Vanderveken O, Verhulst S, Salgado R, et al.Correlation between severity of sleep apnea and upper airway morphology based on advanced anatomical and functional imaging. J Biomech 2007;40:2207-13.
38. Abu Allhaija ES, Al-Khateeb SN. Uvulo-glosso-pharyngeal dimensions in different anteroposterior skeletal patterns. Angle Orthod 2005;75:1012-8.
39. Celikoglu M, Bayram M, Sekerci AE, Buyuk SK, Toy E. Comparison of pharyngeal airway volume among different vertical skeletal patterns: a cone beam computed tomography study. Angle Orthod. 2014;84:782–787.

MITK Workbench Software



Turtleseg software

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PATIENTS PHOTOGRAPHS

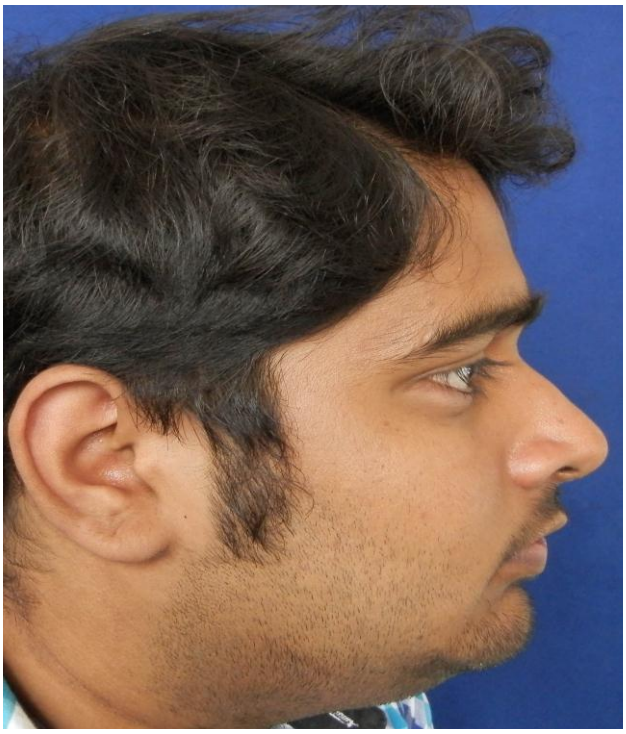
Class I patient:

Lateral Profile view

Occlusal view showing molar relation

Class II Patient:

ISSN 2515-8260 Volume 07, Issue 09, 2020



Lateral Profile view

Occlusal view showing molar relation

CLASS III PATIENT:

Lateral Profile view

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Occlusal view showing molar relation

Figure 1: Image showing dicom data opened using Turtleseg software:

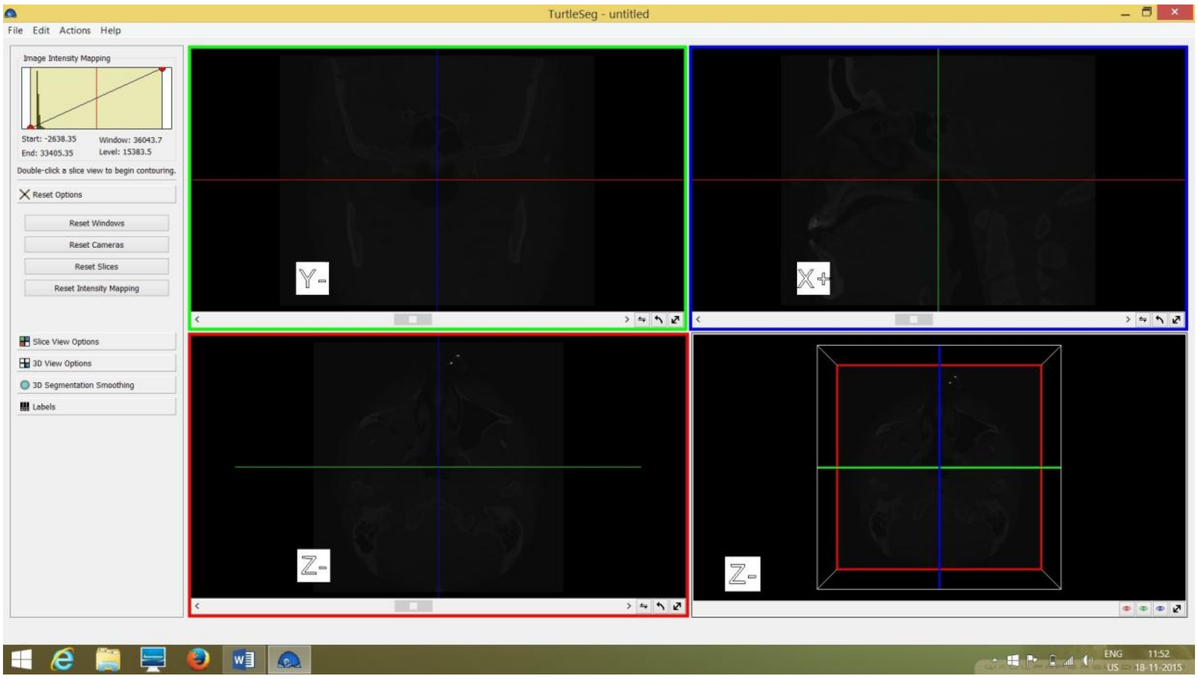

Figure 2: Image intensity mapping to view airway borders using Turtleseg software:

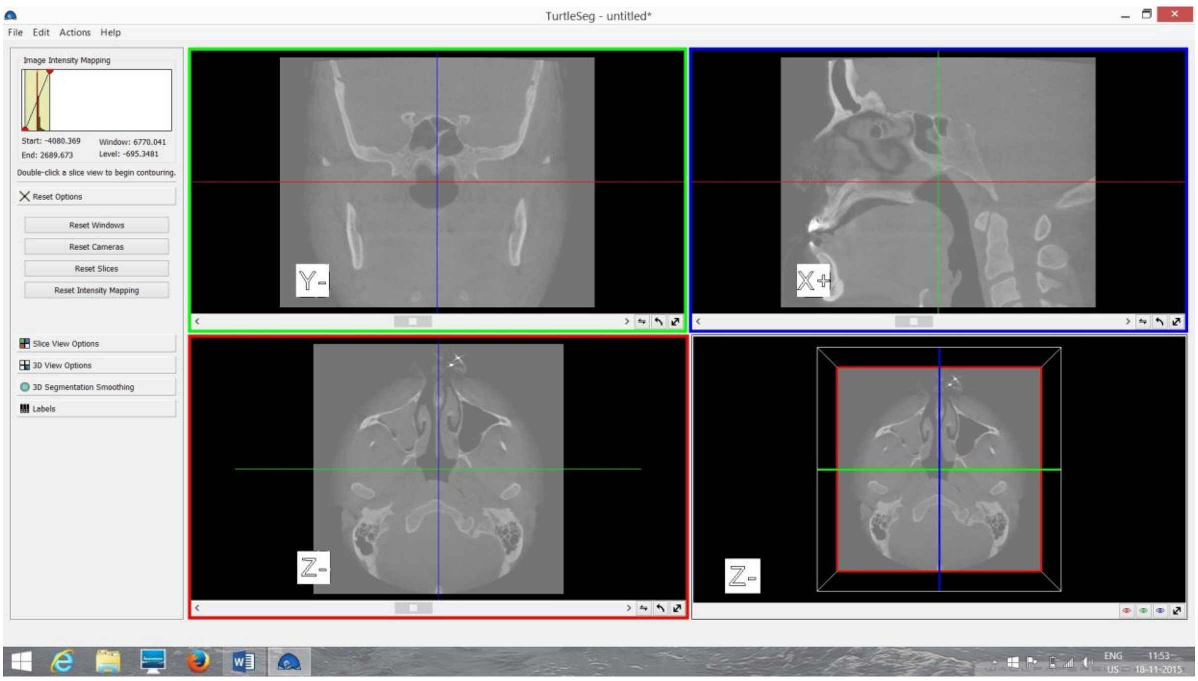

Figure 3: Upper limit contouring in axial slice for oropharynx using Turtleseg software:

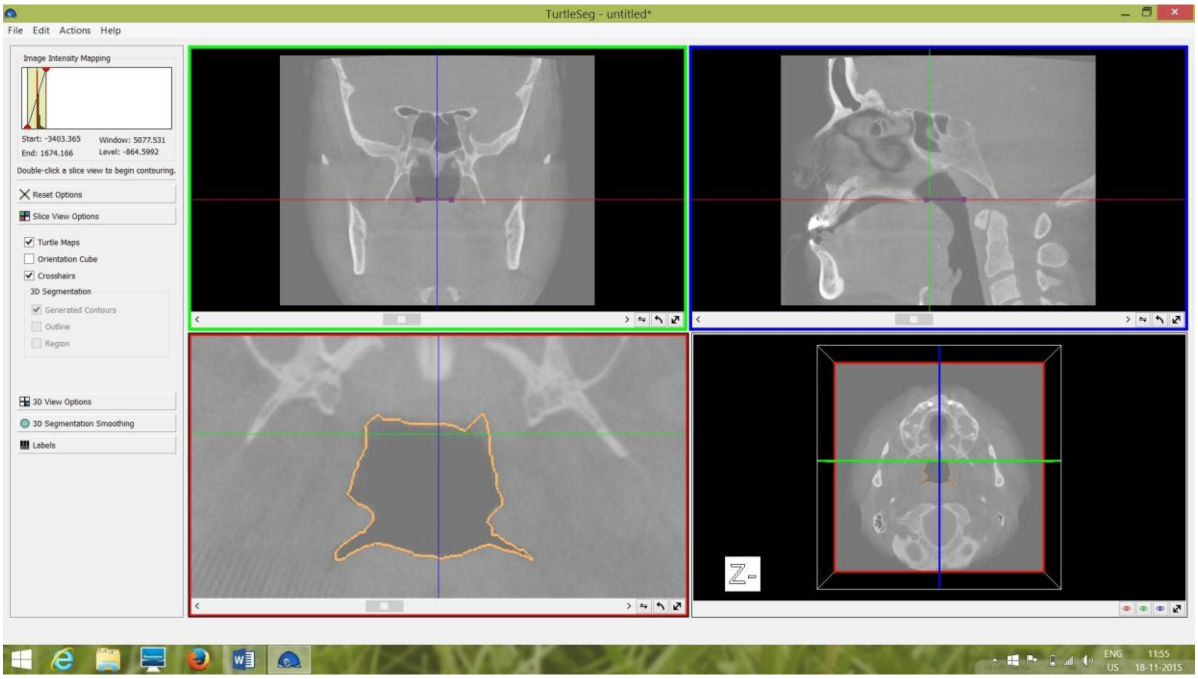

Figure 4: Lower limit contouring in axial slice for oropharynx using Turtleseg software:

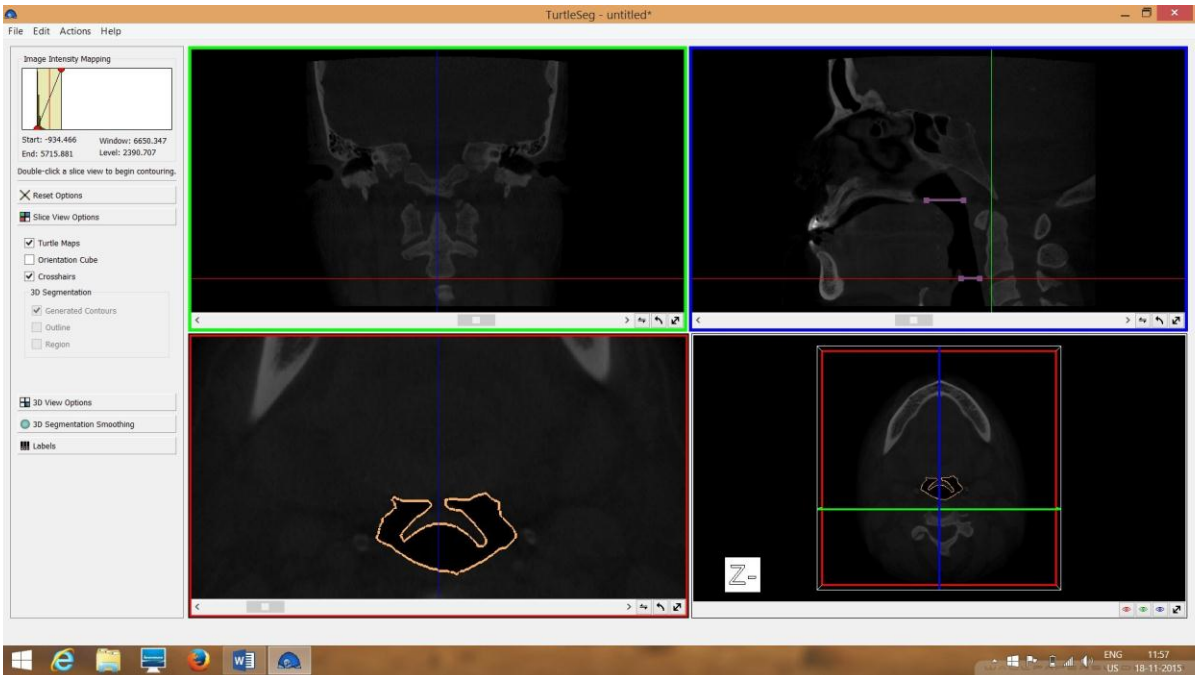

Figure 5: Saggital slice contour marking using Turtleseg software:

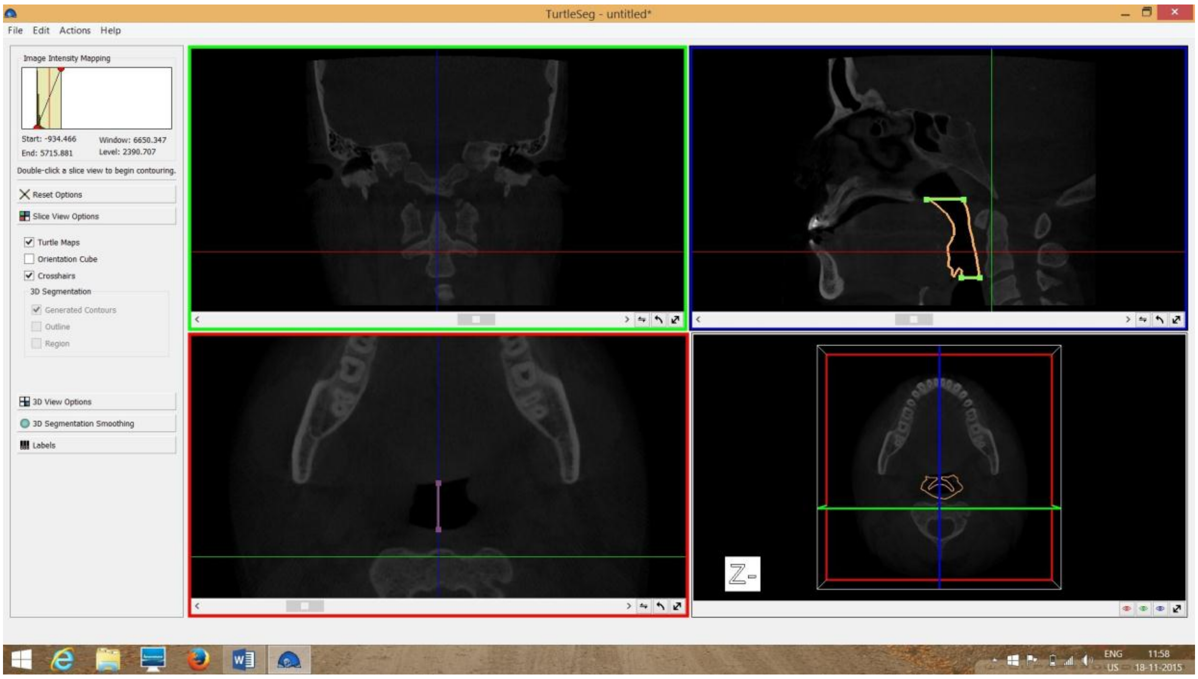

Figure 6: Initial segmentation of oropharynx using Turtleseg software:

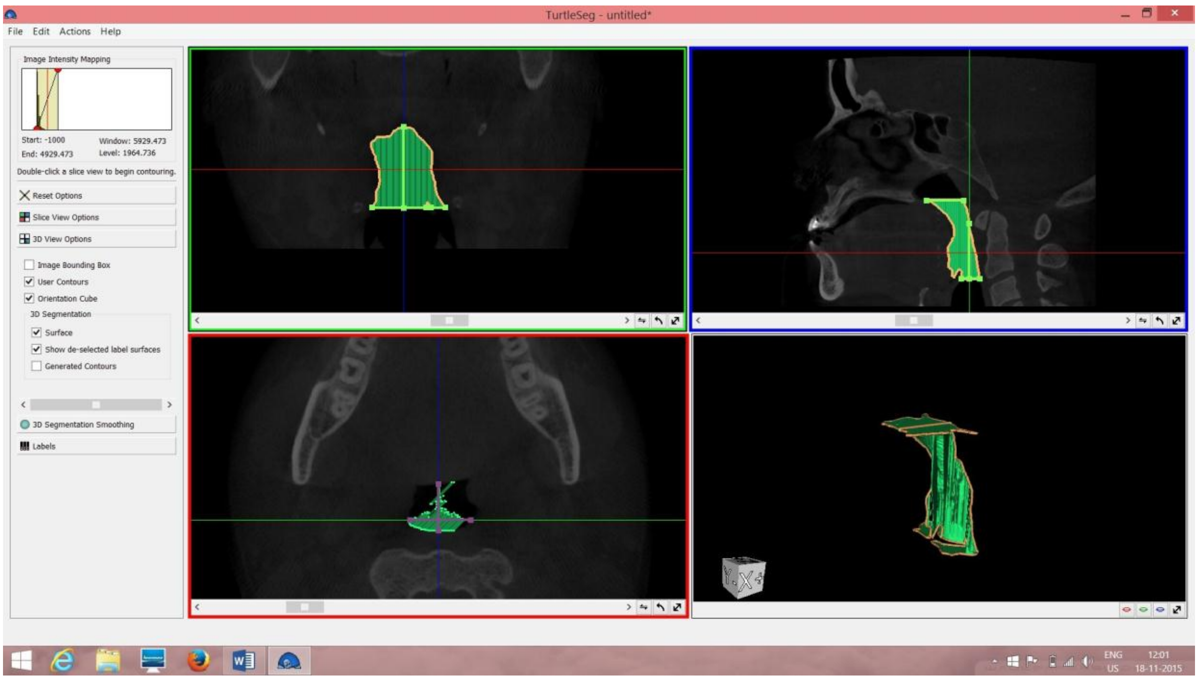

Figure 7: Final Segmentation of oropharynx using Turtleseg software:

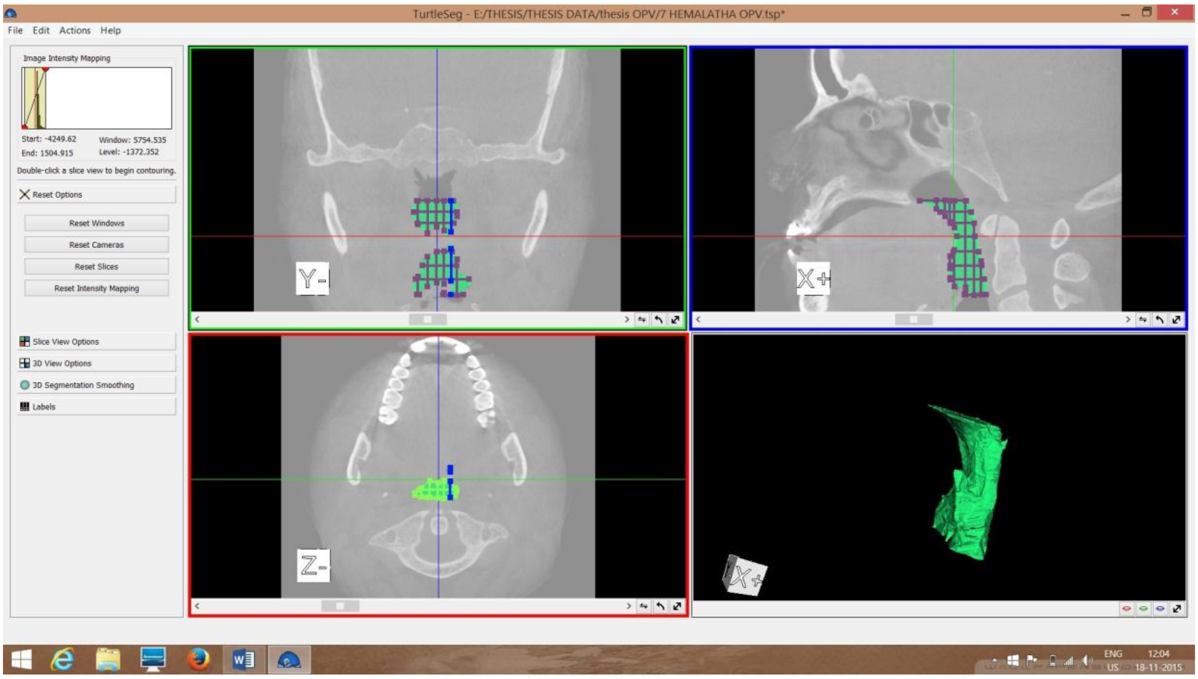

Figure 8: Segmentation volume of oropharynx using Turtleseg software:

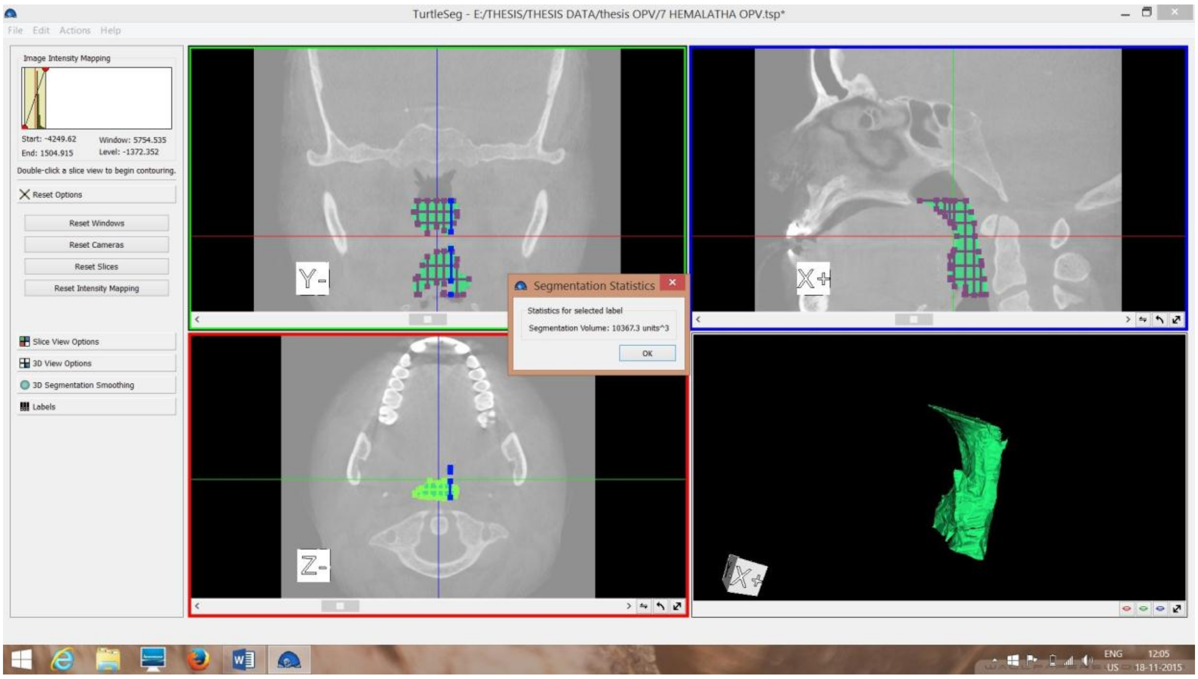

Figure 9: Segmentation of nasopharynx using Turtleseg software:

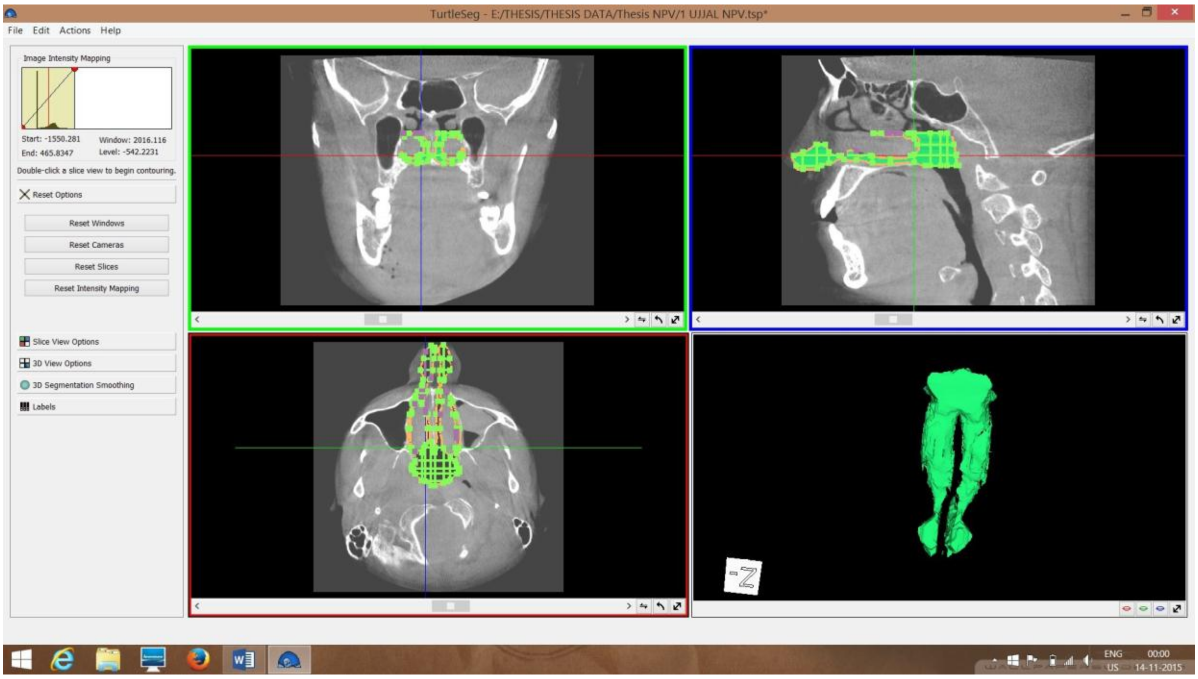

Figure 10: Measurement of CMinAx in axial slice using MITK Workbench software:

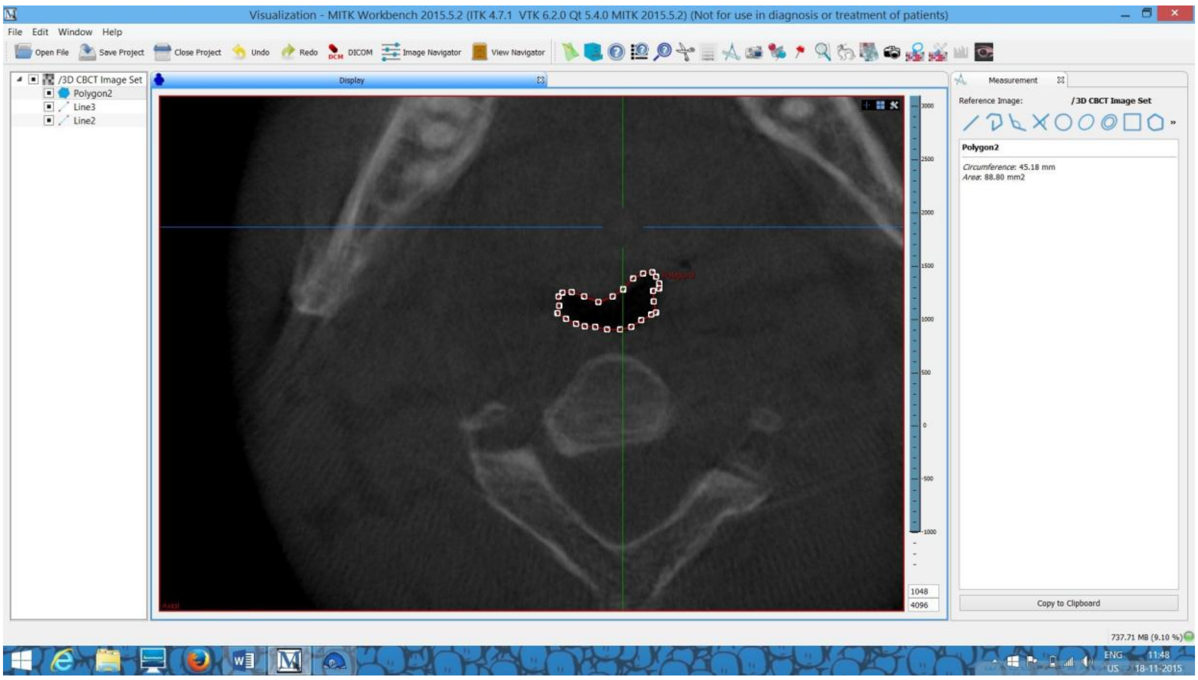

Figure 11: Measurement of CPAS in saggittal slice using MITK Workbench software:

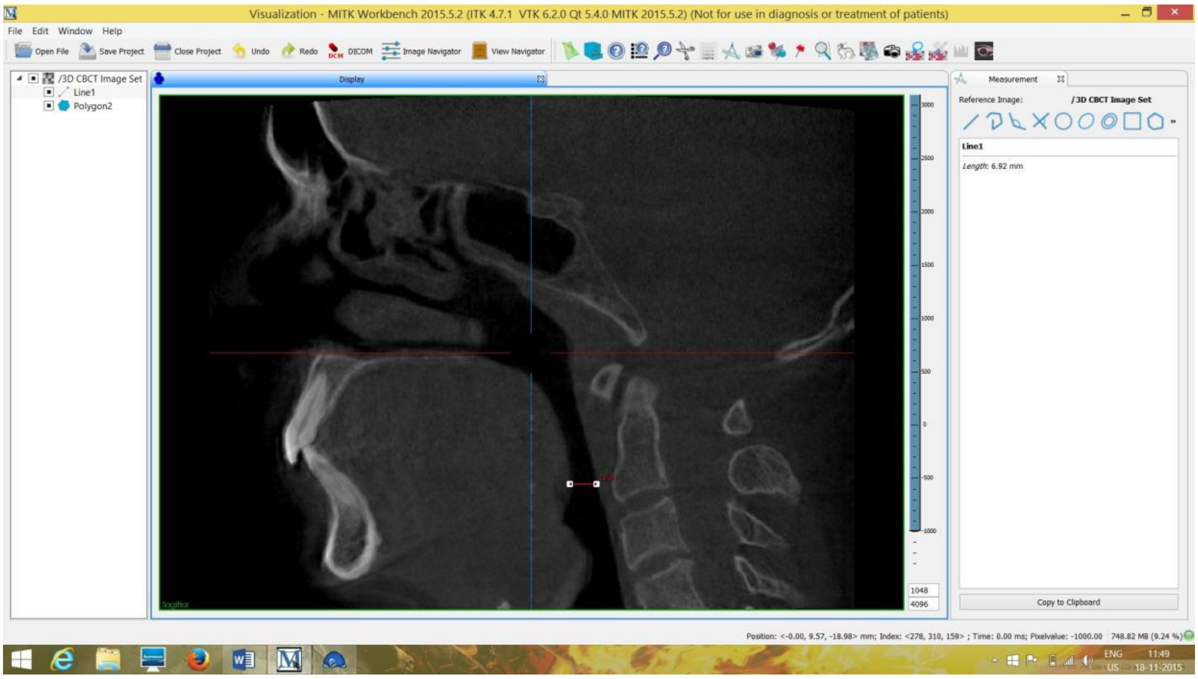

Figure 12: Measurement of HOP in saggital using MITK Workbench software:

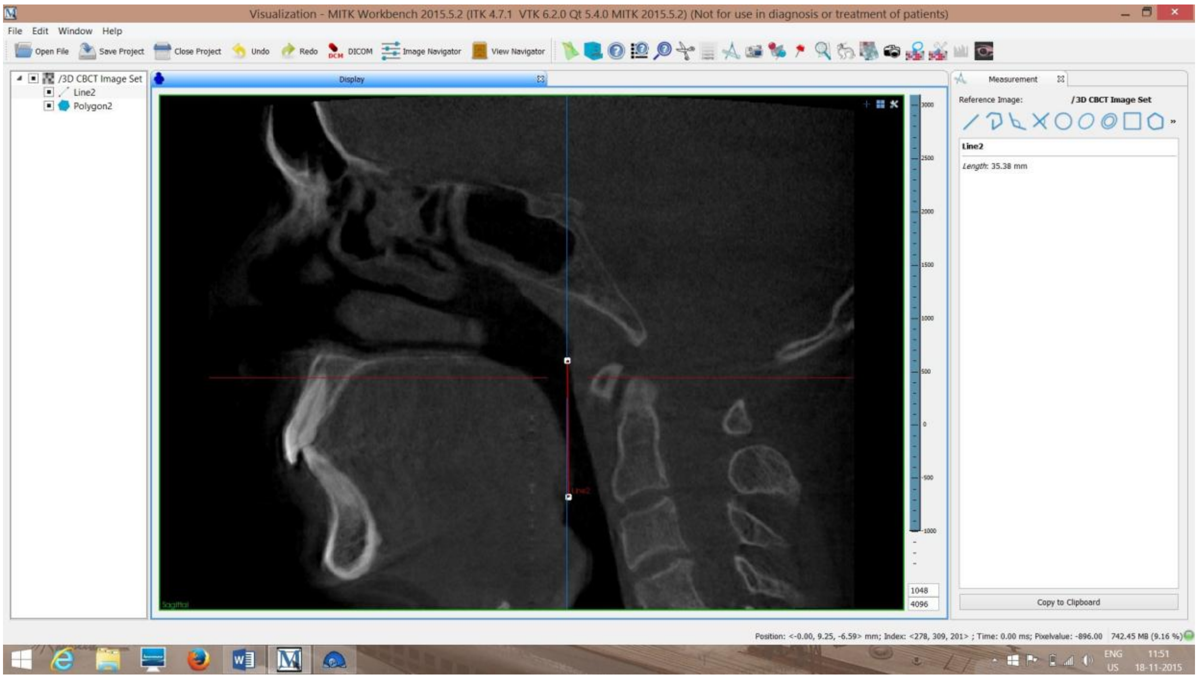

Table 1: TEST FOR NORMALITY

	Class	Min	Max	Shapiro-Wilk		
				Statistic	df	p-value
OPV (mm3)	1	4460.91	10472	0.88	15	0.05(NS)
	2	2114.4	12587.4	0.96	15	0.83(NS)
	3	6233	14758.5	0.91	15	0.17(NS)
NPV (mm3)	1	6602.48	14263.26	0.96	15	0.75(NS)
	2	3791.47	11767.6	0.96	15	0.81(NS)
	3	5501	11420.56	0.96	15	0.74(NS)
HOP (mm)	1	33.14	49.01	0.97	15	0.94(NS)
	2	37.1	49.53	0.96	15	0.80(NS)
	3	38.69	54.21	0.95	15	0.56(NS)
CMinAx (mm2)	1	63.08	282.5	0.92	15	0.23(NS)
	2	28.26	248.97	0.94	15	0.45(NS)
	3	60.85	589.82	0.85	15	0.02*
CPAS (mm)	1	3.84	11.9	0.93	15	0.29(NS)
	2	4.19	12.68	0.83	15	0.01*
	3	3.16	19.11	0.91	15	0.14(NS)
BMI	1	21.11	27.69	0.90	15	0.10(NS)
	2	20.57	25.06	0.96	15	0.77(NS)
	3	20.86	28.52	0.91	15	0.16(NS)

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 2: -Tests of correlation (ANOVA)

		N	Mean	Std. Deviation	ANOVA	
					F value	p-value
OPV (mm3)	1	15	8294.73	1786.59	11.06	<0.001*
	2	15	6876.40	2433.72		
	3	15	10941.43	2863.22		
NPV (mm3)	1	15	9889.57	2274.40	3.90	0.03*
	2	15	7916.48	2307.04		
	3	15	8166.30	1673.94		
HOP (mm)	1	15	41.08	4.50	2.67	0.08(NS)
	2	15	43.05	3.25		
	3	15	44.43	4.10		
CMinAx (mm2)	1	15	152.15	71.74	5.38	0.008*
	2	15	122.75	51.31		
	3	15	249.91	170.98		
CPAS (mm)	1	15	6.83	2.46	4.22	0.02*
	2	15	6.75	2.52		
	3	15	10.01	4.94		
BMI	1	15	23.23	1.76	0.35	0.70(NS)
	2	15	22.90	1.31		
	3	15	23.46	2.3		

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 3: -Tests of Intergroup correlation (Tukey post Hoc test)

Variable	(I) Class	(J) Class	Mean Diff. (I-J)	Std. Error	95% Confidence Interval		p-value
					Lower Bound	Upper Bound	
OPV (mm3)	1	2	1418.32	877.19	-712.81	3549.46	0.25(NS)
		3	-2646.70	877.19	-4777.84	-515.57	0.01*
	2	3	-4065.02	877.19	-6196.16	-1933.9	<0.00*
NPV (mm3)	1	2	1973.09	768.76	105.38	3840.80	0.04*
		3	1723.26	768.76	-144.44	3590.97	0.07(NS)
	2	3	-249.82	768.76	-2117.53	1617.88	0.94(NS)
HOP (mm)	1	2	-1.96	1.45	-5.50	1.56	0.37(NS)
		3	-3.35	1.45	-6.89	0.18	0.06(NS)
	2	3	-1.38	1.45	-4.92	2.15	0.61(NS)
CMinAx (mm2)	1	2	29.39	40.56	-69.14	127.93	0.75(NS)
		3	-97.75	40.56	-196.30	0.78	0.05(NS)
	2	3	-127.15	40.56	-225.69	-28.61	0.009*
CPAS (mm)	1	2	0.08	1.28	-3.02	3.19	0.99(NS)
		3	-3.18	1.28	-6.29	-0.07	0.04*
	2	3	-3.26	1.28	-6.37	-0.15	0.03*
BMI	1	2	0.33	0.67	-1.30	1.96	0.87(NS)
		3	-0.23	0.67	-1.86	1.40	0.93(NS)
	2	3	-0.56	0.67	-2.19	1.07	0.68(NS)

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 4.1: -Tests of Intragroup correlation Pearson's correlation test for class I

CLASS	Parameter		OPV (mm3)	NPV (mm3)	HOP (mm)	CMinAx (mm2)	CPAS (mm)
1	OPV (mm3)	r					
		p-value	1				
	NPV (mm3)	r	0.56	1			
		p-value	0.02*				
	HOP (mm)	r	0.47	-0.10	1		
		p-value	0.07(NS)	0.72(NS)			
	CMinAx (mm2)	r	0.54	0.22	0.24	1	
		p-value	0.03*	0.42(NS)	0.37(NS)		
	CPAS (mm)	r	0.22	-0.02	0.01	0.68	1
		p-value	0.42(NS)	0.93(NS)	0.95(NS)	0.005*	
	BMI	r	0.16	-0.008	-0.001	0.35	0.12
		p-value	0.55(NS)	0.97(NS)	0.99(NS)	0.19(NS)	0.64(NS)

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 4.2: -Tests of Intragroup correlation Pearson's correlation test for class II

CLASS	Parameter		OPV (mm3)	NPV (mm3)	HOP (mm)	CMinAx (mm2)	CPAS (mm)
2	OPV (mm3)	r	1				
		p-value					
	NPV (mm3)	r	0.50	1			
		p-value	0.05(NS)				
	HOP (mm)	r	0.41	0.19	1		
		p-value	0.12(NS)	0.48(NS)			
	CMinAx (mm2)	r	0.67	0.27	0.30	1	
		p-value	0.006*	0.32(NS)	0.26(NS)		
	CPAS (mm)	r	0.26	0.24	0.08	0.74	1
		p-value	0.33(NS)	0.37(NS)	0.77(NS)	0.001*	
	BMI	r	0.25	-0.06	0.15	0.03	-0.37
		p-value	0.36(NS)	0.80(NS)	0.57(NS)	0.90(NS)	0.17(NS)

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 4.3: -Tests of Intragroup correlation Pearson's correlation test for class III

CLASS	Parameter		OPV (mm3)	NPV (mm3)	HOP (mm)	CMinAx (mm2)	CPAS (mm)
3	OPV (mm3)	r	1				
		p-value					
	NPV (mm3)	r	0.61	1			
		p-value	0.01*				
	HOP (mm)	r	-0.15	-0.21	1		
		p-value	0.57(NS)	0.45(NS)			
	CMinAx (mm2)	r	0.63	0.48	-0.35	1	
		p-value	0.01*	0.06(NS)	0.19(NS)		
	CPAS (mm)	r	0.60	0.42	-0.46	0.94	1
		p-value	0.01*	0.11(NS)	0.07(NS)	<0.001*	
	BMI	r	-0.21	-0.09	0.57	-0.14	-0.23
		p-value	0.44(NS)	0.75(NS)	0.02*	0.60(NS)	0.39(NS)

