Original Article

Comparison of Ultrasonography and Cone-beam Computed Tomography for Quantitative Assessment of Midpalatal Suture Opening after Rapid Palatal Expansion: A Pilot Study

Madhanraj Selvaraj[1], Ritu Duggal[1]*, Smita Manchanda[2], Prabhat Kumar Chaudhari[1], Ashu Seith Bhalla[2]

[1]Division of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, India, [2]Department of Radiodiagnosis, All India Institute of Medical Sciences, New Delhi, India

Abstract

Background: The study was to compare the ultrasonographic (USG) and cone-beam computed tomographic (CBCT) measurements of the width of anterior midpalatal suture (MPS) opening following rapid palatal expansion (RPE). **Methods:** The study included 13 patients (boys: 6; girls: 7) with a mean age of 11.85 ± 1.82 years who underwent RPE therapy for maxillary transverse deficiency. The width of the anterior MPS opening was measured in real-time USG, postscan USG image, and CBCT that were obtained immediately after maxillary expansion. The postscan USG and CBCT measurements were performed twice by two examiners at different times. The intraclass correlation coefficient (ICC), Bland–Altman plot, and paired *t*-test were performed to evaluate intra- and inter-examiner reliability, level of agreement, and systematic error between different measurements. **Results:** On serial USG evaluation, the MPS opening was seen as the discontinuity in the margins of the maxillary cortical bone, which was not evident before expansion or after the retention period. The intra- and inter-examiner reliability was high (ICC >0.9) for all the measurements. The Bland–Altman plot showed considerable agreement between the different methods, with maximum observations having a mean difference which was within the 95% limits of agreement (real-time vs. postscan USG: ±0.75 mm; CBCT vs. real-time USG: ±0.93 mm; and CBCT vs. postscan USG image: ±1.09 mm). The systematic differences were not statistically significant ($P < 0.05$) for all the computed measurements. **Conclusion:** USG can be used as a reliable nonionizing imaging modality to assess the anterior MPS opening following RPE.

Keywords: Cone-beam computed tomographic, maxillary expansion, radiation, ultrasonography

Introduction

Maxillary transverse deficiency can be seen in patients of all ages seeking orthodontic treatment. It may manifest as dental crowding, unilateral or bilateral posterior crossbites, and may be associated with mandibular deviation.[1] Transverse discrepancy usually does not correct itself and can affect the sagittal relationships between the jaws. If not addressed early on, the discrepancy may worsen and require surgical correction after growth completion.[1] Therefore, early treatment is warranted to restore a normal transverse relationship and attain a good occlusal intercuspation.[1,2] Rapid palatal expansion (RPE) is advocated in young patients to correct the transverse maxillary discrepancy and increase the arch perimeter to relieve dental crowding.[2] It also facilitates orthopedic correction in skeletal Class II and III malocclusions.[3]

The primary goal of RPE therapy is to disarticulate the circum-maxillary suture, particularly the midpalatal suture (MPS), and achieve skeletal expansion.[1] The opening of MPS following RPE therapy has been documented in histological[4] and radiological studies.[5] Clinically, MPS separation is confirmed by the appearance of a diastema

Received: 21-11-2023 **Revised:** 03-01-2024 **Accepted:** 31-01-2024 **Available Online:** 30-06-2024

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jmut

DOI: 10.4103/jmu.jmu_154_23

Address for correspondence: Dr. Ritu Duggal, Division of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi - 110 029, India. E-mail: drmadhanrajs@gmail.com

How to cite this article: Selvaraj M, Duggal R, Manchanda S, Chaudhari PK, Bhalla AS. Comparison of ultrasonography and cone-beam computed tomography for quantitative assessment of midpalatal suture opening after rapid palatal expansion: A pilot study. J Med Ultrasound 2025;33:54-60.

between the maxillary central incisors.[6] However, the diastema may not be clinically visible due to the crowded or overlapping maxillary central incisors. Conventionally, a two-dimensional occlusal radiograph has been used to evaluate the MPS opening.[7] However, the occlusal radiographs are unreliable for quantifying MPS opening due to projection error, lack of standardization, and superimposition of adjacent bone and soft tissues.[5]

The development of three-dimensional (3D) imaging techniques, such as cone-beam computed tomography (CBCT), has made the visualization and assessment of craniofacial structures more accessible and accurate.[8] In addition, the 3D technique can precisely quantify the MPS opening on all three planes. However, despite the numerous advantages of CBCT, the potential hazards of radiation exposure are a major concern, especially in young children. Although the effective dose of CBCT with a smaller field of view (FOV) is lower, repeated radiation exposure has a cumulative effect.[8]

