EVALUATION OF VOLUMETRIC CHANGES IN UPPER AIRWAY AFTER RAPID PALATAL EXPANSION USING A CUSTOM MADE BONE BORNE PALATAL EXPANDER- A CLINICAL TRIAL ON YOUNG ADULTS AND ADOLESCENTS.

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ABSTRACT
Aim: To study the change in upper airway volume immediately after transverse skeletal expansion of the palatal vault in adolescents and young adults using a bone anchored palatal expander.
Objective: To assess the volume of upper airway after rapid palatal expansion and compare them with preoperative values to establish any statistically significant changes.
Design: This was a clinical trial study.
Setting: The study was conducted in the Department of Orthodontics and Dentofacial Orthopedics
Methods: A total of 12 patients were chosen for the clinical trial. Preoperative and post operative CBCT were used for evaluating the parameters. Patients within the age group of 14 to 28 years who had transverse skeletal deficiency with constricted inter canine and interpmolar widths were chosen for the study. The airway changes were assessed using pre expansion and post expansion CBCT using Dolphin 3D software (Dolphin Imaging, Chatsworth, California,USA).
Results: Mean cross sectional area at the nasal cavity was $982.60 \pm 459.41 \text{ mm}^2$ preoperatively and was found to be $1342.20 \pm 488.25 \text{ mm}^2$ after palatal expansion. Mean volume of nasal cavity was $32516.20 \pm 7110.93 \text{ mm}^3$ before palatal expansion and was $33967 \pm 6688.56 \text{ mm}^3$ postoperative. Among the pharyngeal parameters the nasopharyngeal cross section of $190.80 \pm 44.42 \text{ mm}^2$ was found to increase to $223.40 \pm 46.15 \text{ mm}^2$ postoperative. The mean volume of the nasopharynx was found to change from $4461.20 \pm 719.49 \text{ mm}^3$ to $4723.60 \pm 1023.83 \text{ mm}^3$. The oropharyngeal cross sectional area changed from $405.80 \pm 128.67 \text{ mm}^2$ to $458.40 \pm 140.76 \text{ mm}^2$ while the volume increased from $10677 \pm 1282.05 \text{ mm}^3$ to $11893 \pm 1958.6 \text{ mm}^3$. The least change was found in the hypopharynx where the change in cross sectional area was $171.20 \pm 50.42 \text{ mm}^2$ to $195.20 \pm 49.04 \text{ mm}^2$ and volumetric change was from $4402.40 \pm 858.94 \text{ mm}^3$ to $4430.40 \pm 864.26 \text{ mm}^3$.
Conclusion: Increase in cross section and volume were seen in all segments of the upper airway with maximum changes in nasal cavity and minimal increase in the hypopharynx. No statistically significant differences were seen for the volume of each specific airway compartment.
Keywords: Cone-Beam Computerized Tomography, Maxillary Expansion, Orthodontics, Palate
INTRODUCTION
Rapid maxillary expansion has been a treatment option in patients with transverse discrepancies and a method of achieving skeletal expansion in prepubertal patients up to early adolescence[1]. With the modus operandi of disrupting mid palatine and circum maxillary sutures, many RME appliances have managed to achieve transverse maxillary expansion along with an increase in nasal airway. Mini implants have proven to be a versatile anchorage device to provide bone borne anchorage in treatment of transverse discrepancies [2]. Miniscrew assisted rapid palatal expansion has now made it possible to treat transverse discrepancies despite age and with minimal detrimental changes to posterior teeth [3].

The impact of orthodontic treatment on the airways has received increased interest in the latter years with studies showing that, in addition to its orthodontic effects, RME can have a positive effect on airway dimensions and breathing function. The upper airway consists of the nasal cavity and the pharyngeal airway. While the nasal cavity has a bony framework with a soft tissue lining, the pharyngeal airway is mostly a muscular channel connecting the nasal cavity to the larynx and lower airway. While a number of conditions such as deviated nasal septum, polyps and enlarged adenoids are known to restrict air flow in the upper airway, skeletal malocclusions involving the maxilla or mandible can alter airflow in the upper airway. Transverse maxillary deficiency or skeletal crossbite are often associated with narrow nasal cavities and high arched palatal vaults which increase the resistance to airflow. Treatment options in early childhood with the help of rapid expanders such as hyrax have shown to produce increase in nasal cavity dimensions apart from transverse skeletal expansion of the palate predominantly by splitting the intermaxillary, inter palatine and circum maxillary sutures. The mechanism of action is believed to derive from the increase of nasal width with subsequent enlargement in upper airway volume and decrease in nasal resistance [4]. A significant increase in nasal airflow and reduction in airway resistance was found with Hybrid-Hyrax expanders using rhinomanometry immediately after expansion [5]. RME resulted in relatively small increases in total upper airway volume and its separate compartments, with mostly no statistically significant differences across the Hyrax, Hybrid-Hyrax, and Keles keyless expanders [6]. The beneficial effects of RME have been highlighted as a therapeutic possibility in children diagnosed with obstructive sleep apnoea, who showed a reduction in the Apnoea–Hypopnea Index (AHI) after RME treatment [7].

