A Retrospective CBCT Investigation utilizing a New 3D Segmentation Method to Assess Mid-Palatal Suture Response After Rapid Maxillary Expansion with a Hybrid Expander in Adolescents

Mohamed A Shendy[1], Mohamed I Assadawy[2], Abdelrahman M Galal[3], Hany M Mahmoud[4], Atef I. Ahmed[5], Wael B Abdelhameed[6], Galal Abou Elyazied Nasr[7]

1. Lecturer, Department of Orthodontics, Faculty of Dental Medicine, Al- Azhar University, Cairo –Boys. Egypt.
2. Lecturer, Department of oral medicine-radiology and periodontology, Faculty of Dental Medicine, Al- Azhar University, Cairo –Boys. Egypt.
3. Lecturer,Department of Oral Biology, Faculty of Dental Medicine, Al- Azhar University, Cairo –Boys. Egypt.
4. Lecturer, Department of Oral Biology, Faculty of Dental Medicine, Al- Azhar University, Cairo –Boys. Egypt.
5. Assistant professor,Department of Oral Biology, Faculty of dental medicine, Al-Azhar University (Assiut, Boys) Egypt
6. Lecturer,Department of Oral Biology, Faculty of dental medicine, Al-Azhar University (Assiut, Boys) Egypt.
7. Assistant professor,Department of Oral Biology, Faculty of dental medicine Al- Azhar University, Cairo –Boys. Egypt.

Abstract

Background/purpose: The effect of hybrid expander with rapid palatal expansion (RPE) technique on changes in the mid-palatal suture's morphometry (MPS) utilizing cone beam computed tomography (CBCT) could provide important clues in the diagnosis and clinical efficacy of RPE in orthodontics and improve evidence-based treatment procedures. CBCT-based three-dimensional (3D) examination approaches of anatomical structures would be beneficial. The goal of this retrospective study was to evaluate alterations in the mid-palatal suture (MPS) following Hybrid rapid palatal expander (RPE) through using cone beam computed tomography (CBCT). **Materials and methods:** A total sample of 246 pre and post expansion CBCTs of 123 adolescent orthodontic patients (87 girls and 36 boys) with a constricted maxilla average age of 13.9 years (Y) was evaluated through a retrospective study. 123 CBCT data were obtained prior to and another 123 CBCT following 3 months after the last hybrid rapid expander activation; the MPS was segmented using grow from seeds algorithm, and segment statistics was utilized for quantifying morphological parameters, the T-test was utilized to compare pre- and post-expansion data. When $P \leq 0.05$, the significance level was established. **Results:** Our investigation revealed a statistically significant increase in the mean number of voxels, volume, surface area, and oriented bounding box (OBB) Diameter-X post-treatment as well as post-treatment significant decrease in mean elongation parameter. **Conclusion:** The volumetric and morphometric alterations in MPS assessed using the CBCT segmentation technique could help in better visualization and formulation of expansion procedures.

KeyWords: Cone beam computed tomography; Hybrid hyrax; Mid-palatal suture; Morphometry; Rapid Palatal expansion; 3D Segmentation.

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Introduction:

Patients who have a constricted maxilla with or without posterior crossbite can be managed through Rapid palatal expansion (RPE) and it is successful when the mid palatal suture (MPS) is opened (1,2). In 1860, Angell was the first to introduce RPE to a 14-year-old girl. The opening of MPS is a sign of effective expansion therapy. Pre-clinical studies were performed on Monkeys (3), rats (4), and biopsies from children have all been used to understand sutural reactions to orthopedic stresses (5). The histopathological study (6) confirmed that sutural fusion begins in the posterior area and progresses anteriorly (7) with no relation to chronological age (5).

The evidence for a link between skeletal age and RPE is currently lacking and of low quality (8). Other researchers looked into the relationship between MPS maturation utilizing cone beam computed tomography (CBCT) (9–11) or cervical vertebral maturation (CVM) in the post-pubertal stage (12), but another systematic review revealed that no specific approach is taken into account (13). Another study found that females have a higher MPS density than males, but that it is not a reliable tool for predicting sutural opening and, as a result,

it is challenging to anticipate how much the skeletal effect will be (14).