In an effort to reduce exposure to ionizing radiation, the use of ultrasonography (USG) as a nonionizing radiation-free imaging technique in dentistry is gaining attention. USG also allows for a real-time examination with the additional benefit of lower costs. In recent years, the USG has been used to visualize maxillofacial hard- and soft-tissue structures such as soft-tissue pathology,[9] masseter muscle thickness,[10] dental cracks and fractures,[11] periodontal bony defects,[12] and to assess periapical lesions.[13] In addition, callus formation is estimated following distraction osteogenesis (DO),[14-17] and diagnosis of fractures in maxillofacial region,[18,19] In orthodontics TMJ complex can be visualized for temporomandibular disorders,[20] and soft tissue gingival thickness can be measured during miniscrew placement.[21]

Previous studies suggested that USG could be useful for assessing the MPS opening in patients undergoing RPE[22] and surgically assisted RPE (SARPE).[23] However, the two-dimensional (2D) occlusal radiograph, which is unreliable for quantitative analysis, was used to validate the usefulness of USG. Moreover, USG was used as a visual inspection tool, and the accuracy of quantitative measurements following RPE was not evaluated previously using a reliable method. CBCT has an ability to provide detailed, high-resolution three-dimensional images, allowing precise quantification of MPS opening. Therefore, the main objective of this study was to assess the accuracy of USG in quantifying the MPS opening after RPE compared with the CBCT measurements. Consequently, a USG scan of MPS was done before and after RPE, and CBCT was taken once after the expansion protocol.

Materials and Methods

Patient selection

The consecutive sample consisted of 15 growing patients who were recruited from the postgraduate orthodontic clinic at Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, India. The study was conducted in accordance with the Declaration of Helsinki. Approval was obtained from the institutional ethics committee before the start of the study (IECPG-308/29.05.2019, RT-21/27.06.2019). One patient refused the treatment before the expansion was started due to the bulkiness of the intraoral appliance, and another denied treatment due to pain during initial screw activation. Hence, 13 patients (6 boys; 7 girls) with a mean age of 11.85 ± 1.82 years (range: 9–14 years) underwent RPE therapy for the maxillary transverse discrepancy. The details of sample characteristics and the amount of calculated and achieved expansion are given [Table 1]. The inclusion criteria used in this study were patients aged 8–14 years in mixed or early permanent dentition stage with maxillary transverse discrepancy with posterior unilateral or bilateral crossbites, healthy dental and periodontal status, and positive informed consent. Patients with a history of previous orthodontic treatment, any systemic disease affecting bone metabolism, history of facial trauma, craniofacial anomalies, and syndromes were excluded from the study. All the patients and guardians were given an information sheet about the study, and written informed consent was obtained before the start of the study.

Appliance design and expansion protocol

All patients underwent RPE therapy with a conventional acrylic-bonded HYRAX appliance (Leone®, Sesto Fiorentino, Firenze, Italy), covering the crown of fully erupted posterior teeth bilaterally. The activation schedule was one-quarter turn twice daily (0.25 mm each turn, 0.5 mm/day).[1] The difference between the mesiobuccal cusp of maxillary first molars and the maximal gingival extension of buccal grooves on mandibular first molars was used to calculate the required amount of expansion, and 2–4 mm was added to accomplish overcorrection. After overcorrection, the expander was stabilized and left in place for 3 months as retention.

Ultrasound imaging protocol and measurements

Using a standardised protocol, the ultrasound probe was placed on the anterior maxillary region (area within the nasal columella–labial junction and the upper lip), with the beam oriented perpendicular to it [Figure 1a]. The interpretation of USG image landmarks is demonstrated in [Figure 1b]. USG was performed at three time points: before the start of expansion (T0), immediately after the expansion (T1), and after 3 months of retention (T2) [Figure 2a-c]. USG scan was conducted twice within an interval of 15 minutes. USG was performed using the Aixplorer ultrasound system (SuperSonic

Table 1: Summary of age and gender of included patients and amount of expansion screw activation

Particulars	Mean±SD, median (minimum–maximum)
Age (years)	11.85±1.82, 12 (9–14)
Gender (number and frequency in %)	6 males (46.2); 7 females (53.8)
Amount of screw activation (mm)	7.30±0.44, 6 (6–10)

SD: Standard deviation

Imagine S.A., Aix-en-Provence, France) with a linear transducer probe (2–10 MHz) to obtain B-mode images. During USG, the patients were made to sit straight, with the occlusal plane parallel to the floor. The ultrasound probe was placed on the anterior maxillary region (area within the nasal columella–labial junction and the upper lip), with the beam oriented perpendicular to it [Figure 2].