*P<0.05 statistically significant
p>0.05 non significant, NS

Figure 1: MEAN AGE IN CLASS I , CLASS II & CLASS III GROUP

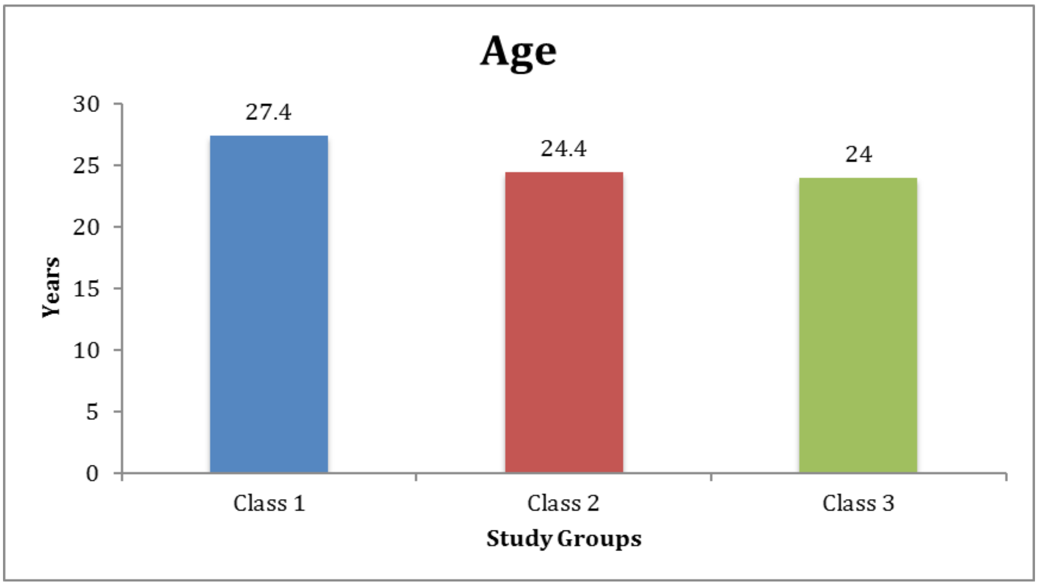

FIGURE 2 MEAN OPV AND NPV IN CLASS I, CLASS II AND CLASS III

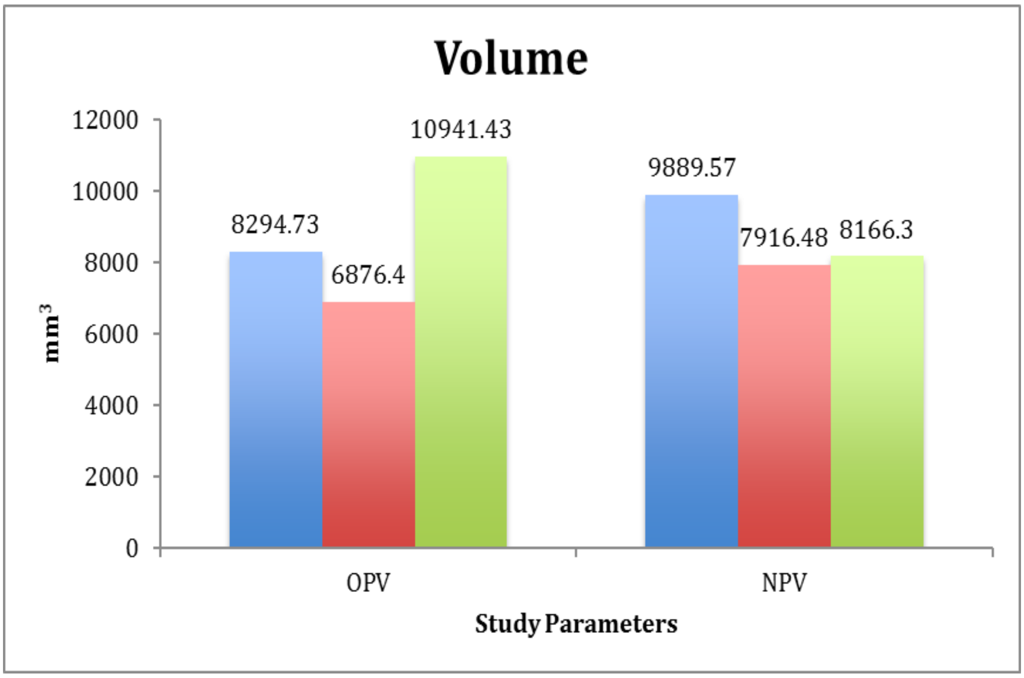

FIGURE 3: MEAN HOP IN CLASS I, CLASS II AND CLASS III

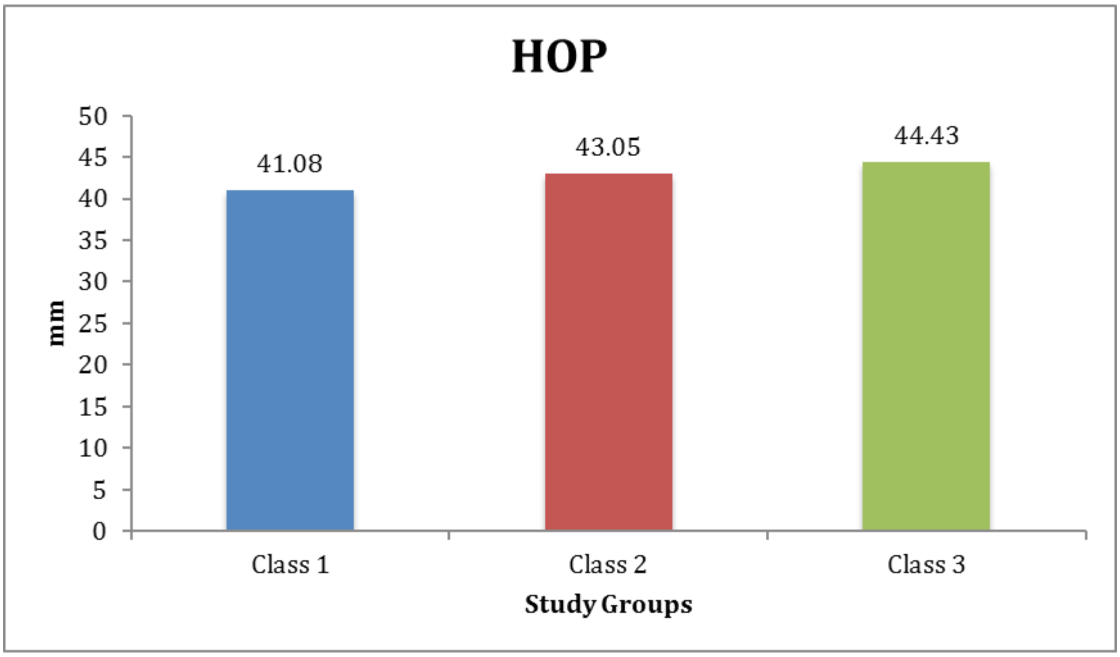

FIGURE 4: MEAN CMinAx IN CLASS I, CLASS II AND CLASS III

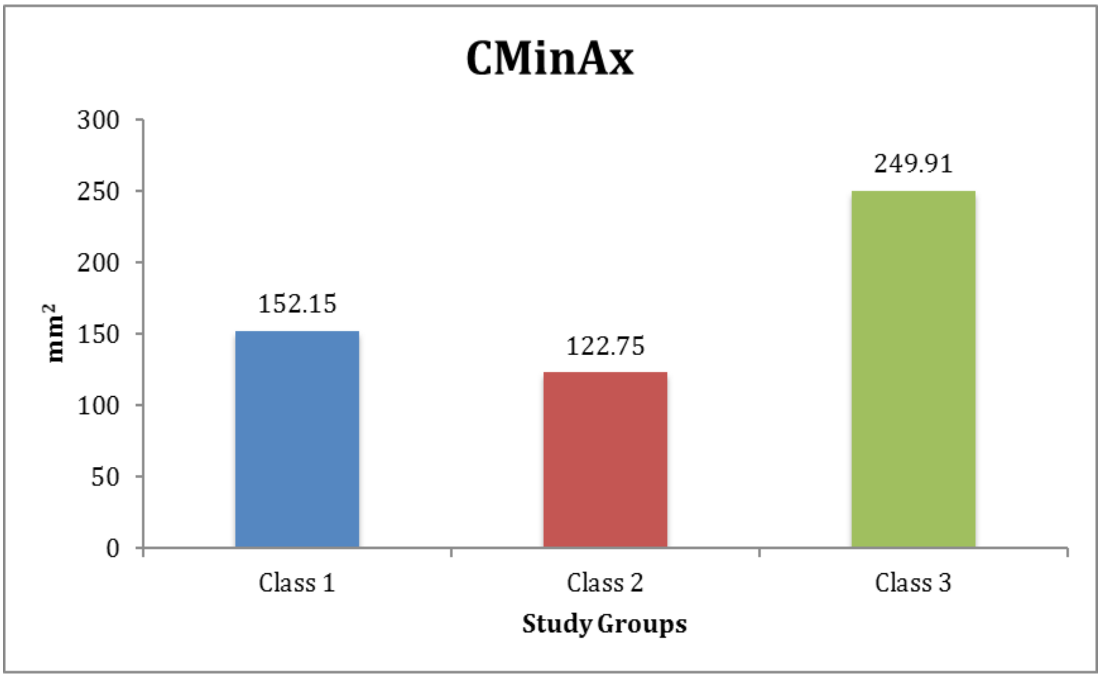

