Analysis of inferior nasal turbinate volume in subjects with nasal septum deviation: a retrospective cone beam tomography study

Shishir Shetty[1], Saad Wahby Al-Bayatti[1], Mohammad Khursheed Alam[2], Natheer Al-Rawi[1], Vinayak Kamath[3], Shoaib Rahman Tippu[4], Sangeetha Narasimhan[1], Sausan Al Kawas[1], Walid El-sayed[5], Kumuda Rao[6], Renita Castelino[6]

[1]Department of oral and craniofacial health sciences, College of Dental Medicine, University of Sharjah, United Arab Emirates
[2]Preventive dentistry department, College of Dentistry, Jouf University, Saudi Arabia
[3]Department of Public health dentistry, Goa Dental College and Hospital, Goa, India
[4]Department of Diagnostic and Surgical Dental Sciences, College of Dentistry, Gulf medical University, United Arab Emirates
[5]College of Dentistry, Gulf medical University, United Arab Emirates
[6]Department of Oral medicine and radiology, AB Shetty Memorial Institute of Dental Sciences, Nitte (Deemed to be University), Mangalore, India

Corresponding Author:
Shishir Shetty[1]
College of Dental Medicine, University of Sharjah, United Arab Emirates
Email address: sshetty@sharjah.ac.ae

Abstract

Background- The association of the linear dimensions of the inferior turbinate hypertrophy with nasal septal deviation has been studied recently. However, the volumetric dimensions provide more accurate status of the turbinate hypertrophy compared to linear measurements. The aim of this study was to analyze the association of inferior nasal turbinate volume with the degree of nasal septal deviation (NSD).

37   **Methods-** A retrospective evaluation of the cone beam computed tomography (CBCT) scans of

38   412 patients was carried out to obtain 150 scans which were included in the study. . The scans

39   were categorized into 3 groups. Group 1 comprised of 50 scans of patients with no inferior

40   turbinate hypertrophy (ITH) and no nasal septal deviation . Group 2 comprised of 50 scans of

41   patients with ITH and no NSD. Whereas Group 3 included 50 scans of patients with ITH and

42   NSD.

43   The total turbinate volume of inferior turbinates (bilateral) were determined by using Vesalius 3D

44   software (PS-Medtech, Amsterdam, Netherlands).

45   **Results-** The intraclass correlation coefficient (ICC) between the volumetric estimations

46   performed by the two radiologist was 0.82. There was no significant age and gender related

47   changes in the total turbinate volume. Patients in Group 3 had significantly higher (p=0.001) total

48   turbinate volume compared to Group 2 and Group 1. There was a positive and a significant

49   correlation (r= 0.52, P=0.002) between the degree of septal deviation and total turbinate volume.

50   When the total turbinate volume of the patients with different types of septal deviation was compared in

51   Group 3, a statistically significant difference (P=0.001) was observed. Regression analysis revealed that

52   the septal deviation angle (SDA) (P=0.001) had a relationship with total turbinate volume.

53   From the results of the study we can conclude that the total turbinate volume is higher in patients

54   with nasal septal deviation. It can also be concluded that the septal deviation angle has a positive

55   correlation with total turbinate volume. The data obtained from the study can be useful in post-

56   surgical follow up and evaluation of patients with nasal septal deviation and hypertrophied inferior

57   nasal turbinate.

58

59   **Introduction**

60   Prolonged obstruction of the nasal cavity is usually caused by nasal septal deviation (NSD) and

61   inferior turbinate hypertrophy (ITH) *(Abdullah & Singh, 2021).* In most of the cases of ITH,

62   medical line of treatment yields satisfactory results. However, in some instances when medical

63   line of treatment does not provide satisfactory results surgical intervention is required *(Aslan,*

64   *2013)* Turbinate volume reduction is the main aim of all the protocols used for the treatment of

65   ITH *(Numminen et al., 2003).* Although acoustic rhinometry (AR) is frequently used to study

66   airway volume, accurate details of the especially regarding the posterior areas of the turbinate have

67   been questionable *(Numminen et al., 2003).* Computed tomography (CT) provides the most

68   accurate volume measurement of the paranasal structures and volume *(Orhan, Aksoy & Oz, 2017).*

69   Though CT scans provide appropriate diagnostic quality, the radiation dose considerations are

70   debatable.[4] Cone beam tomography (CBCT) has recently evolved as low radiation imaging

71   modality for evaluating sinonasal structure *(Orhan, Aksoy & Oz, 2017).* Apart from lower radiation