The literatures disagree on the exact ossification of the MPS (3,15,16). MPS resistance may be owing to circumoral muscle activity and soft tissue inclusion, maturation stage (17,18), so the usefulness of retainers in controlling perioral stresses and maintaining stability was demonstrated over a one-year after expansion (19). Resistance of MPS usually occurs after fusion with circum maxillary sutures as in stage D&E, particularly in females (9). With the growing use of 3D radiographic imaging in orthodontics, hence, the right method for measuring the effect of RPE on bone using CBCT should be clarified (20,21).

Although RPE is a popular orthodontic treatment option when required (21,22), more research into the impact of the Hybrid RPE on morphometric alterations in MPS utilizing CBCT is needed. A collection of subjective diagnostic criteria for palatal suture maturation and a better understanding of MPS morphology is beneficial to the clinical efficacy of RPE in orthodontics to improve evidence-based treatment procedures. CBCT-based on three-dimensional (3D) examination approaches of anatomical structures would be beneficial.

To put it another way, a 3D assessment of the MPS morphology could aid in the right selection of the expander equipment and improve expander device modification, evaluation of the sutural opening morphogenic pattern in 3D geometric measurements and finally, clarification of any radiographic sign for bone deposition in MPS after 3 months which might be helpful in the determination of retention duration protocol, this study directed to use CBCT to assess morphological changes in the MPS after utilizing the Hybrid RPE.

Material and methods:

Study design

The Orthodontic outpatient clinic at Al- Azhar University in Cairo (Boys), Faculty of Dental Medicine, did a retrospective study on a total of 246 pre and post expansion CBCTs of 123 patients having transverse maxillary constriction who were adolescent orthodontic patients

(average age, 13.9 years) included 87 girls and 36 boys.

Ethical approval

The ethical approval was authorized by the ethics committee of the faculty under (number 779/220) - the research's goals were communicated with the participants and parents verbally and in writing, and prior starting treatment, a permission document (consent form) for the patient's involvement in the study program was acquired. Inclusion criteria included healthy patients with narrowing maxilla regardless presence or absence of posterior crossbite. Cleft palate patients or others with craniofacial deformities or any periodontal affection were excluded (23–26).

Clinical procedure

Clinical approach Hyrax expanders 9mm screw length was employed and supported bilaterally by maxillary first permanent molars in addition to two mini-screws. All appliances were implanted and cemented in the patient's mouth, then activated two quarter turns in the same visit (0.5 mm), then half turn per day by the patient or parents for the following 15 days, resulting in a net enlargement of roughly 8 mm in all patients (23–25,27). The patients were examined on the fourth, seventh, and tenth days to verify and validate the appliance's activation process. A little piece of composite material was used to secure the screw, then three months retention following the final opening of hybrid expander. After the retention phase, which lasted roughly three months, non-additional orthodontic intervention was begun in either of the jaws.

CBCT assessment

CBCT images were captured utilizing a Planmeca ProMax 3D Mid (at T1 and T2). Scan duration: 18 seconds, 90 kV, 12.5 mAs, and a viewable area of 20 x 17 mm, 194 degrees and a 200 mm voxel size. High-resolution CBCT scans were performed in a standard way before the initiation of treatment (T1) three months following the final opening of hybrid expander (T2). These have been downloaded to an individual laptop like a digital imaging and communications in medicine (DICOM) file, and the mid-palatal suture was segmented as label map volume using open source software and exported as a surface model (Figures 1,2,3,4&5). The morphological changes were assessed before and after expansion using segment statistics of label map volume, which included voxel count of the segment, volume in mm, ferret diameter, centroid axes right, anterior and superior (RAS), surface area mm, roundness, flatness. Elongations, oriented bounding box (OBB) origin RAS. OBB diameter XYZ and direction.