During the T1 USG scan, real-time measurement of the width of the anterior MPS opening was performed twice on the axial slices of the B-mode images [Figure 2d]. All the USG scans and real-time measurements were performed by the same radiologist (S.M.), having 15 years of experience. In addition, the USG images were exported for performing measurements using ImageJ software (National Institutes of Health, Bethesda, MD). After adequate training and calibration, the postscan USG image measurements were performed by two examiners (M.S. and K.S.) at two different times that were at least 3–4 weeks apart. The examiners were adequately blinded to the patient data and other measurements.

Cone-beam computed tomography imaging and measurement protocol

A small FOV CBCT image was obtained only during T1, i.e., immediately after the expansion. All CBCT images were obtained using the same scanner, iCAT Next Generation (iCAT; Imaging Sciences International, Hatfield, PA, USA), by a single experienced radiographer. The scanner was operated using a standardized protocol with a 120 KV, 5 mAs, 0.3 mm isometric voxel size, 8.9 s exposure time, and 8 cm × 8 cm FOV. During acquisition, the patients were in a sitting position, stabilized with a head strap and chin support, and remained motionless throughout the scan.

The CBCT scan was imported to Dolphin 3D software (version 11.95, Patterson Inc., Chatsworth, Calif) to perform the measurements. First, the orientation of CBCT was done with the sagittal plane passing through the palatal plane (connecting the anterior and posterior nasal spine), the coronal plane passing through the Jugale (intersection point of outline of the maxillary tuberosity and zygomatic buttress) point bilaterally, and the axial plane passing perpendicular to the sagittal and coronal plane [Figure 3a-c]. After the orientation of CBCT, the X-axis (blue line) and Y-axis (green line) were made to pass through point A (subspinale point) in the sagittal section. Next, the width of the MPS opening was measured in the axial section at point A and verified in the coronal section of CBCT [Figure 3d]. As the linear ultrasound probe height was 15 mm, the opening of the MPS was measured 2 mm above and below point A in the CBCT dataset, and the mean was obtained. After adequate blinding, two trained examiners (M.S. and K.S. with experience of more than three years in the relevant field) performed the CBCT measurements twice after a 3–4-week interval.

Statistical analysis

The data were analyzed using SPSS software (Windows version 22.0; IBM Corp., Armonk, NY). Descriptive statistics were used to summarize the continuous data: mean with standard deviation, median with interquartile range, and minimum and maximum [Table 2]. The real-time USG scan measurements were performed twice by the radiologist. To evaluate reliability, two independent examiners (E1 and E2)

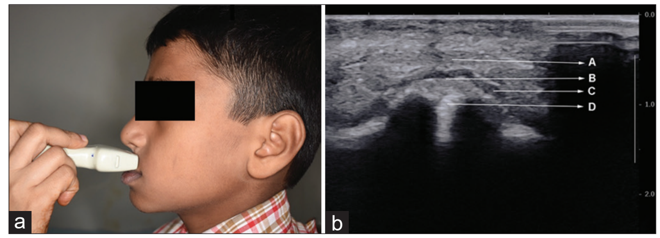

Figure 1: Ultrasonography scanning protocol and image. (a) Extraoral placement of the linear transducer probe over the anterior maxilla. (b) Landmarks in the USG image (A- orbicularis oris muscle, B- labial cortical border of anterior maxilla, C- labial vestibule, D-midpalatal suture opening)

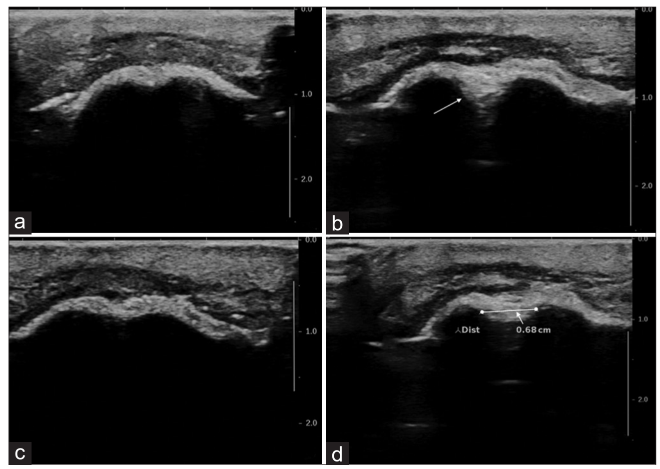

Figure 2: Serial USG images and measurement. (a) Before start of expansion (T0), (b) Immediately after expansion (T1), (c) After three months of retention (T2), and (d) Width of maximum anterior midpalatal suture opening performed in axial slice