72   dose CBCT has higher image resolution, lower cost and provides thinner image slices compared

73   to CT. In our previous work we have studied the association between NSD and inferior turbinate

74   hypertrophy (ITH) using CBCT *(Shetty et al., 2021).* We found that the width of the inferior nasal

75   turbinates had an association with the degree of nasal septal deviation. Based on the experience of

76   our previous work we believe that the total turbinate volume of the inferior nasal turbinates may

77   have an association with the degree of nasal septal deviation. We also wanted to determine whether

78   there was association of the total turbinate volume with age and gender of the patients. To the best

79   of our knowledge we did not find any studies investigating the total turbinate volume with the

80   NSD. We believe that the results obtained from the volumetric analysis will aid in the diagnosis

81   and management of cases with of NSD with ITH. With this background we conducted a study to

82   determine the association between NSD and the volume of the inferior turbinates using CBCT.

83

Materials & Methods

85 A retrospective evaluation of CBCT scans of 412 patients who had attended University Dental

86 Hospital Sharjah (UDHS) clinics for various dental treatments from January 2017 to December

87 2020 was carried out. Based on the eligibility criteria for the three groups to obtain 150 scans were

88 selected for the study. Ethical approval for the study was obtained from the institutional ethical

89 committee (Reference number: REC-21-01-10-01, University of Sharjah). Informed written

90 consent was obtained from all patients involved in the study.

91 CBCT scans of male and female patients between 18 to 75 years of age were included in the study.

92 The study data is available at figshare; doi 10.6084/m9.figshare.19103570

93 CBCT scans that were obtained using Galileos, Sirona CBCT Dental Systems (Bensheim

94 Germany) x-ray machine (Field of View 15 cms X 24 cms and voxel size 0.25 mm), were used for

95 this study. The machine was operated using SIDEXIS Operating system at 85 kVp and 7 mA.

96 Assessment of CBCT was be performed directly on a 1920 X 1080 pixel and 23-inch DELL

97 monitor screen.

98 Two dental radiologists with 10 years' experience examined the CBCT scans. A third examiner

99 with equivalent expertise was consulted in case of a disagreement between the two primary

100 examiners. Sample size estimation was done using statistical Software G*Power 3.1. Based on

101 the observation made from previous literature (Anwar et al., 2017; Orhan et al., 2014) and

102 considering effect size of 0.26, 80% power and α error of 5%, a sample size of 49 was calculated

103 which was rounded off to 50 per group

104 . The CBCT scans were screened between January 2021 and June 2021. The scans screened and

105 included based on the grouping criteria until 50 from each group were obtained

106 Group 1- 50 patients with no ITH and no NSD.

107   Group 2- 50 patients with ITH and no NSD.

108   Group 3- 50 patients with ITH and NSD.

109   The criteria for determining ITH was based on the maximal width of inferior turbinate in the

110   coronal CBCT section. A width of more than 10 mm was considered as ITH, based on the

111   findings of published CT and CBCT studies.*(Jha et al., 2020; Shetty et al., 2021)* . Based on the

112   maximal width of the right and left turbinates the scans were further subdivided as unilateral or

113   bilateral ITH. CBCT scans in Group 1 and 2 had no evidence on NSD when viewed from the

114   coronal section of CBCT at the point of crista galli. In CBCT scans of Group 3 the septal

115   deviation angle was determined by the method used *by Shetty et al.,2021* and *Alrawi et al.,2019*

116   (**Figure 1**) . The scans were further classified into mild (1 to 9°), moderate (10° to 15°), and

117   severe (>15°). CBCT scans with artifacts, and incomplete anatomical coverage of the region of

118   interest, scans of patients with mid facial trauma, orthognatic surgery and cleft palate were

119   excluded from the study

120   The total turbinate volume of inferior turbinates (bilateral) were determined by using Vesalius 3D

121   software (PS-Medtech, Amsterdam, Netherlands). The volumetric analysis was performed by the

122   two radiologist separately. To achieve uniformity in volumetric analysis a prior agreement was

123   reached regarding the anterior, posterior and the lateral extent of the inferior nasal turbinates. The

124   mean total turbinate volume was the calculated. In the first step, CBCT scans were imported into

125   the software. The inferior nasal turbinates were then segmented using surface in built extraction

126   tools (scissors and eraser**). After completing the segmentation of inferior nasal turbinates the

127   volume was determined using the picking section of the software **(Figure 2).**

