

# Cephalometric and Audiological Assessment of Eustachian Tube in Down Syndrome and Chronic Otitis Media

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## ABSTRACT

**Objective:** Cephalometric assessment of Eustachian tube (ET) parameters and audiological evaluation in Down syndrome (DS) and Chronic Otitis Media (COM) and comparison with controls. The ET length, Total Cranial Base (TCB), Posterior Upper Facial Height (PUFH), Maxillary Depth (MD), s-ba (sella-basion) to Palatal Line (PL) and s-ba to ET length were considered.

**Materials and methods:** The study comprised of 75 subjects of both sexes in the age range of 7 to 20 years. Digital lateral cephalometry was performed for DS, COM and controls (n = 25). Pure tone audiometry (PTA) and immittance audiometry (IA) was performed to assess audiological status.

**Results:** ET length, PUFH, TCB and MD was found to be significantly reduced in DS and COM. s-ba to PL and s-ba to ET was significantly reduced in DS and COM. The s-ba to PL and s-ba to ET length angle in moderate and severe CHL (Conductive Hearing Loss) was decreased significantly. The s-ba to ET length was significantly decreased in patients with B and C tympanogram.

**Conclusion:** Aberration in the dimension of the region of the ET can be considered as a predisposing factor for otitis media and conductive hearing loss in DS.

**Keywords:** Eustachian tube, Digital lateral cephalometry, Down syndrome, Otitis media, Conductive hearing Loss.

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## INTRODUCTION

Optimum hearing development is known to enhance personal, social, academic and vocational development of the child. The increasing life expectancy of individuals with DS has revealed the presence of several unexpected pathological processes. Among these ear, nose and throat disorders hold an important place because of their high incidence and severity. Accurate knowledge of the pathophysiology underlying oral facial disorders provides an understanding of the reasons for the development of the COM in these children.<sup>1</sup> The multidisciplinary management requires a good knowledge of associated disorders related to DS which would be beneficial for clinicians' and basic researchers. The goal of rehabilitation is to nurture the potential of the differently abled so as to reduce the gap between capacity and performance to facilitate inclusion.

Early identification of ET dysfunction, CHL and immediate intervention has significant effect on management of craniofacial development and hearing acuity. Between 39 and 89% of DS children compared with 2.5% of the general population which is usually attributable to COM and is therefore bilateral and conductive.<sup>1,2</sup>

Anatomical and functional insufficiency of the ET is an important factor in the pathogenesis of chronic otitis media and is linked to its postnatal growth and development.<sup>1,3</sup>

Previous research reveals that ET and its muscles continue to develop up to adulthood during which lumen of ET increases and gets inclined laterally and superiorly.<sup>3,4-8</sup>

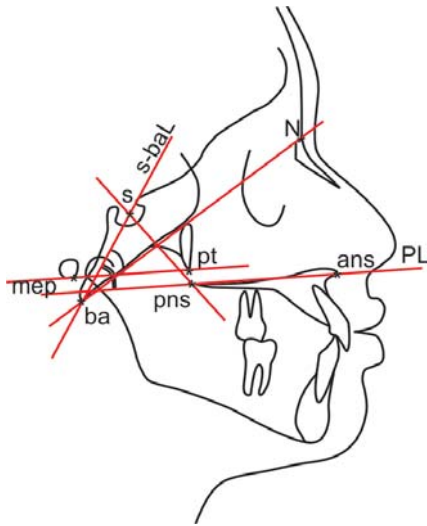
In a stepwise correlation regression analysis of the cephalometric measurements in Japanese adults predictive of the evolution of the ET were found to be the length of the ET, TCB, PUFH, MD, angle s-ba to PL. Moreover, the dimensions of TCB, PUFH and MD illustrated the length of the ET.<sup>9</sup>

Cephalometric radiography is an extensively used technique for making standardized head measurements in orthodontics and growth studies.<sup>9</sup> Lateral cephalometric radiography not only provides for research on living subjects; but has also been used for otologic research and measurement of length and position of ET employing skull base landmarks.<sup>10-16</sup>

This study aimed to evaluate craniofacial parameters of ET that affect its position and function. Furthermore, the effects of alteration of these parameters on hearing and ET function in DS and COM have been studied.