Studies showed that heavy forces generated by expanders could impact the craniofacial structures beyond the midpalatal suture [4, 8]. High levels of stress were observed at the zygomaticomaxillary, zygomaticotemporal, and frontomaxillary sutures, frontal process of the maxilla, and external wall of the orbits [4] post RME expansion. Increase in the transverse width of nasal apertures, separation of the nasal floor, and shifting of the lateral nasal walls were also reported to be associated with sensation of pressure in the maxillary, nasal, or orbital areas [5, 8, 9][10].

However as the aforementioned sutures fuse as age progresses the chances of producing skeletal changes by disruption of circumstances maxillary sutures diminish. Over the years augmented procedures such as SARPE have been used to produce skeletal expansion in patients with fused intermaxillary and inter palatine sutures. The advent of bone screws in orthodontics has opened up new possibilities in the treatment of skeletal malocclusion in adult patients. Bone-borne RME (or miniscrew assisted RME) was proposed to minimize the unwanted dentoalveolar effects of RME and produce skeletal changes similar to SARPE, reducing surgical injury and adverse dentoalveolar side effects. [11][12][13][14]. Studies have shown an increase in the volume and cross sectional area of the nasal cavity after MARPE in adults [15].

Many studies have reported the influence of RME on the upper airway, though the results were different due to various subjects and expansion methods. However, there are few studies about changes of each segment of the upper airway after bone borne implant supported RPE. This study aims to assess the immediate upper airway volume changes after expansion with bone borne implant supported rapid palatal expansion.

MATERIALS AND METHODS
This clinical trial included 12 patients (mean age: 21.4 ± 5.5 years; range: 14-28 years; 4 females, 8 males), who had undergone bone-borne implant supported rapid palatal expansion at the Department of Orthodontics and Dentofacial Orthopedics over a period of 3 months. Sample size for the present study was determined as 10 with a power of 80% and an alpha error of 0.05[6]. The study design was approved by the institutional ethical committee (SDC/SIHEC/2020/DATA/0619-0322). All patients provided written informed consent. Inclusion criteria involved patients in the late adolescents group with constricted upper arch. Individuals who had developmental and craniofacial anomalies, compliance problems, temporomandibular joint disorder, active periodontal diseases and caries, systemic diseases and history of previous orthodontic treatment were excluded from the study.
Every patient was treated with the custom made bone borne implant supported rapid maxillary expander developed in the Department of Orthodontics and Dentofacial Orthopedics. The device obtained skeletal anchorage from the palate without any dental anchorage and was placed on the palatal vault in a simple procedure under local anesthesia. This palatal expansion device was firmly anchored to the bony palatal vault with the help of four miniscrews. The custom-made Bone borne implant supported expander used screw size of 2x12mm. The appliance was fabricated on the cast after obtaining a pick up impression. The device was adapted and positioned between the maxillary first premolar and first molar on the cast. A custom fabricated stent was used to aid in the perfect adaptability, fit and position of the expander and implants.

Four miniscrews (2 mm x 12mm, Favanchor SAS, India) along with the custom-made bone borne palatal expander was positioned into the palatal bone with a perpendicular insertion using a contra-angled driver, gyro attachment (FavAnchor SAS, India) and a palatal driver (L’il One Driver; FavAnchor SAS, India) under local anesthesia. Post insertion of the device, maxillary expansion was initiated. The expander was activated by 4 turns every day until the required expansion was achieved. The required amount of expansion was set according to the diagnosis and treatment objective of each patient: usually 32-36 turns. The mean duration of expansion was 9 days (range:9-12 days)(Figure 1).