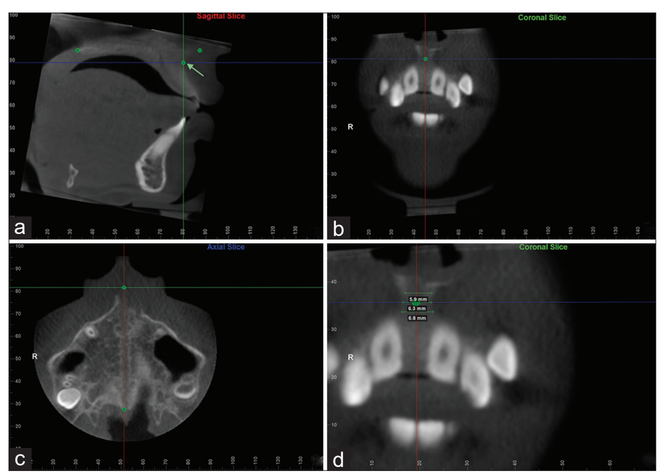

Figure 3: Cone-beam CT orientation and measurements. (a) sagittal section (b) coronal section (c) axial section and (d) Linear measurement of the width of anterior midpalatal suture opening performed in the coronal slice. (The green arrow indicates Point A/ Subspinale point).

repeated measurements in postscan USG images and CBCT. The intra- and inter-examiner reliability of measurements was evaluated using the intraclass correlation coefficient (ICC) test with a 95% confidence interval. An ICC score between 0.75 and 0.9 was considered good reliability, and values >0.90 were considered an excellent reliability. Correlation and level of agreement between real-time USG, postscan USG image, and CBCT measurements were determined by ICC and Bland–Altman plots, respectively. The systematic error between different time periods and methods was calculated using the paired *t*-test. Statistical significance was set at $P < 0.05$.

Results

This prospective study was conducted to compare the measurement of anterior MPS opening obtained using real-time USG, postscan USG image, and CBCT images. On visual inspection of serial USG images before the suture opening, the continuity of the maxillary alveolar bone was seen as a continuous hyperechoic line [Figure 2a and c]. However, with the MPS opening, there was a discontinuity in the margins of the maxillary alveolar bone, which was filled with increased echogenicity with ring-down artifact [Figure 2b].

The intra-examiner reliability, as calculated from ICC, showed a high correlation between the first and second measures of real-time USG (ICC: 0.95), postscan USG image (ICC [E1]: 0.98 and ICC [E2]: 0.98), and CBCT (ICC [E1]: 0.98 and ICC [E2]: 0.98). The results of ICC, evaluating the inter-examiner reliability, showed a high correlation between both the examiners for postscan USG image (ICC: 0.99) and CBCT (ICC: 0.98] [Table 3]. The measurements performed at two different times showed no statistically significant systematic error with mean differences of 0.08 mm, 0.04 mm, and 0.01 mm in real-time USG, postscan USG image, and CBCT measurements, respectively [Table 4].

Similarly, the measurements showed no statistically significant systematic error with a mean difference of 0.09 mm for real-time USG versus postscan USG image, 0.2 mm for CBCT versus real-time USG, and 0.29 mm for CBCT versus postscan USG image [Table 4]. Furthermore, a strong correlation was observed between the measurements obtained from different methods as calculated from ICC, i.e., real-time versus postscan USG image (ICC: 0.96), CBCT versus real-time USG (ICC: 0.94), and CBCT versus postscan USG image (ICC: 0.90) [Figure 4].

The Bland–Altman plot showed that the maximum observations (100% for real-time vs. postscan USG image, 92.3% for CBCT vs. real-time USG, and 92.3% for CBCT vs. postscan USG image) had a mean difference within the limits of agreement [Figure 4]. The 95% limits of agreement between real-time versus postscan USG image were -0.84 to 0.66 mm (mean difference: −0.09), CBCT versus real-time USG were -1.13 to 0.73 (mean difference: −0.2 mm), and CBCT

Table 2: Descriptive statistics for the amount of anterior midpalatal suture opening measured using different modalities