128   The data was statically analyzed using IBM SPSS statistics (Version 22, Armonk. NY: IBM Corp).

129   The total turbinate total turbinate volume of the patients among the three groups was compared

130   using the ANOVA and Tukey Post Hoc Test. The total turbinate volume of the patients with

131   different types of septal deviation in Group 3 was compared using ANOVA and Tukey Post Hoc

132   Test. The correlation between total turbinate volume and septal deviation angle in Group 3 was

133   determined using Pearson's Correlation Test. The total turbinate volume between the male and

134   female patients in study groups was compared using Independent sample t test. Regression analysis

135   and dot plots were used to describe the correlation/difference between turbinate volume and other

136   continuous/categorical factors.

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142   **Results**

143   The intraclass correlation coefficient (ICC) between the volumetric estimations performed by the

144   two radiologist was 0.82. Each examiner re-evaluated 5% of the scans from the total samples

145   after a gap of 15 days to determine the intra-examiner reliability (ICC=0.93)

146   This value indicates a good reliability of the volumetric estimation technique used in the study.

147   When the total turbinate total turbinate volume of the patients among the three groups was

148   compared, there was statistically significant difference (P=0.001) (Table 1, Table 2). Patients in

149   Group 3 had significantly higher total turbinate volume when compared to Group 1 and Group 2.

150   Patients in Group 1 had lowest total turbinate volume among the groups.

151   On comparison of the total turbinate volume between patients with unilateral and bilateral

152   hypertrophy in Group 2, there was no statistically significant difference (P=0.99). However, there

153   was a significant difference (P=0.01) of the total turbinate volumes between patients with

154   unilateral and bilateral turbinate hypertrophy in Group 3 (Table 3). This suggested that in the

155   presence of NSD there is a significant increase in the total turbinate volume in patients with

156   unilateral turbinate hypertrophy.

157   When the total turbinate volume of the patients with different types of septal deviation was

158   compared in Group 3, a statistically significant difference (P=0.001) was observed (Table 4).

159   However, during pairwise comparison the difference in total turbinate volume between mild and

160   moderate type of septal deviation was not significant (P=1.0) (Table 5)

161   Correlation of the total turbinate volume in patients of study group 3 with septal deviation angle

162   revealed a moderate statistically significant correlation (r=0.52, P=0.001) (Table 6). This finding

163   suggests that the total turbinate volume tends to increase as the degree of nasal septal deviation

164   increases.

165   There was no significant correlation between total turbinate volume and age of the patients in the

166   study groups (Table 7).There was no statistically significant difference in the total turbinate

167   volume between the male and female patients of the study groups (Table 8).

168

169   Regression analysis of the parameters in group 3 revealed that septal deviation type (P=0.001),

170   septal deviation angle (P=0.001) and type of hypertrophy (P=0.001), had significant relationship

171   with the total turbinate volume. Whereas no significant change in the total turbinate volume was

172   observed when the gender (P=0.68) and age (P=0.53) of the patients was considered. (Table

173   9)(Figure 3).

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177 **Discussion**

178 Chronic nasal obstruction can be caused due several factors, including NSD and mucosal turbinate

179 hypertrophy of the nasal turbinates *(Kumar, Anand & Pal, 2017).* In order to reduce nasal

180 obstruction and improve air passage into the nasal valve reduction in the volume of ITH and

181 correction of NSD should be addressed simultaneously *(Illum, 1997).* Earlier studies have

182 investigated the linear dimensions of ITH and correlated them with SDA *(Chiesa Estomba et al.,*

183 *2015).* Recent studies have revealed that volumetric measurements are more accurate in

184 demonstrating the extent of the pathology compared to the linear measurements *(Clarke et al.,*

185 *2012; Pérez Sayáns et al 2020).* In the present study we have determined the volume of ITH and

186 associated it with NSD. Vesalius SD software was used for the purpose of segmentation and

187 volume determination of the ITH in the present study. Recent studies have demonstrated that

188 Vesalius 3D provides precise volumetric analysis of the anatomic structures *(Almgoter & Ziad Al-*

189 *Dahan, 2020)*

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191 In the present study there was no significant change in the total turbinate volume of patients when

192 the age was considered. Similar age related findings were observed in a computed tomography CT

193 based study *(Uzun, 2004).* However, the turbinates were evaluated on the basis of linear

194 dimensions observed on the CT scans in the later study *(Uzun, 2004).*

195

196 In the present study there was no significant difference in the gender distribution of the total

197 turbinate volume. In a recently published CT based study conducted to evaluate three dimensional