FIGURE 5: MEAN CPAS IN CLASS I, CLASS II AND CLASS III

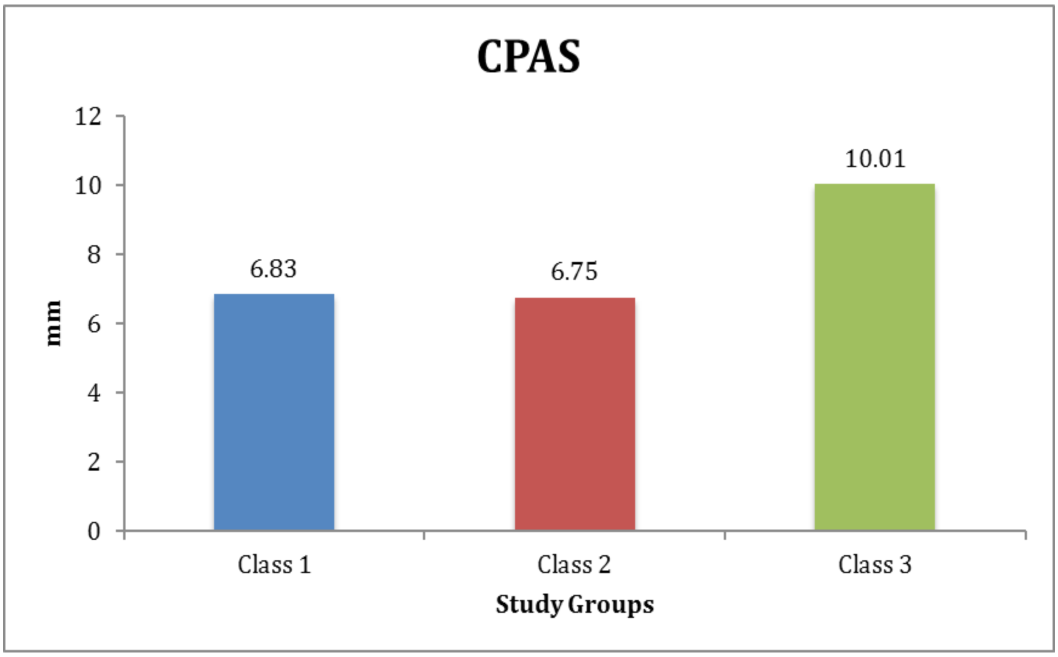

FIGURE 6: MEAN BMI IN CLASS I, CLASS II AND CLASS III

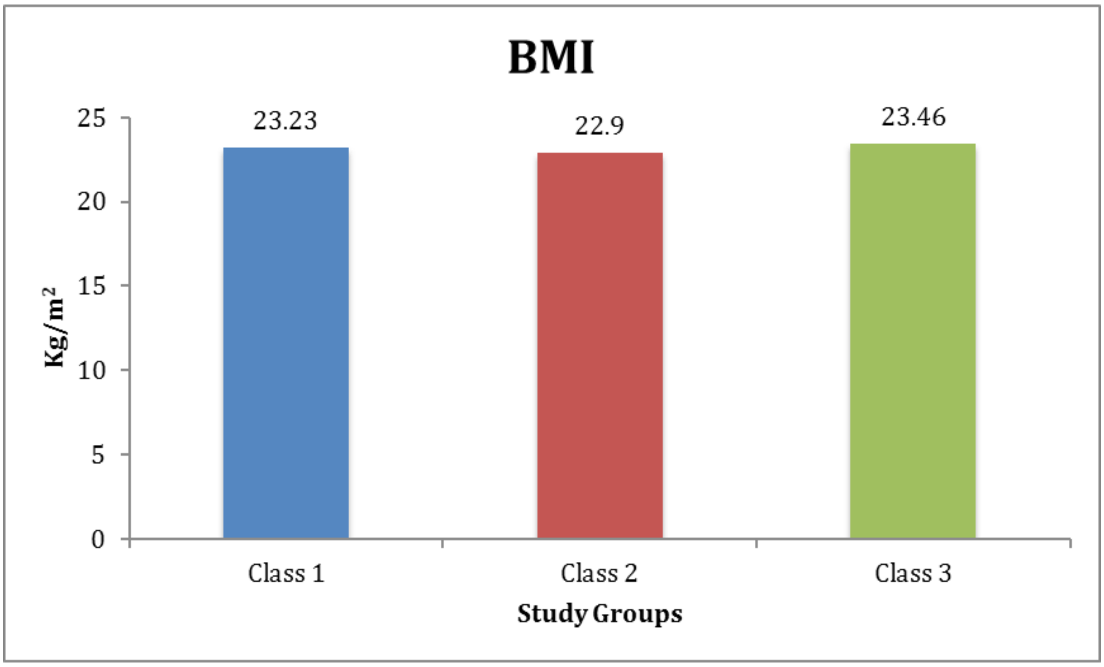

FIGURE 7: Correlation between OPV & HOP in class I, class II and class III

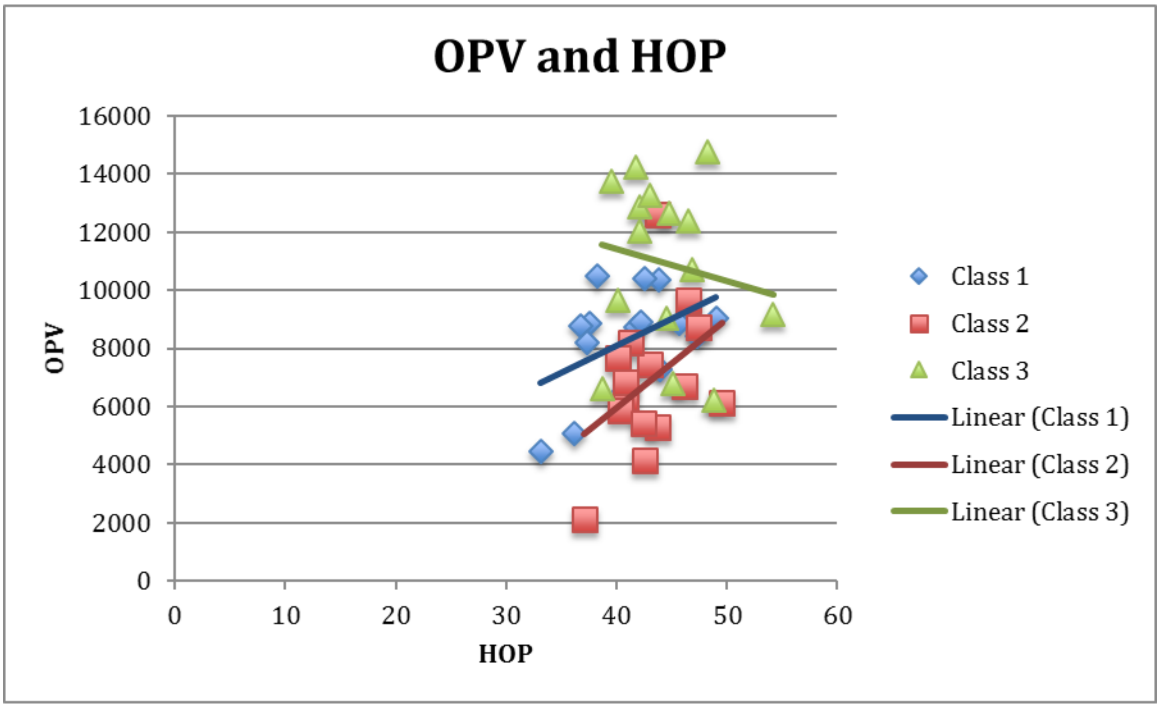

FIGURE 8: Correlation between OPV & CMinAx in class I, class II and class III

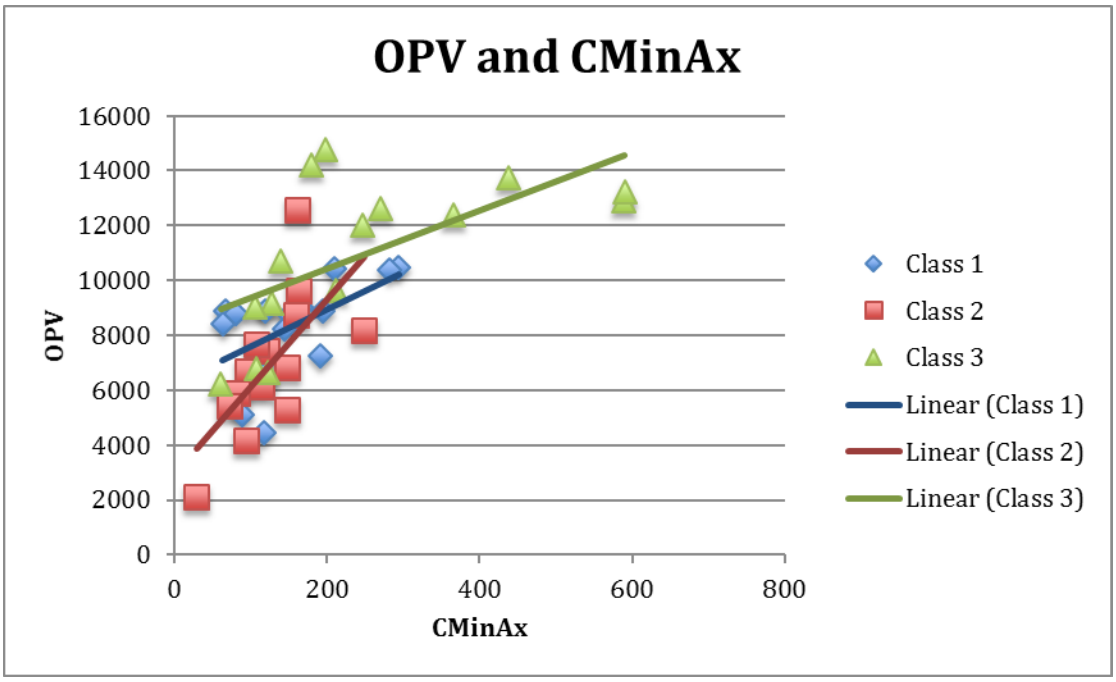