Method	Amount of suture opening (mm)					
	Examiner 1			Examiner 2		
	Mean±SD	Median (IQR)	Minimum–maximum	Mean±SD	Median (IQR)	Minimum–maximum
Real-time USG						
M1	3.15±1.35	2.60 (2.30–3.00)	2.1–6.8	-	-	-
M2	3.07±1.17	2.60 (2.30–3.30)	2.1–6.3			
Postscan USG image						
M1	3.24±1.17	2.90 (2.56–3.01)	2.3–6.4	3.30±1.02	2.90 (2.80–3.20)	2.10–6.00
M2	3.20±1.13	2.76 (2.47–3.22)	2.1–6.2	3.20±1.11	2.90 (2.50–3.00)	2.20–6.20
CBCT						
M1	2.95±1.33	2.30 (2.26–3.00)	1.8–6.6	3.23±1.31	2.70 (2.60–3.40)	2.10–7.10
M2	2.95±1.39	2.50 (2.40–2.91)	1.6–7.0	3.06±1.33	2.60 (2.50–3.20)	1.60–6.90

CBCT: Cone-beam computed tomography, USG: Ultrasonography, M1: First measure, M2: Second measure, IQR: Interquartile range, SD: Standard deviation

Table 3: Intra- and inter-examiner reliability of amount of anterior midpalatal suture opening measurement using different modalities

Method	Examiner	Intra-examiner reliability			Inter-examiner reliability		
		ICC	95% CI	*P*	ICC	95% CI	*P*
Real-time USG	Single examiner	0.95	0.87–0.99	<0.0001*	-	-	-
Postscan USG image	Examiner 1	0.98	0.95–0.99	<0.0001*	0.99	0.98–0.99	<0.0001*
	Examiner 2	0.98	0.92–0.99	<0.0001*			
CBCT	Examiner 1	0.98	0.93–0.99	<0.0001*	0.98	0.68–0.99	<0.0001*
	Examiner 2	0.98	0.86–0.99	<0.0001*			

*P<0.05 significant. CBCT: Cone-beam computed tomography, USG: Ultrasonography, ICC: Intraclass correlation coefficient, CI: Confidence interval