After achieving the intended expansion, the expansion screw was blocked and post expansion CBCT(T1) was taken. The retention time was at least 3 months. CBCT scans (CS9600 Carestream Dental) machine with the settings: 85KV, 10 mA, exposure time 15 seconds, voxel 300 microns and FOV 16x17cm) were performed before expansion(T0) and after 3 month’s retention (T1) by the same operator. The patients were scanned in supine position with the Frankfort plane perpendicular to the floor, keeping the teeth in centric occlusion and the tongue in the position at the end of swallowing (against the palate), breathing smoothly, and no swallowing. The digital imaging and communications in medicine (DICOM) data were imported into Dolphin Imaging software (Chatsworth, CA, USA) and airway volume and area was assessed.

Prior to orthodontic intervention, full records were taken for each patient, including study models, extra-oral photos, and intra-oral photos. At the first appointment, patients were informed about their treatment, received their baseline CBCT (T0), and impressions of upper arch. Approximately a week later, bone borne implant supported RPE devices were fitted. 1.0 ml Lignocaine 1:80 000 adrenaline was administered as a local anaesthetic infiltration in the anterior palatal area. A sterile gauze soaked in betadine was used to disinfect the palate in the area of insertion. Following this, pre-drilling was performed using a SK surgical drilling bur (0.9mm) adapted to contra-angle handpiece and rotated by hand to a depth of 8 mm at a 90 degree angle to the palate at approximately the area of the third palatal rugae. Four Favanchor Medusa miniscrews of 12 mm and 10 mm length with 2mm width were placed bilateral to the mid-palatal suture. Patients were instructed to use chlorhexidine mouthwash thrice a day for 2 weeks, with gentle brushing of the miniscrews.

The device was activated 1mm a day for 10 days and to return for weekly reviews until palatal cusps of the upper first molars were in contact with the buccal cusps of the lower first molars. The expander was then locked and the patient instructed to return in 3 months unless there were any breakages. At the end of 6 months, the appliances were removed and full records were taken, including a second CBCT (T1). Treatment was provided by three providers (HB, ASK and AM). Patients did not receive any orthodontic treatment during the study period apart from the correction of constricted maxilla.

Figure 1: Pre and Post bone borne implant supported expansion (successfully treated under the clinical trial)
The two examiners (A.M) and (H.B) analyzed the pre and post expansion CBCT scans. All images were orientated prior to landmark identification. The sagittal plane was orientated in the Frankfort horizontal plane, with the coronal and axial plane orientated to the skeletal midline using the crista galli, anterior nasal spine, nasal bone, and orbits as reference points. In the Dolphin software, the boundaries of the nasal cavity, nasopharynx, oropharynx, and hypopharynx were first located on the mid-sagittal position in the coronal view. The sinuses were outlined on the coronal view at the section of the furcation of the maxillary first molar. Seed points were positioned in all air cavities within the boundaries. The images were cross-checked in all three planes of place (sagittal, coronal, and axial) and the new seed points were placed to include all the air cavities(Figure 2).

Re-evaluation was done in case of disparity among the observations of two examiners and the observations were reconfirmed. To avoid the errors due to fatigue not more than 3 CBCT were analyzed per day.

![Figure 2: Nasal cavity airway changes at T0 & T1.](image)

**STATISTICAL ANALYSIS**

The statistical analysis was carried out using Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA). Paired T test was used to assess the changes in pre and post expansion nasal and airway volume. Intra operator reliability was checked by the paired T- test. Kappa statistics were used to evaluate inter-operator reliability between the observations by two observers (A.M, H.B).

**RESULTS**

Mean cross sectional area at the nasal cavity was 982.60 ± 459.41 mm² preoperatively and was found to be 1342.20 ± 488.25 mm² after palatal expansion. Mean volume of nasal cavity was 32516.20 ± 7110.935 mm³ before palatal expansion and was 33967 ± 6668.56 mm³ postoperative. Among the pharyngeal parameters the nasopharyngeal cross section of 190.80 ± 44.421mm² was found to increase to 223.40 ± 46.150 mm²-postoperative. The mean volume of the nasopharynx was found to change from 4461.20 ± 719.495mm³ to 4723.60 ± 1023.83mm³ . The Oropharyngeal cross sectional area changed from 405.80 ± 128.675mm² to 458.40 ± 140.767 mm² while the volume increased from 10677 ± 1282.051mm³ to 11893 ± 1958.6mm³ . The least change was found in the hypopharynx where the change in cross sectional area was 171.20 ± 50.425 mm² to 195.20 ± 49.043mm² and volumetric change was from 4402.40 ± 858.949mm³ to 4430.40 ± 864.261mm³. The intra operator reliability was assessed using a paired T-test and was estimated to be 0.93 and the inter-operator reliability by Kappa statistics was 0.321.