The craniofacial landmarks included were (Table 1 and Fig. 1):

- A. Linear measurements
  - i. Eustachian tube length {ET length (mep-pt)}
  - ii. Total cranial base (TCB) {nasion (n)-basion (ba)}
  - iii. Posterior Upper facial height (PUFH) {sella (s)-posterior nasal spine (pns)}
  - iv. Maxillary depth (MD) {(anterior nasal spine (ans)-posterior nasal spine (pns))}.
- B. Angular measurements
  - i. s-ba to Palatal Line (PL)
  - ii. s-ba to ET length



**Fig. 1:** Reference points, linear and angular parameters of this study

**MATERIALS AND METHODS**

The exploratory study comprised of DS, COM and normal groups and 25 subjects of both sex in the age range of 7 to 20 years were included in each group (n = 25). Approval was obtained from the Institutional Ethics Committee. Digital Lateral Cephalometry was performed for all the subjects in an identical manner.<sup>12,13</sup> They were briefly exposed in erect position. Teeth were occluded, lips were in repose and head was stabilized with a cephalostat.

Radiation protection parameters were adhered to during the procedure. Tracings were done for the cephalograms and measurements of linear and angular measurements were recorded. Informed written consent for participation in the study in local language before inclusion in the study was obtained. Patients of DS with determined genotype and COM persisting over 8 weeks with bilateral perforation. Tympanometry was carried out for DS group and controls. The DS group subjects were appropriately conditioned prior to testing. All subjects underwent ENT and audiological examination. The tests were conducted by Rehabilitation Council of India certified audiologists in standard audiometric sound treated rooms; using standardized equipment which was calibrated as per specifications of ANSI: S3.6-1996 or BIS specifications IS 10565:1999 (R 2005) for diagnostic audiometers.<sup>17,18</sup>

The data was subjected to statistical analysis using both Microsoft Office Excel (Microsoft Corporation, Redmond, WA, USA) and Statistical Package for Social Sciences (SPSS) software. The chosen confidence level was 95%. Univariate statistical methods were used to calculate descriptive statistical parameters (mean, median and standard deviation) for each parameter in the three groups. One-way ANOVA, Tukey test and Kruskal Wallis one way analysis of variance (for results with a non-normal distribution) were applied for analysis.

**Table 1:** Reference points, linear and angular parameters

ans	<i>Anterior nasal spine:</i> The apex of the most anterior part of the nasal floor
ba	<i>Basion:</i> The most posteroinferior point of the spheno-occipital bone on the anterior margin of the foramen magnum
mep	<i>Middle ear point:</i> The most anteroinferior point on the middle ear shadow (instead of 'A' in Todd and Martin's study <sup>20</sup> )
n	<i>Nasion:</i> The most anterior point of the frontonasal suture
pns	<i>Posterior nasal spine:</i> The most posterior point of the hard palate
pt	<i>Pterygoid:</i> The most inferior point of the fissure between the pterygoid plate and the posterior contour of the maxilla, <sup>20</sup> as landmark of the pharyngeal end of the ET
s	<i>Sella:</i> The center of the sella turcica (the upper limit of the sella turcica is defined as the line joining the tuberculum and dorsum sella)
<i>Reference lines</i>	
PL	<i>Palatal line:</i> The line through 'ans' and 'pns'
s-baL	Sella-basion line (posterior cranial base line); line through 's' and 'ba'
<i>Linear parameters</i>	
mep-pt	The distance from 'mep' to 'pt' length of the ET <sup>20</sup>
s-ba	The distance from 's' to 'ba'; posterior cranial base length
n-ba	The distance from 'n' to 'ba'; total cranial base length
s-pns	The distance from 's' to 'pns' posterior upper face height (PUFH)
ans-pns	The distance from 'ans' to 'pns' maxillary depth (MD)
<i>Angular parameters</i>	
s-ba to PL	The angle between s-baL and PL
s-ba to ET Length	The angle between s-ba and ET length (mep-pt)

**OBSERVATION AND RESULTS**

The mean linear measurement of ET length (mep-pt) was decreased in both DS and COM group as compared to the controls ( $p < 0.001$  or  $2.45E-05$ ) (Graph 1).

The mean ET length in subjects with bilateral mild, moderate and severe CHL was 39.08, 38.25 and 39.86 mm respectively as compared to 39.76 mm in controls. This was not statistically significant ( $p = 0.80$ ).

The mean ET length in subjects with type B and C tympanogram was 37.33 and 35.67 mm respectively as compared to 39.57 in controls (type A). There is a decrease in subjects with B and C tympanograms but is not statistically significant ( $p = 0.09$ ).

The mean linear measurement of TCB (n-ba) in DS group was decreased as compared to COM and controls; which was statistically significant ( $p < 0.001$ ) (see Graph 1).

The mean TCB in subjects with mild, moderate and severe CHL was 99.35, 99.25, 100.86 mm respectively as compared to 101.35 mm in controls. This decrease was not statistically significant ( $p = 0.79$ ).