198 (3D) polymorphism of the inferior turbinates, no gender dimorphism was observed *(de Bonnecaze*

199 *etal., 2018)*

200 In our study three the total turbinate volumes of the of three groups were compared. The

201 categorization of scans in three groups was intended to assess the change in the total turbinate

202 volume in the presence of NSD and ITH. The total turbinate volume of the group having NSD

203 with ITH had significantly higher turbinate volumes compared to the other groups (without NSD

204 and ITH)

205 The hypertrophy of inferior turbinates occurs as a compensatory reaction in individuals with NSD.

206 It has been found that the hypertrophy is not just caused by mucosal hypertrophy, but also by

207 hypertrophy of the turbinate bone *(Orhan et al., 2014).* Though the soft tissue and bone component

208 contribute to the ITH, the bony component is responsible for the major contribution *(Berger et al.,*

209 *2000)* However, it is important to note that when the bony and soft tissue components are

210 individually correlated with the degree of nasal septal deviation it was not significant *(Akoğlu et*

211 *al 2007).* Therefore, it can be inferred that the volumetric analysis has a more significant

212 correlation when compared to linear measurements of the bony or soft tissue components of the

213 ITH.

214 In the present study the there was no significant difference in the total turbinate volume in mild

215 and moderate type of NSD. However, the total turbinate volume difference was highly significant

216 between mild and severe type of NSD. Similarly, the total turbinate volume was significantly

217 higher in severe type of NSD when compared to mild type of NSD. In earlier studies conducted

218 by Grymer et al compensatory inferior turbinate hypertrophy was observed more commonly in the

219 septal deviation of moderate or severe degree of NSD *(Grymer et al, 1989; Grymer et al, 1991;*

220 *Grymer et al., 1993)*

221 From the results of our study it can be inferred that, patients with NSD the have significantly higher

222 total turbinate volume when the hypertrophy is unilateral in nature.

223 The increase in total volume in unilateral type of hypertrophy is a compensatory mechanism to

224 reduce the adverse effects of one sided breathing resulting from NSD *(Sharma, 2016).* The adverse

225 effects commonly associated with NSD include dryness of the nasal passage, alteration of air

226 filtration, and mucociliary flow *(Teixeira et al., 2016).*

227 In the present study regression analysis revealed a positive relationship between total turbinate

228 volume and SDA. In a study by Tombilson et al regression analysis revealed that the ITH thickness

229 had positive relationship with severity of NSD *(Tombilson et al., 2016)*

230 The results of the present study demonstrate the effectiveness of three dimensional volumetric

231 analyses of turbinates in CBCT scans. Recently a study was conducted by *Valtonen et al., 2021*,

232 to evaluate the volume of ITH pre operatively and post-operatively *().* Results of the study

233 revealed that CBCT scans offer more complete and precise information of the turbinates. The

234 results of their study also revealed that three dimensional analyses of the ITH provides more

235 accurate dimensions compared to acoustic rhinometry *(Valtonen et al., 2021).* Studies have

236 revealed that the volumetric measurements in the middle and posterior parts of the nasal passage

237 are not accurately measured by acoustic rhinometry because of the sound loss through ostia. This

238 often causes overestimation of airspace cross section and volume *(Cankurtaran et al., 2007;*

239 *Hilberg et al., 1998; Terheyden et al., 2000).* The use of CBCT or CT based volumetric analysis

240 software can be used to overcome this problem. In the present study Vesalius 3D was used to

241 perform volumetric analysis of the ITH, whereas in the study by Valtonen O et al OnDemand3D™

242 software was used to perform three dimensional volumetric measurements.

243

244 One of the major limitations of our study is the time required for the volumetric analysis of ITH.

245 The semi-automated segmentation software considerably reduces segmentation time and improves

246   accuracy compared to manual segmentation *(McGrath et al., 2020)..* However, the segmentation

247   procedure still takes considerable amount of time, This can be overcome in the future by using

248   deep learning based fully automated segmentation software which can provide faster results with

249   minimal intra examiner and inter examiner variabilities *(Vaidyanathan et al.,2021).*

250

251   **Conclusions**

252   The results of the study reveal that the total turbinate volume is higher in patients with nasal septal

253   deviation. It can also be concluded that the septal deviation angle has a positive correlation with

254   total turbinate volume. In the future, volumetric analysis of turbinates can be used in the pre-

255   treatment evaluation and post treatment follow-up of patients with inferior turbinate hypertrophy

256   with nasal septal deviation.