<table>
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<th>Volume(mm³)</th>
<th>Pre-expansion</th>
<th>Post-expansion</th>
<th>p-value</th>
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<td>32516.20 ± 7110.935</td>
<td>33967 ± 6668.56</td>
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<tr>
<td>Nasopharynx</td>
<td>4461.20 ± 719.495</td>
<td>4723.60 ± 1023.83</td>
<td>0.671</td>
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Table 1: The mean, standard deviation and significance of the upper airway volume was evaluated.

<table>
<thead>
<tr>
<th>Area(mm³)</th>
<th>Pre-expansion</th>
<th>Post-expansion</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
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<td>Nasal Cavity</td>
<td>982.60 ± 459.41</td>
<td>1342.20 ± 488.25</td>
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<tr>
<td>Nasopharynx</td>
<td>190.80 ± 44.421</td>
<td>223.40 ± 46.150</td>
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<tr>
<td>Oropharynx</td>
<td>405.80 ± 128.675</td>
<td>458.40 ± 140.767</td>
<td>0.775</td>
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<tr>
<td>Hypopharynx</td>
<td>171.20 ± 50.425</td>
<td>195.20 ± 49.043</td>
<td>0.829</td>
</tr>
</tbody>
</table>

Table 2: The mean, standard deviation and significance of the upper airway area was evaluated.

DISCUSSION
This study was conducted to study the immediate effects on the upper airway after transverse skeletal expansion of the maxillary arch using a Bone Borne Rapid Palatal expander. The palatal expander used in this study was anchored rigidly on to the palatal vault by miniscrews and when activated exerted separating forces directly onto the intermaxillary and interpalatine sutures apart from other circum maxillary sutures. Traditional RME devices and even some recent MARPE devices are solely anchored or derive additional anchorage from the dentition unlike the totally bone anchored expander used here. The study also chose a sample population of higher age group in anticipation of increased interdigitation and ossification at mid palatine sutures. Observations from the study have shown clinical signs of skeletal transverse maxillary expansion substantiated later by CBCT. The use of 3D volumetric data in this study has allowed us to overcome the limitations of analyses on 2D lateral cephalograms. This study focused on the changes in cross section and volume of the upper airway after bone borne expanders were used.

The nasal cavity and upper airway compartments are complex three dimensional structures which need to be investigated using three dimensional imaging as CBCT. Comparison of CBCT images have shown numerically greater cross sectional as well as volumetric values after palatal expansion using bone anchored expanders. The greatest increases were observed in the nasal cavity and the increase in cross sectional and volumetric values were minimal in the hypopharynx.

Previous studies on nasal flow rates and airway resistance have shown expanders supported by Temporary Anchorage Devices (TADs) may have increased benefits to the patient when compared to tooth-borne expanders [16]. A systematic review and meta-analysis on volumetric upper airway changes with tooth-borne RME reported an increase of 1218.3 mm³ in the total upper airway immediately post-expansion and in the nasal cavity. While some studies have reported clinically insignificantly changes from baseline, others have shown airway changes in the volume of the nasal cavity and the nasopharynx after RME using a Hyrax which were statistically significant[17, 18]. The results differ from the present study due to the older age group selected, as well as the shorter duration (10 days) before obtaining the post-treatment scan. In another retrospective study, significant changes in nasal cavity volume was seen when a tooth borne and bone anchored expanders were compared, with the bone borne expanders producing greater increase in volume[19]. But these changes were not statistically significant. This is in agreement with our results. It should be noted here that variable amounts of interdigitation and ossification of midpalatal sutures can give rise to varying responses of patients to maxillary expansion. Given the increased age group used in our study these statistically insignificant changes are to be expected within this sample size. Different palatal vault depths and shapes along with root proximity can influence expansion screw placement and force vectors for expansion. This could be another contributing factor.

CONCLUSION
No statistically significant differences were seen in cross sectional area as well as overall airway volume or for the volume of each specific airway compartment.
LIMITATIONS
The limitation of the present study is that the lack of statistically significant differences between devices in changing the airway volume between T0 and T1 indicates differences of small magnitude that might not be necessarily clinically relevant; however, a study with a larger sample size will be required to confirm these findings.

DECLARATION OF INTEREST STATEMENT
The Author(s) declare(s) that there is no conflict of interest.

APPENDICES
Abbreviations
CBCT: Cone beam computed tomography
MARPE: Miniscrew assisted rapid palatal expansion
RME: Rapid maxillary expansion
SPSS: Statistical package for the social sciences

REFERENCES