The mean TCB in subjects with type B and C tympanogram was 95.44 and 98.50 mm respectively as compared to 100.46 in controls (type A). There is a decrease in subjects with B and C tympanograms but is not statistically significant ( $p = 0.34$ ).

The mean linear measurement of PUFH (s-pns) was decreased in the DS and COM groups as compared to controls; which was statistically significant ( $p = 2.37E-07$ )  $p < 0.001$ . The decrease was more in the DS group (see Graph 1).

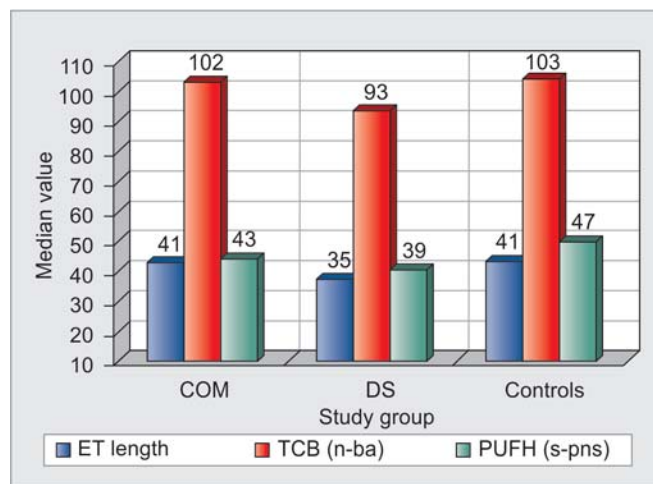
The mean PUFH in subjects with mild, moderate and severe CHL was 41.42, 41.50, 44.57 mm as compared to 44.44 mm in controls. There was a decrease which was found to be statistically not significant ( $p = 0.10$ ).

The mean PUFH in subjects with type B and C tympanogram was 38.56 and 39.67 mm respectively as compared to 44.09 in controls (type A). There was a decrease in subjects with B and C tympanograms but was not statistically significant ( $p = 0.02$ ).

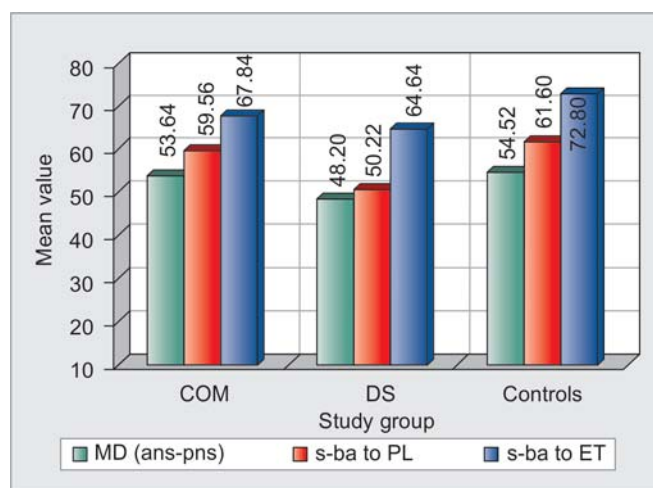
The mean MD (ans-pns) in DS and COM group was markedly decreased as compared to controls. The decrease was more in DS group and was statistically significant ( $p = 1.01E-06$ )  $p < 0.001$  (Graph 2).

The mean MD in subjects with mild, moderate and severe CHL was 51.31, 51.38, 53.86 mm respectively as compared to 52.56 in controls. There was a decrease in the mild and moderate CHL groups which was found to be statistically not significant ( $p = 0.58$ ).

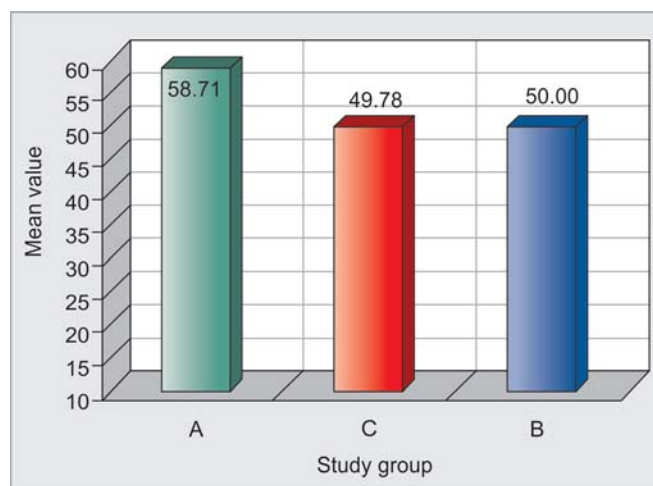
The mean MD in subjects with type B and C tympanogram was 49.11 and 48.67 mm respectively as compared to 52.40 in controls (type A). There is a decrease