257

258   # Acknowledgements

259   NIL

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Figure 1

Figure 1

Figure 1- Shows the radiographic landmarks used for determining the SDA (represented as angle ABC). The Point A represents the junction of the nasal septum with the floor of the nasal cavity. Point B represents the Crista Galli. The line BC represents a tangent drawn from point B and passing through the outermost part on the convexity of the deviated septum
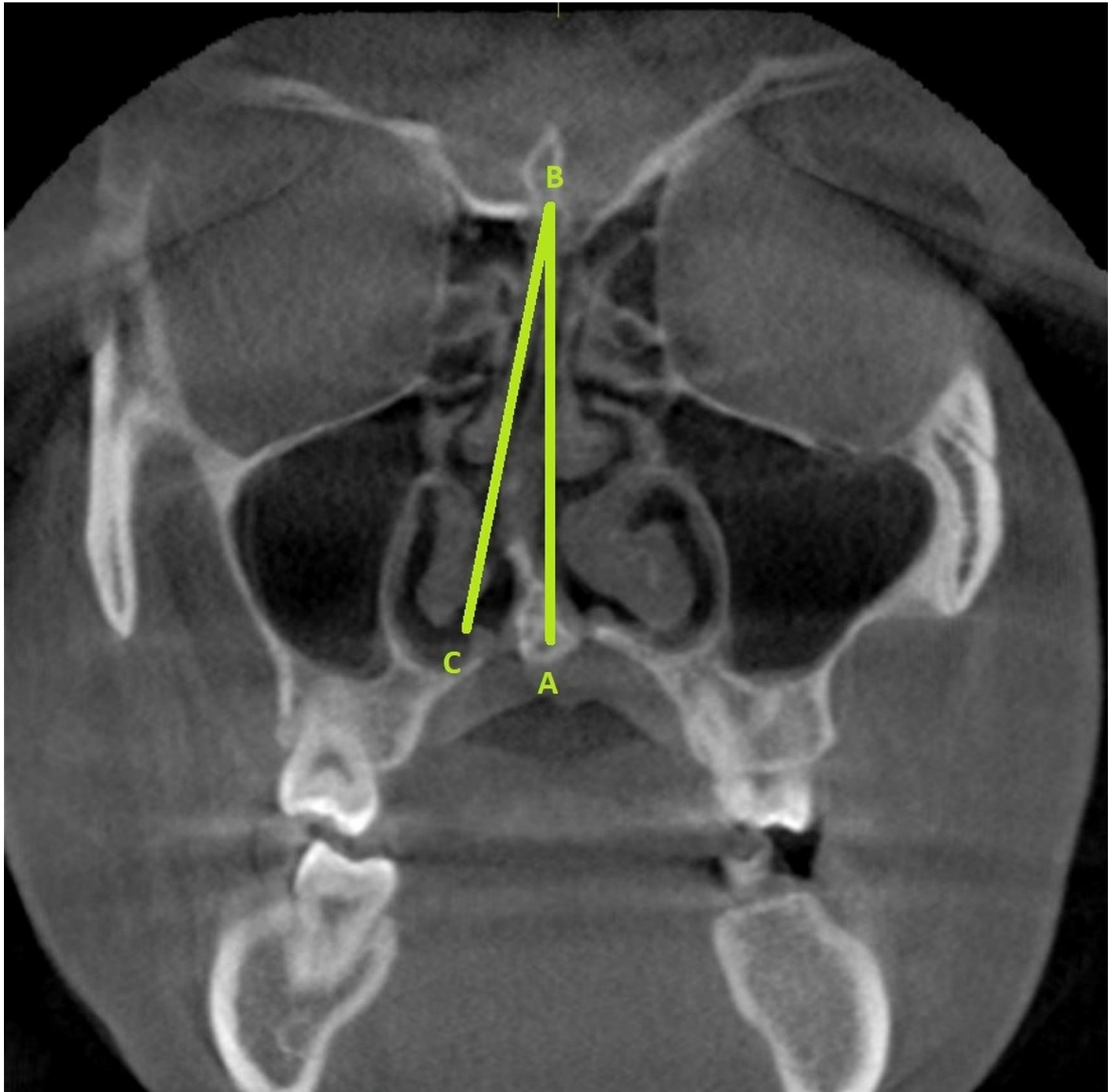
Figure 2