Statistical Analysis

Through examining the pattern of the data utilizing tests for normalcy (Shapiro-Wilk tests), numerical data was analyzed for normality. Centroid measurements, Feret diameter, roundness, flatness, elongation, OBB origin-r, OBB origin-s, OBB origin-s, OBB diameters X, Y, Z as well as OBB X diameter-r the data were distributed normally (parametrically) while all other measurements demonstrated an abnormal (non-parametric). Presenting of data through mean and standard deviation (SD) values. Paired t-test was used to compare pre-and postoperative parametric measurements. Wilcoxon signed-rank test was used to compare pre-and postoperative non-parametric data. When $P \leq 0.05$, the significance level was established. Using IBM SPSS Statistics for Windows, Version 23.0, statistical analysis was carried out. IBM Inc., Armonk, New York.

Results:

After treatment, the mean number of voxels, volume, surface area as well as OBB Diameter-X post-treatment showed significant increase. On the other hand, post-treatment significant decrease in mean elongation parameter. The remaining parameters showed no statistically significant change after treatment **Table (1)Figures (6), (7), and (8).**

Discussion:

Rapid palatal expansion (RPE) is recommended for patients with a narrow maxilla. However, it comes with a few drawbacks, including dental tilting of the anchorage unit (1,27). Hybrid hyrax (HH) is a suitable expander with forces above 120 Newton, making it effective in cases where there are fewer anchorage units, boosting skeletal impact, reducing anchor tooth tipping, and facilitating maxillary protraction with less anterior tooth proclination (28–30).

The advantage of HH is that the expander produces an even distribution of force on each minis crew, resulting in fewer dental adverse effects on the anchor teeth (29). Unfortunately, research into the effects of HH on mid-palatal suture (MPS) morphology alterations has been restricted. So, the primary outcome was to see how HH affected the MPS morphology. In comparison to immediate or long-term periods, the observational period in this study is an intermediate term of around 3 months, which is advantageous to both the patient and the clinician and is unaffected by stability or growth. CBCT has a substantial benefit in that it can identify and quantify 3D morphologic alterations in MPS (31). CBCT is also helpful for determining the precise location of mini screw insertion (32)

RPE, associated with sutural opening, is an excellent procedure to widen constricted maxilla and relieve crowding. The sutural opening was assessed qualitatively rather than quantitatively (2). However, there were differences in the quantity of sutural openings described in previous research (27,33), while Kwak et al. (34) described a quantitative method for MPS evaluation. The skeletal or dentoalveolar effect response is dependent on the MPS stage of skeletal maturity (13).

Although matching all patients' expansion amounts was complex, the small number of patients in this study made it more accessible. This was concomitant with Garib et al. (26) and against Grünheid et al., who considered the ratio of expansion for each patient instead of a constant amount (16). The pyramidal shape was clearly recorded in this investigation, which was consistent with earlier research (21,33).

The findings of this study showed asymmetrical MPS opening could be attributable to the restricted opening of medial pterygoid plates alone of pterygomaxillary junctions or opening of one side only; this was consistent with Colak et al. (35). Some anatomical references points are only applicable in 2D evaluation techniques but not in 3D evaluation techniques (36), Hence, the CBCT scan must be utilized to develop novel volumetric measuring techniques as well as to confirm anatomical reference with the 2D radiograph (37).

Requena Pérez et al. innovative.'s approach for palatine suture volumetric evaluation after RPE demonstrated high repeatable and reproducible volumetric measurements while linear one did not, so CBCT was mandatory (37). Koçer et al. claim that volumetric measurements can be used in conjunction with linear measurements to identify edema caused by RPE operations directly in the clinical setting, hence enhancing treatment results and prognosis. (38).

In the present study, the MPS dimensions equal to the size of a minimal oriented bounding box (OBB)

is a typical technique used in engineering? The primary idea behind this method is to place the investigated shape in a cuboidal bounding volume that is "smallest" in some way ("smallest" might be

defined in terms of volume or surface) (39). For professional measurements, the orientation of the smallest oriented bounding box was made automatically but not visually because the visual method has disadvantages due to human individual variation and bias such as difficulty to determine the minimal bounding box, user-induced inaccuracies, for example, the three measured sizes may not be perfectly perpendicular to each other. Feret diameters (FD) are the perpendicular distances between parallel tangents touching opposite sides of the MPS surface. We therefore have FD vertical and horizontal. (40).