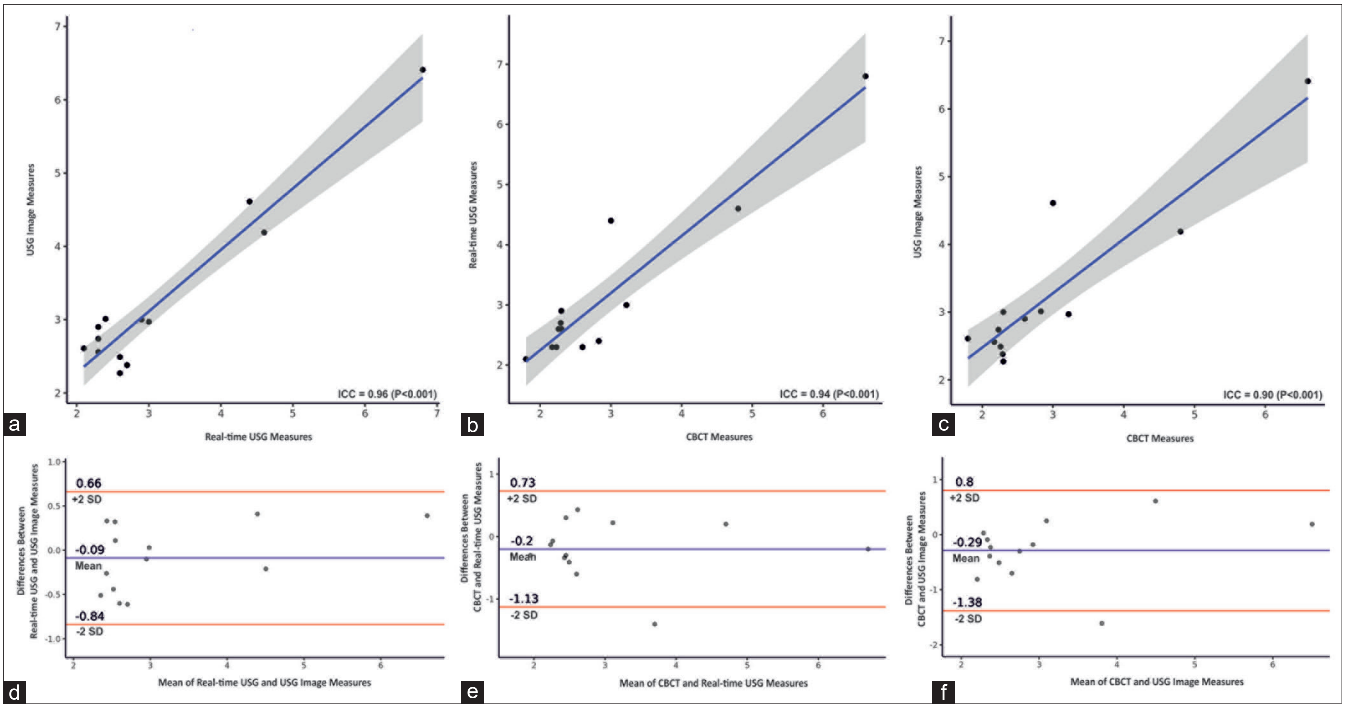

Figure 4: Scatterplots depicting the correlation between the measures obtained from (a) real-time and postscan ultrasonography (USG) image, (b) cone-beam computed tomography (CBCT) and real-time USG, and (c) CBCT and postscan USG image. The blue line represents the general trend of correlation between the two methods. The shaded gray area represents the 95% confidence interval of this trendline. The Bland–Altman plots comparing the mean of two measures (x-axis) to the difference between the two measures (y-axis) obtained from (d) real-time and postscan USG image, (e) CBCT and real-time USG, and (f) CBCT and postscan USG image. The blue line represents the mean difference between the two measures, and the red lines represent the limits of agreement (mean ± 2 standard deviation of difference). All measurement values are in millimeters

Table 4: Paired sample *t*-test for the assessment of systematic error

Comparison	Mean±SD	*t*	*P*
Real-time USG: First versus second measure	0.08±0.37	0.831	0.422 (NS)
Postscan USG image: First versus second measure	0.04±0.21	0.73	0.479 (NS)
CBCT: First versus second measure	0.01±0.29	0.096	0.925 (NS)
Real-time versus postscan USG image	0.09±0.38	−0.827	0.424 (NS)
CBCT versus real-time USG	0.2±0.47	−1.523	0.154 (NS)
CBCT versus postscan USG image	0.29±0.56	−1.861	0.087 (NS)

CBCT: Cone-beam computed tomography, SD: Standard deviation, USG: Ultrasonography, NS: Nonsignificant

versus postscan USG image were -1.38 to 0.8 mm (mean difference: −0.29 mm).

Discussion

Young and adolescent patients with maxillary transverse deficiency are usually treated by RPE therapy. The stages of midpalatal sutural maturation provide a reliable method for treatment planning in both young and adult patients.[24] To confirm the MPS opening and to evaluate the amount of skeletal changes, an occlusal radiograph and a frontal cephalogram are commonly used. However, the superimposition of the anatomical structures results in a limited view of the region, leading to measurement error. On the other hand, advancements in 3D imaging systems and software technology have led to the accurate and precise evaluation of complex craniofacial structures.

Previously, the measurement of the MPS opening has been evaluated using both computed tomography (CT)[25] and CBCT.[26] Although the radiation doses from CBCT are generally lower than those from multidetector CT, the patients are still exposed to more radiation than any conventional 2D radiography.[5] Most of the patients undergoing orthodontic treatment belong to the younger age group, and they are at a higher risk of ionizing radiation. Ionizing radiation can damage DNA and can cause mutation effects. Notably, the young age group is at risk as less developed, and more undifferentiated cells have increased tissue radiosensitivity.[27] CBCT can deliver 8–40 times higher dosage than panoramic radiographs.[28,29] The exposure parameters must be chosen with the patient's radiation exposure in mind.[30] Therefore, a low-dose CBCT imaging protocol with a small FOV of 8 cm × 8 cm was used in all our patients to reduce radiation exposure.

As a result of harmful radiation from conventional radiography, the alternate use of nonionizing radiation-based approaches such as ultrasonography and magnetic resonance imaging (MRI) is being explored. Ultrasonography is a noninvasive and real-time imaging method which helps assess osteotomy gap and bone remineralization semi-quantitatively.[14] Other advantages include cost-effectiveness and offering a radiation-free alternative for monitoring changes over time. In addition, the B-mode scanning of USG created two-dimensional images with different gray scales used to assess the surrounding soft tissue and bone mineralization of the MPS. Our study evaluated the MPS opening with serial USG images (real time and postscan) and compared it with CBCT obtained after maxillary expansion. The MPS opening in the USG was visualized in the transverse plane depicting the two-dimensional nature of the measurement. In contrast, the multiplanar reconstruction view (axial and coronal sections) was used to measure the amount of suture opening in the CBCT dataset. Therefore, multiple sections above and below point A were selected to conform to the thickness of the linear probe (approximately 15 mm) of the USG instrument. Then, the averaged CBCT measurements were compared with the USG measurement.