Figure 2

Figure 2- Image showing the volume determination (yellow circle) of the segmented inferior nasal turbinates.
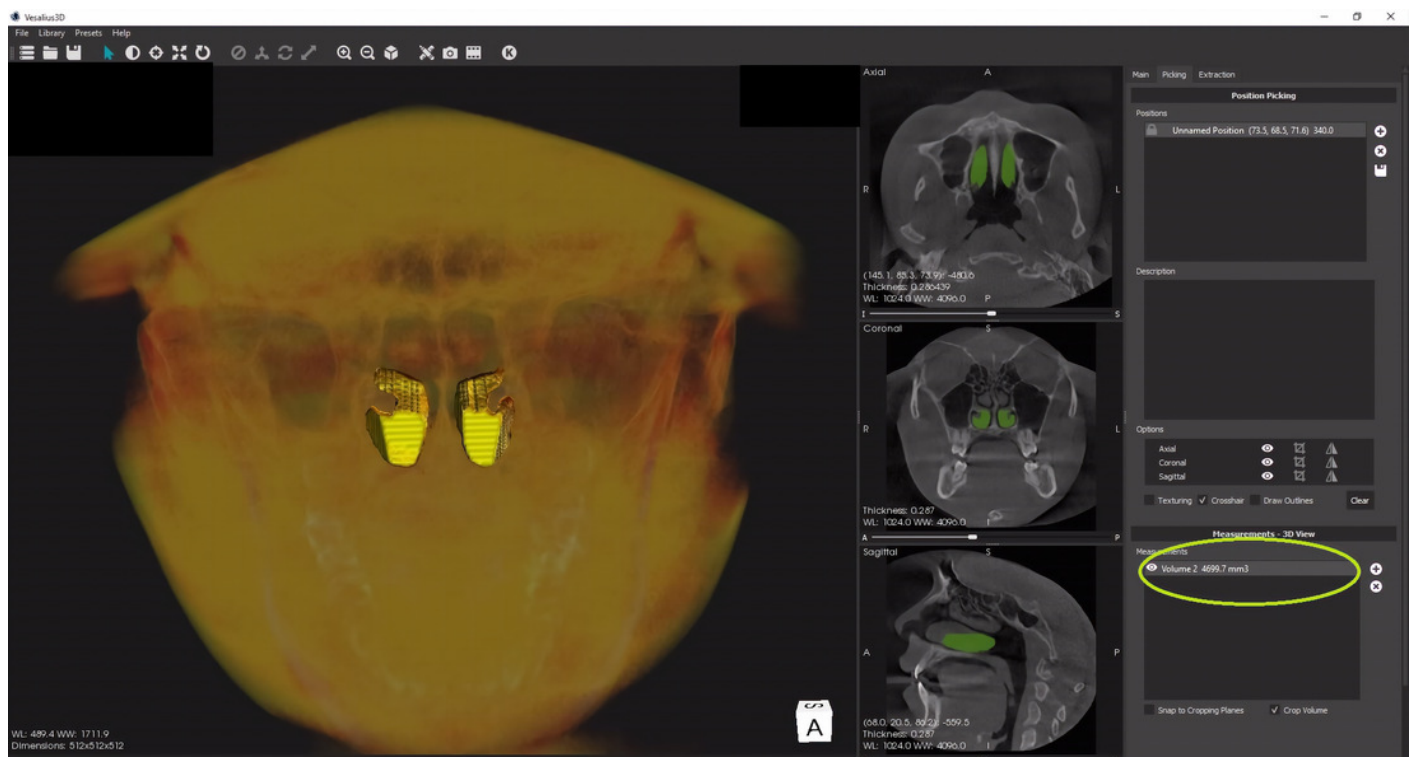
Figure 3