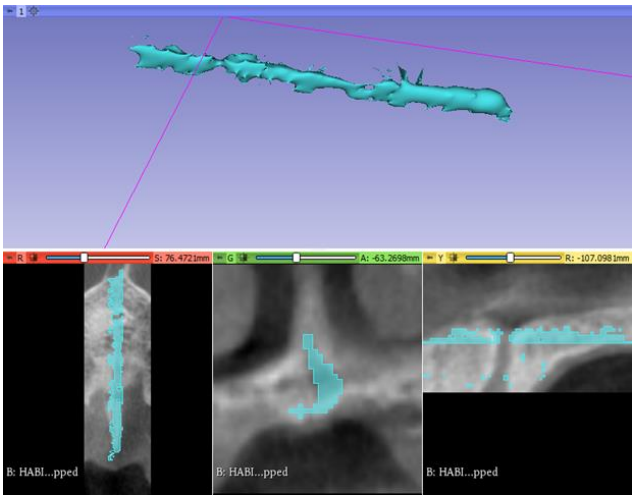
The results showed, a significant increase in voxels, volume, surface area as well as OBB Diameter-X mean number post-treatment. This was in accordance with Requena Pérez et al. (37). The results showed, a significant decrease in elongation mean number post-expansion. This might be attributed to after RME, the palate widens and gets a lower position. This was in accordance with Smith et al. (40).

Conclusion:

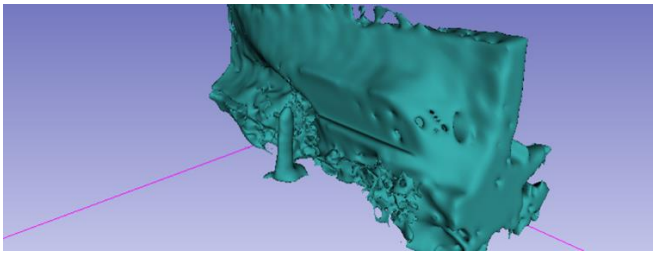
The volumetric and morphometric alterations in MPS assessed using the CBCT segmentation technique could help in better visualization and formulation of expansion procedures. Even though there was no control group because of ethical and medico-legal concerns, and the requirement for comparisons with other active control groups (i.e., other expander appliances), the following are the findings: The morphology of the MPS revealed various interdigitating lines at different levels as bone thickness varied, the volumetric and morphometric alterations in MPS could be assessed using CBCT segmentation, and finally this segmentation improved easy visualization and detection of fine bony spicules at the expanded MPS.

Data availability statement: On logical demand, the corresponding author will be given access to the data that underpins this paper.

Conflict of interest: This study's authors have no financial or other conflicts of interest.