FIGURE 9: Correlation between OPV & CPAS in class I, class II and class III

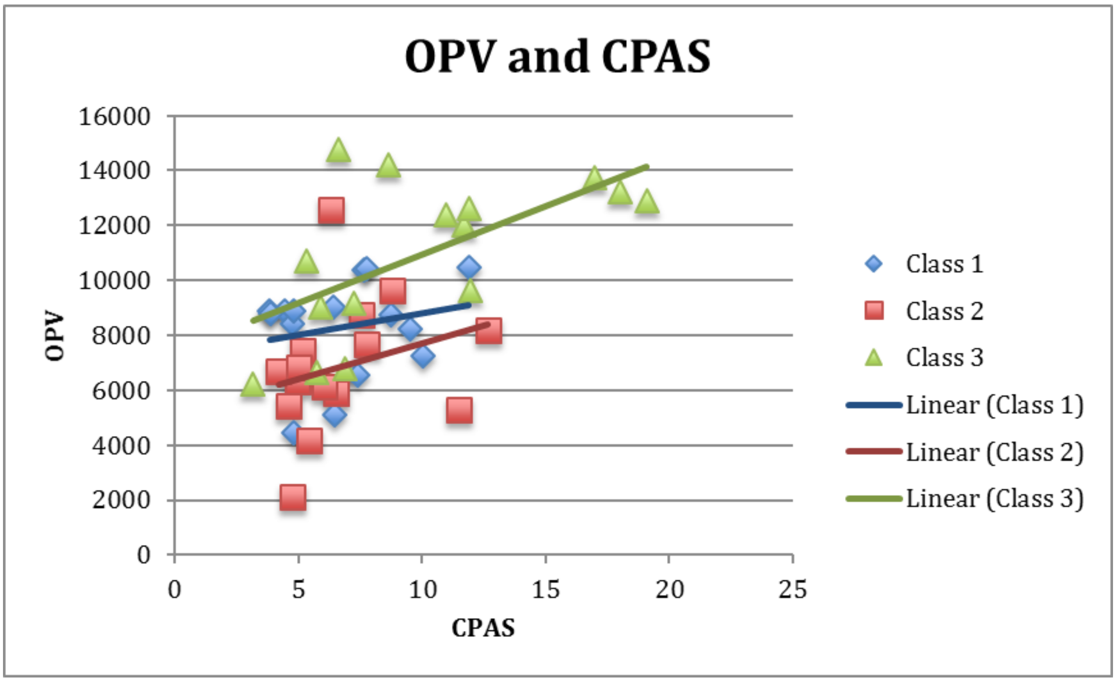

FIGURE 10: Correlation between NPV & HOP in class I, class II and class III

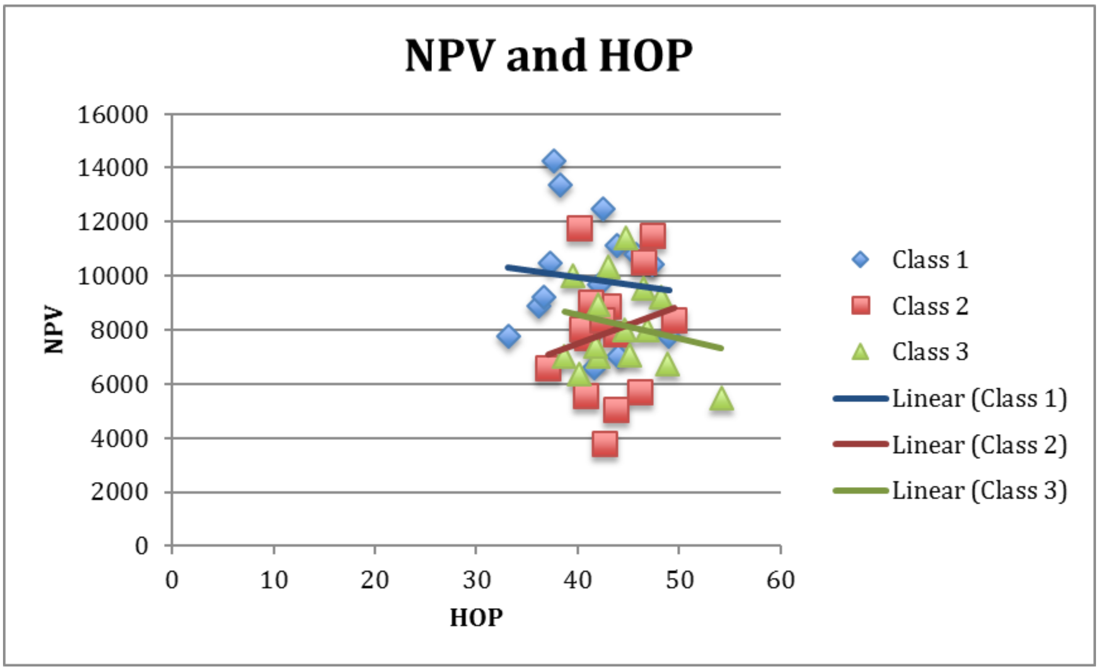

FIGURE 11: Correlation between NPV & CMinAx in class I, class II and class III

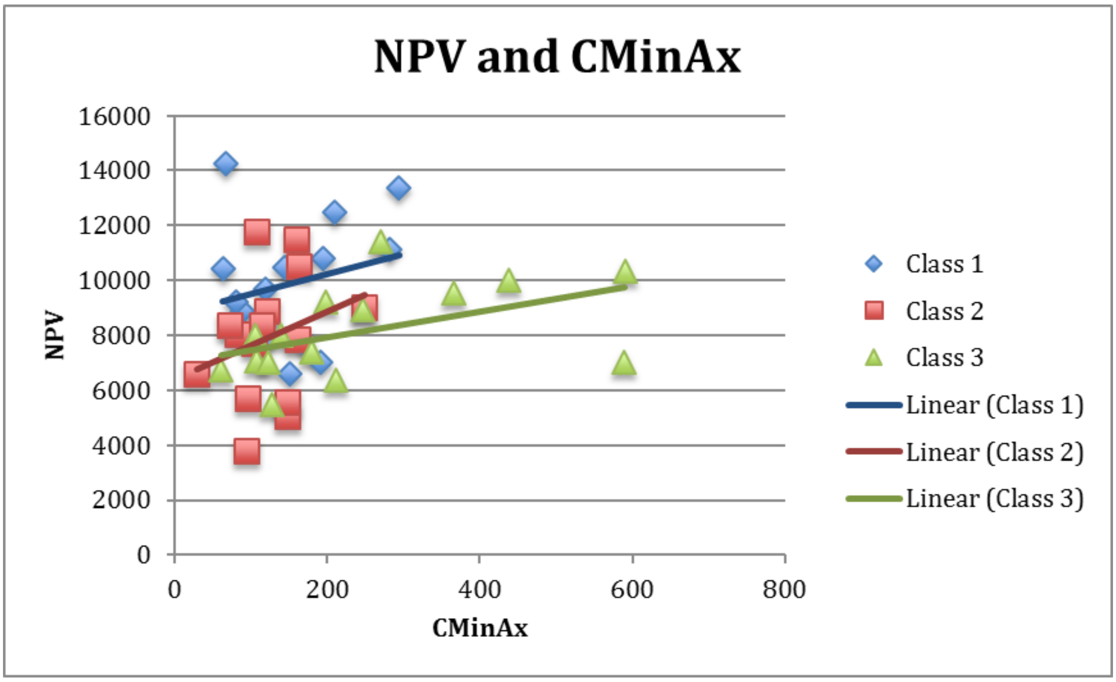

FIGURE 12: Correlation between NPV & CPAS in class I, class II and class III