Figure 3

Figure 3- Dot plots showing the correlation/difference between turbinate volume and other factors (A. Gender, B. Study groups, C. Septal deviation angle and D. Type of hypertrophy)
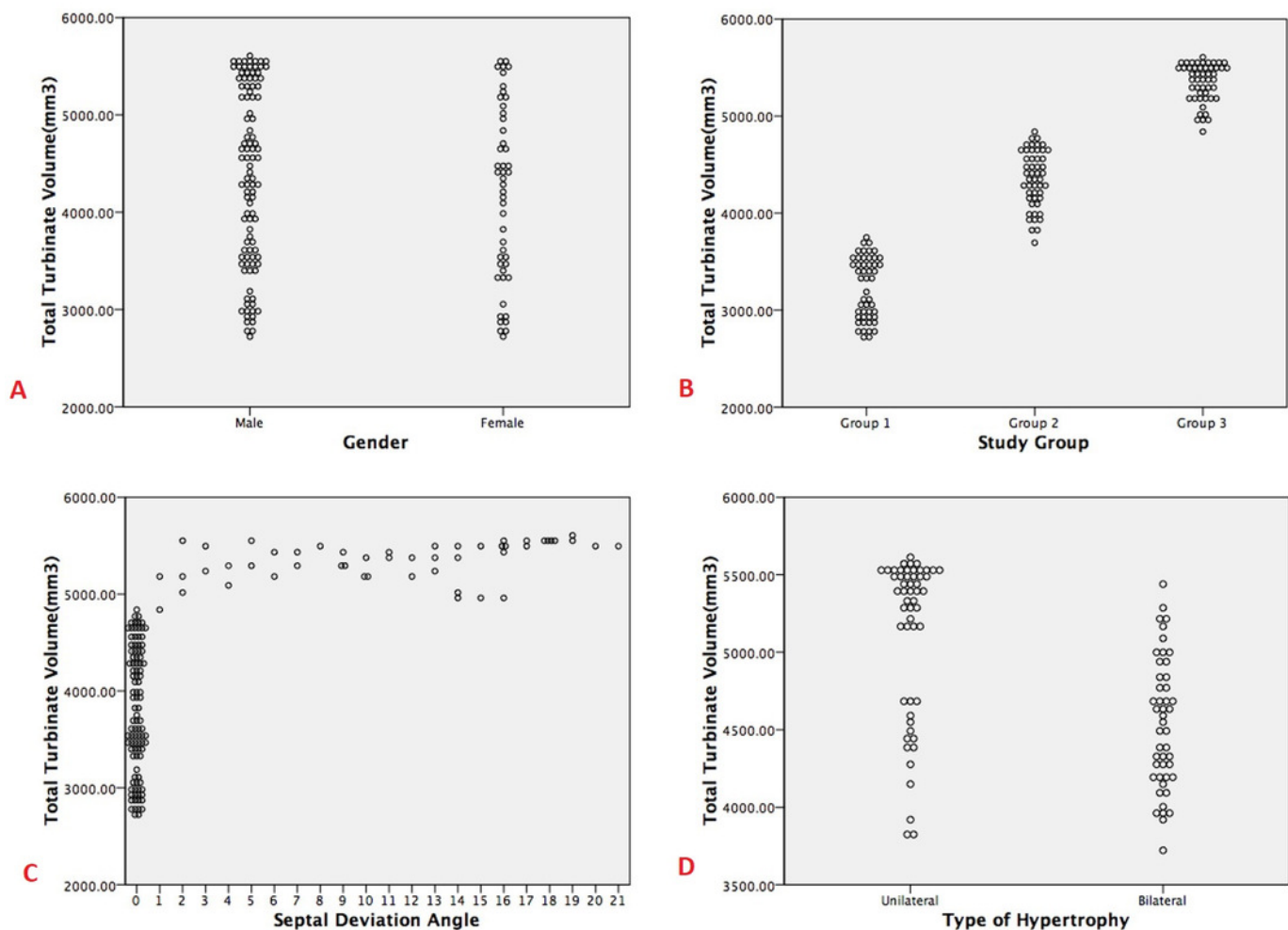
Table 1

Table 1: - Comparison of total turbinate volume of the study subjects among the study group

1   **Table 1: - Comparison of total turbinate volume of the study subjects among the study group**

Study Groups	N	Mean	SD	Min	Max	ANOVA	
						F	p-value
Group 1	50	3228.44	314.04	2699.78	3728.56	759.10	0.001*
Group 2	50	4354.58	289.15	3722.01	4833.40		
Group 3	50	5347.12	199.54	4844.66	5598.09		

2   *$p < 0.05$ statistically significant $p > 0.05$ non-significant, NS

Table 2

Table 2: - Pairwise comparison of total turbinate volume between the study groups

1 **Table 2: - Pairwise comparison of total turbinate volume between the study groups**

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	-1126.14	54.41	0.001*	-1254.97	-997.31
	Group 3	-2118.68	54.41	0.001*	-2247.51	-1989.85
Group 2	Group 3	-992.54	54.41	0.001*	-1121.37	-863.71

2 Tukey Post Hoc Test

3 *p<0.05 statistically significant   p>0.05 non-significant, NS

Table 3

Table 3:- Comparison of total turbinate volume between the type of hypertrophy in study groups