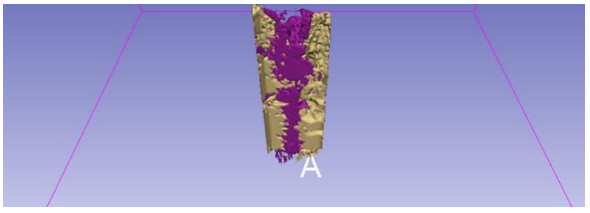


•**Fig (1):** Mid Palatal Suture Segmented Using Grow and Seed Method

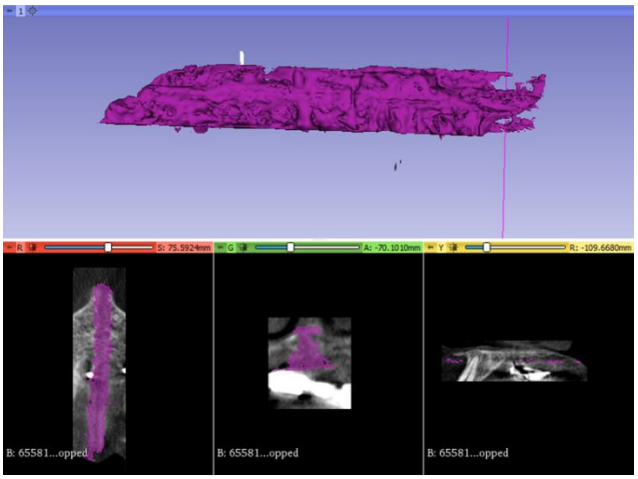


•**Fig (2):** Mid Palatal Suture Segments After Expansion Showing Increase in Morphological Parameters.

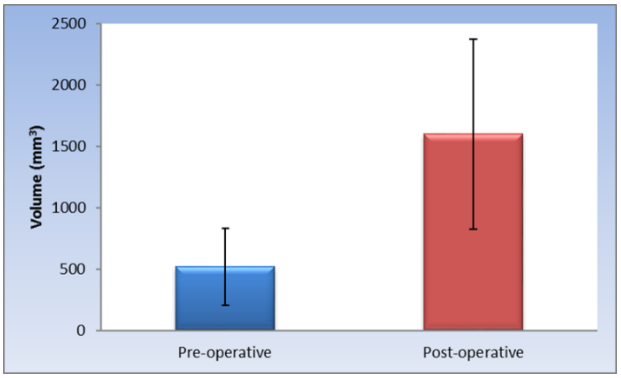
•**Fig (3):** CBCT Showing Coronal Section of Mid-Palatal Suture.



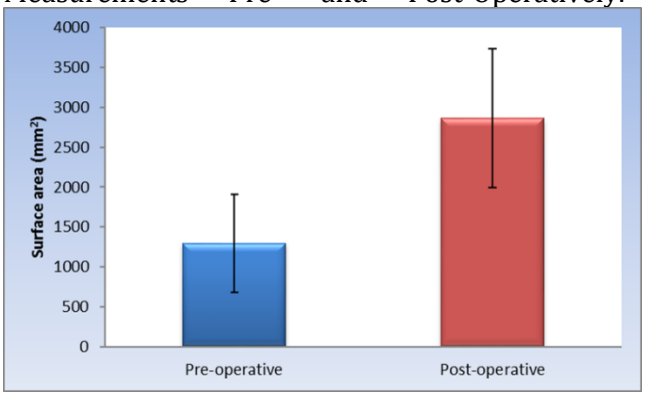
•**Fig (4):** Label Map Volume Demonstrating Mid-Palatal Suture and Para-Sutural Bone.



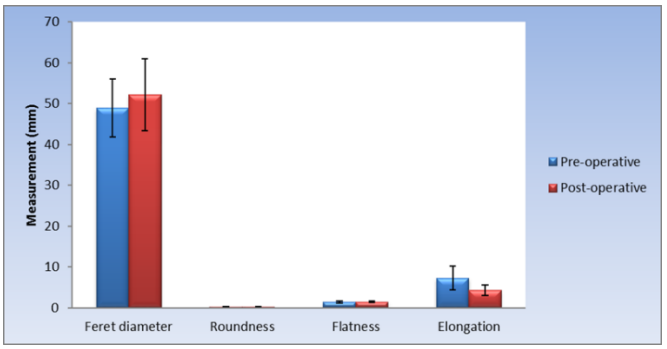
•**Fig (5):** Mid- Palatal Suture Illustrated in Axial, Coronal and 3D Views.



•**Fig (6):** Bar Chart Representing Mean and Standard Deviation Values for Volume Measurements Pre- and Post-Operatively.



•**Fig (7):** Bar Chart Representing Mean and Standard Deviation Values for Surface Area Measurements Pre- and Post-Operatively.



•**Fig (8):** Bar Chart Representing Mean and Standard Deviation Values for Feret Diameter, Roundness, Flatness and Elongation Measurements Pre- and Post-Operatively.

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