In DO patients, the amount of osteotomy gap and monitoring of callus formation and mineralization has been assessed by serial USG. It has been shown that USG is reliable for evaluating bone maturation and equally accurate as two-dimensional radiographs in DO patients. Furthermore, at the end of the distraction, the gap appeared echolucent with distinct discernible boundaries. At the end of the consolidation period, no visible gap with a distinct margin was seen.[14-17] The current study also revealed similar observations on visual inspection of serial ultrasound images.

Previous studies compared USG and occlusal radiographs following RPE[21] and SARPE[22] therapy. The amount of suture opening and sutural mineralization after expansion was compared. However, using occlusal radiographs for quantitative measurements can prove to be unreliable. CBCT, with a voxel size of 0.3 to 0.4 mm, provides highly accurate and reliable linear measurements in cross-sectional images.[31] Hence, in the present study, CBCT measurement was used as the standard for comparison. The amount of screw opening and observed suture opening was compared in the current study. The mean percentage of opening seen in the anterior midpalatal region was 43.15%, 44.35%, and 40.42% of the total screw expansion in real-time USG image, postscan USG image, and CBCT, respectively. Liu *et al*., in their systematic review, found that the amount of suture opening in the anterior region was between 2.4 and 4 mm, which translated to approximately 34.6%–50% of the total screw expansion, which correlated with our study.[32]

A high correlation, low measurement error, and considerable agreement with CBCT measurements indicate the usefulness of USG as an alternate modality for assessing the midpalate suture opening. However, these findings must be interpreted with caution because of the limited sample size. In this study, the agreement between the real-time and postscan USG measurements differed by -0.84 to 0.66 mm. It could be due to the fact that real-time and postscan USG measurements were performed by two examiners in different settings. Furthermore, the results of the Bland–Altman plots showed that the mean differences in measurements between different methods were less, and the limits of agreement were within ±1 mm. Considering that most of the measurements were below 3 mm, an agreement range of ±1 mm may be clinically significant. Therefore, the factors related to the wider range of disagreement between the methods, such as repeatability, examiner's experience, and training, should be identified and considered.

The study's strengths lie in its meticulous methodology, including the use of CBCT as the gold standard, repeated measurements by different examiners, and the exploration of potential applications for USG in orthodontic assessments. Despite the encouraging results, this study does have limitations, such as a small sample size. The results of this study are, therefore, preliminary and need to be replicated with a larger sample size. In addition, the mean suture opening measured in the radiographs was around 3 mm, so the agreement between the methods at larger suture openings could not be ascertained. Therefore, patients requiring larger maxillary expansion need to be studied for the generalizability of the results. Moreover, only the width of the anterior MPS opening was measured because USG scanning of the anterior maxilla was done using the extraoral approach. Future intraoral probes designed for the palate may make it possible to measure the anteroposterior length and vertical height of the suture opening, much like with 3D datasets. The study encourages a shift toward exploring nonionizing imaging modalities in orthodontics, aligning with the broader trend in health care to prioritize patient safety while maintaining diagnostic accuracy.

Conclusion

Within the limits of this study, the results suggest that USG is a reliable method to assess the width of the anterior midpalatal suture opening following RPE. USG also offers the benefit of being a nonionizing imaging method and obtaining real-time measurements. The findings support the feasibility of using USG as a reliable alternative for evaluating MPS opening in growing children, particularly in scenarios requiring serial radiographic assessments. The small sample size may limit the generalizability of the findings, and further research with larger cohorts is warranted. In addition, while the study addresses the width of the anterior MPS opening, future investigations could explore additional dimensions using intraoral ultrasound probes designed for the palate.