1 **Table 3:- Comparison of total turbinate volume between the type of hypertrophy in study groups**

Group	Type of hypertrophy	N	Mean	SD	Mean Difference	95% Confidence Interval of the Difference		t	df	p-value
						Lower	Upper			
Group 2	Unilateral	15	4354.96	296.64	0.55	-180.72	181.83	0.006	48	0.99(NS)
	Bilateral	35	4354.41	290.27						
Group 3	Unilateral	38	5427.79	128.37	336.14	243.94	428.34	7.33	48	0.01*
	Bilateral	12	5091.65	168.09						

2 Independent sample t test

3 *p<0.05 statistically significant   p>0.05 non-significant, NS

Table 4

Table 4: - Comparison of total turbinate volume between septal deviation type in study group

1   **Table 4: - Comparison of total turbinate volume between septal deviation type in study group 3**

Septal deviation type	N	Mean	SD	Min	Max	ANOVA	
						F	p-value
Mild	16	5284.01	204.53	4844.66	5533.08		
Moderate	19	5283.12	175.57	4933.11	5498.70	7.50	0.001*
Severe	15	5495.49	145.62	4987.09	5598.09		

2   *p<0.05 statistically significant   p>0.05 non-significant, NS

Table 5

Table 5: - Pairwise comparison of total turbinate volume between septal deviation type in study group 3

1 **Table 5: - Pairwise comparison of total turbinate volume between septal deviation type in study group**

2 **3**

(I) Septal deviation type	(J) Septal deviation type	Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Mild	**Moderate**	0.89	60.20	1.00(NS)	-144.79	146.57
	Severe	-211.48	63.76	0.005*	-365.78	-57.17
Moderate	**Severe**	-212.37	61.27	0.003*	-360.66	-64.07

3 Tukey Post Hoc Test

4 *p<0.05 statistically significant   p>0.05 non-significant, NS

Table 6

Table 6:- Correlation between total turbinate volume and septal deviation angle in group 3.

1 **Table 6:- Correlation between total turbinate volume and septal deviation angle in group 3.**

Group		Group 3
Septal deviation angle	**r**	0.52
	p-value	0.002*

2 Pearsons Correlation Test

3 *p<0.05 statistically significant   p>0.05 non-significant, NS

Table 7

Table 7:- Correlation between total turbinate volume and age of the subjects in the study groups.

1 **Table 7:- Correlation between total turbinate volume and age of the subjects in the study groups.**

Group		Group 1	Group 2	Group 3
Age	**r**	0.25	0.33	0.31
	p-value	0.08(NS)	0.74(NS)	0.86(NS)

2 Pearsons Correlation Test

3 *p<0.05 statistically significant   p>0.05 non-significant, NS

Table 8

Table 8:- Comparison of total turbinate volume between the male and female subjects in the study groups

1   **Table 8:- Comparison of total turbinate volume between the male and female subjects in the study**

2   **groups**

Group	Gender	N	Mean	SD	Mean Difference	95% Confidence Interval of the Difference		t	df	p-value
						Lower	Upper			
Group 1	Male	32	3242.94	312.48	40.29	-147.31	227.89	0.43	48	0.67(NS)
	Female	18	3202.65	324.21						
Group 2	Male	33	4343.92	302.10	-31.35	-206.47	143.78	-0.36	48	0.72(NS)
	Female	17	4375.27	269.87						
Group 3	Male	37	5364.62	195.31	67.31	-61.92	196.53	1.05	48	0.3(NS)
	Female	13	5297.31	210.96						

3   Independent sample t test

4   *$p<0.05$ statistically significant   p>0.05 non-significant, NS

Table 9

Table 9:- Linear Regression to predict total turbinate volume based on study variables

1   **Table 9:- Linear Regression to predict total turbinate volume based on study variables**

	Unstandardized Coefficients		Standardized Coefficients	t	p-value	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	3385.34	184.16		18.38	0.001*	3021.36	3749.32
Gender	-33.73	81.64	-0.02	-0.41	0.68(NS)	-195.08	127.62
Age	1.64	2.58	0.03	0.64	0.53(NS)	-3.46	6.74
Septal deviation angle	91.73	6.26	0.63	14.65	0.001*	79.36	104.10
Type of hypertrophy	563.0	49.57	0.50	11.36	0.001*	465.01	660.98

2    $F(5,145)= 106.97$, $p<0.001$, $R^2 = 0.75$

3   *$p<0.05$ statistically significant $p>0.05$ non significant, NS