**Graph 1:** Comparison of ET length, TCB and PUFH among study groups



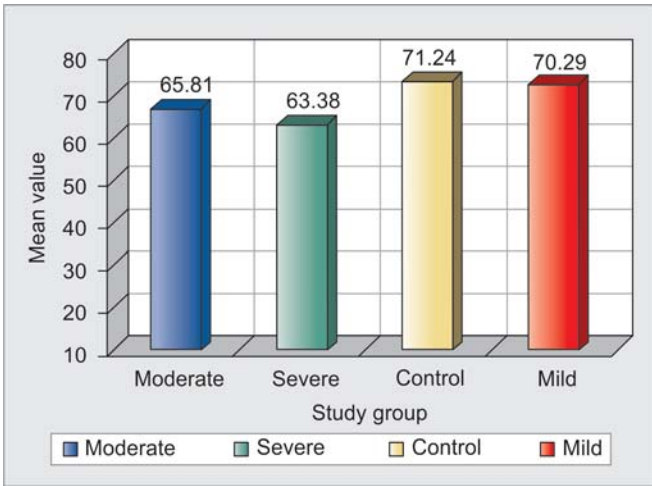
**Graph 2:** Comparison of MD (ans-pns), s-ba to PL and s-ba to ET length among study groups



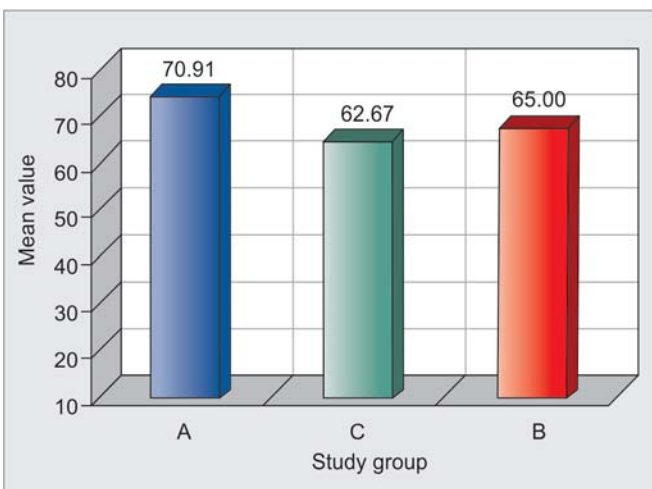
**Graph 3:** Comparison of s-ba to PL and IA among study groups

in subjects with B and C tympanograms but was not statistically significant ( $p = 0.08$ ).

Mean angle s-ba to PL was decreased in DS and COM as compared to controls and the decrease was more in DS which was statistically significant ( $p = 3.44E-10$ ) (see Graph 2).



**Graph 4:** Comparison of s-ba to ET and PTA among study groups



**Graph 5:** Comparison of s-ba to ET and IA among study groups

The mean s-ba to PL angle in subjects with mild, moderate and severe CHL was 70.29°, 65.81°, 63.38° respectively as compared to 71.24° in controls. Mild and moderate groups showed a decrease ( $p = 0.15$ ).

The mean s-ba to PL in subjects with type B and C tympanogram was 50.00 and 49.78 mm respectively as compared to 58.71 in controls (type A). There was a decrease in subjects with B and C tympanograms and was statistically significant ( $p = 5.82E \times 10^{-5}$ ) (Graph 3).

Mean angle s-ba to ET length was significantly decreased in DS and COM groups as compared to controls decrease was more marked in DS group which was statistically significant ( $p = 2.35E-05$ ,  $p < 0.001$ ) (see Graph 2).

The mean s-ba to ET length angle in subjects with mild, moderate and severe CHL was 65.81°, 63.38° and 70.29° respectively, as compared to 71.24° in controls. There was a decrease in the mild and moderate CHL groups which was statistically significant ( $p = 0.001$ ) (Graph 4).

The mean s-ba to ET length in subjects with Type B and C tympanogram was 65.00° and 62.67° respectively,

as compared to 70.91° in controls (type A). There is a marked decrease in subjects with B and C tympanograms which was statistically significant ( $p = 0.001$ ) (Graph 5).

## DISCUSSION

Data analysis of this study shows that craniofacial malformations have a deterministic effect on dimension of the region where ET is located (ET length). The 'pt' point considered was a point between posterior border of the maxilla and anterior border of the pterygoid plates and served as an indicator of nasopharyngeal end of ET. Therefore, this point was not located on the medial pterygoid plates, which is the true localization of nasopharyngeal end of ET.<sup>14-16</sup>

Previous research suggests that the ET length abnormalities increase the risk of otitis media.<sup>14-17,19</sup> Lateral Cephalograms provide bilateral data and measurements are the mean of the left and right sides of the skulls.<sup>9</sup> Previous data indicates that there was high correlation of measurements of cranial base and ET between the left and right halves of the skull.<sup>20,21</sup> Otitis Media is a bilateral disease and using mean data of left and right sides to correlate midline parameters of the craniofacial skeleton is therefore justified.

As sella, 'ans' and basion are considered constant points through life; the s-ba reference for angular parameters was appropriate. Angulation of the ET length to this reference would help gauge the superior-inferior relation of the area where ET is located. In this study, use of mean data of left and right sides to correlate with midline parameters of the craniofacial skeleton and s-ba to ET length parameter was therefore appropriate. The angulation of the ET length to this reference would help gauge the superior-inferior relation of the area where ET is located.

Otitis media is most common during childhood when tubal dysfunction is more prevalent; its incidence decreases with maturity. This decrease has been correlated with the shift in the position of the tube; which is more vertical in adults. This change can be attributed to the growth of the cranial base, nasomaxillary complex and mandible, which are the major developing units of the craniofacial skeleton. The region of the ET is between the maxilla and PCB.<sup>4,5,22</sup>

The development of the brain leads to the anterior movement of the middle cranial fossa along with nasomaxillary complex and pterygoid plates. The bone remodeling and primary displacement of the posterior maxilla lead to downward and forward movement of the nasomaxillary complex.<sup>9</sup> The expansion of the posterior maxilla, posterior upper facial height and maxillary depth is considered to be the main explanatory variables of the region of ET.<sup>20,21</sup>

Previous research suggests that the genesis of otitis media could be linked to poor ET function.<sup>23</sup> It is established that brachycephalic adults were more likely to have relatively straight tubes which are associated with otitis media.<sup>24,25</sup> Cranial base dimensions, maxillary depth and posterior upper facial height are linked to otitis media.<sup>9-11,20,21</sup> ET dimensions reach adult length by 7 years.<sup>26</sup> In the adult, the tube is approximately 45° related to the horizontal plane. ET length, PUFH and MD is shorter in DS and children with secretory otitis media, so it is more likely that secretions reflux into the middle ear.<sup>10-12</sup> It is also established that the length of PCB is shorter in cleft palate and children with COM with effusion.<sup>9</sup> Histopathological studies also reveal that ET length in dysfunction specimens is shorter than in age-matched controls, which might explain tubal dysfunction.<sup>25</sup>

It has also been reported that developmental structure of the supratubal recess and its pneumatization is associated with growth of the bony ET and precedes formation of air cells in the mastoid process.<sup>26</sup>

The bone remodeling and primary displacement of the posterior maxilla lead to downward and forward movement of the nasomaxillary complex. The expansion of the posterior maxilla, PUFH and MD is considered to be the main explanatory variables of the region of ET.

ET length, TCB, PUFH and MD is shorter in DS and children with sensory otitis media, so it is more likely that secretions reflux into the middle ear. The findings in our study are in accordance with previous studies. In this study there was a decrease in the mean s-ba to PL angle in subjects with mild and moderate CHL. Moreover, subjects with B and C type tympanograms had s-ba to PL angle lesser than those with type A tympanogram. s-ba to ET length was decreased in subjects with mild, moderate and severe CHL and subjects with B and C tympanograms. The length of ET and the superior-inferior angulation of the ET are decreased in DS and COM groups which indicates its effect on the hearing acuity.

## CONCLUSION

ET length, PUFH, TCB and MD was found to be significantly reduced in the DS and COM as compared to the controls. s-ba to PL and s-ba to ET was significantly reduced in the DS and COM groups. The s-ba to PL and s-ba to ET length angle in moderate and severe CHL was significantly decreased. The s-ba to ET length was significantly decreased in subjects with B and C tympanogram.

The results indicate that the alterations in the dimensions of the region where the ET is located predisposes to COM in DS.

Moreover, it can be hypothesized that aberration or cessation in growth of parts of the craniofacial skeleton lead to imbalances in the ET which predispose to otitis media. This was a pioneering study toward combined assessment of audio logical and radiographic perspective of ET in DS and COM. The study aimed to bridge the research gap between craniofacial malformations of DS and their association with COM.

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