Acknowledgments

We are grateful to all the patients who participated in this research. We want to acknowledge the contribution of Dr. Karthik Sennimalai, Assistant Professor, Department of Orthodontics, All India Institute of Medical Sciences, Jammu-180001, India, for his contribution as the second examiner and for reviewing the manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. McNamara JA. Maxillary transverse deficiency. Am J Orthod Dentofacial Orthop 2000;117:567-70.
2. Bishara SE, Staley RN. Maxillary expansion: Clinical implications. Am J Orthod Dentofacial Orthop 1987;91:3-14.
3. Farronato G, Giannini L, Galbiati G, Maspero C. Sagittal and vertical effects of rapid maxillary expansion in Class I, II, and III occlusions. Angle Orthod 2011;81:298-303.
4. Murray JM, Cleall JF. Early tissue response to rapid maxillary expansion in the midpalatal suture of the rhesus monkey. J Dent Res 1971;50:1654-60.
5. da Silva Filho OG, Lara TS, de Almeida AM, da Silav HC. Evaluation of the midpalatal suture during rapid palatal expansion in children: A CT study. J Clin Pediatr Dent 2005;29:231-8.
6. Wertz R, Dreskin M. Midpalatal suture opening: A normative study. Am J Orthod 1977;71:367-81.
7. da Silva Filho OG, Boas MC, Capelozza Filho L. Rapid maxillary expansion in the primary and mixed dentitions: A cephalometric evaluation. Am J Orthod Dentofacial Orthop 1991;100:171-9.
8. Kapila SD, Nervina JM. CBCT in orthodontics: Assessment of treatment outcomes and indications for its use. Dentomaxillofac Radiol 2015;44:20140282.
9. Chandak R, Degwekar S, Bhowte RR, Motwani M, Banode P, Chandak M, *et al*. An evaluation of efficacy of ultrasonography in the diagnosis of head and neck swellings. Dentomaxillofac Radiol 2011;40:213-21.
10. Reis Durão AP, Morosolli A, Brown J, Jacobs R. Masseter muscle measurement performed by ultrasound: A systematic review. Dentomaxillofac Radiol 2017;46:20170052.
11. Culjat MO, Singh RS, Brown ER, Neurgaonkar RR, Yoon DC, White SN. Ultrasound crack detection in a simulated human tooth. Dentomaxillofac Radiol 2005;34:80-5.
12. Tsiolis FI, Needleman IG, Griffiths GS. Periodontal ultrasonography. J Clin Periodontol 2003;30:849-54.
13. Gundappa M, Ng SY, Whaites EJ. Comparison of ultrasound, digital and conventional radiography in differentiating periapical lesions. Dentomaxillofac Radiol 2006;35:326-33.
14. Hughes CW, Williams RW, Bradley M, Irvine GH. Ultrasound monitoring of distraction osteogenesis. Br J Oral Maxillofac Surg 2003;41:256-8.
15. Bruno C, Minniti S, Buttura-da-Prato E, Albanese M, Nocini PF, Pozzi-Mucelli R. Gray-scale ultrasonography in the evaluation of bone callus in distraction osteogenesis of the mandible: Initial findings. Eur Radiol 2008;18:1012-7.
16. Issar Y, Sahoo NK, Sinha R, Satija L, Chattopadhyay PK. Comparative evaluation of the mandibular distraction zone using ultrasonography and conventional radiography. Int J Oral Maxillofac Surg 2014;43:587-94.
17. Dabas J, Mohanty S, Chaudhary Z, Rani A. Assessment of mandibular distraction regenerate using ultrasonography and cone beam computed tomography: A clinical study. Craniomaxillofac Trauma Reconstr 2016;9:69-75.
18. Blessmann M, Pohlenz P, Blake FA, Lenard M, Schmelzle R, Heiland M. Validation of a new training tool for ultrasound as a diagnostic modality in suspected midfacial fractures. Int J Oral Maxillofac Surg 2007;36:501-6.
19. Adeyemo WL, Akadiri OA. A systematic review of the diagnostic role of ultrasonography in maxillofacial fractures. Int J Oral Maxillofac Surg 2011;40:655-61.
20. Manfredini D, Guarda-Nardini L. Ultrasonography of the temporomandibular joint: A literature review. Int J Oral Maxillofac Surg 2009;38:1229-36.
21. Parmar R, Reddy V, Reddy SK, Reddy D. Determination of soft tissue thickness at orthodontic miniscrew placement sites using ultrasonography for customizing screw selection. Am J Orthod Dentofacial Orthop 2016;150:651-8.
22. Gumussoy I, Miloglu O, Bayrakdar IS, Dagistan S, Caglayan F. Ultrasonography in the evaluation of the mid-palatal suture in rapid palatal expansion. Dentomaxillofac Radiol 2014;43:20140167.
23. Sumer AP, Ozer M, Sumer M, Danaci M, Tokalak F, Telcioglu NT. Ultrasonography in the evaluation of midpalatal suture in surgically assisted rapid maxillary expansion. J Craniofac Surg 2012;23:1375-7.
24. Angelieri F, Franchi L, Cevidanes LH, Gonçalves JR, Nieri M, Wolford LM, *et al*. Cone beam computed tomography evaluation of midpalatal suture maturation in adults. Int J Oral Maxillofac Surg 2017q;46:1557-61.
25. da Silva Filho OG, Lara TS, da Silva HC, Bertoz FA. Post expansion evaluation of the midpalatal suture in children submitted to rapid palatal expansion: A CT study. J Clin Pediatr Dent 2006;31:142-8.
26. Cantarella D, Dominguez-Mompell R, Mallya SM, Moschik C, Pan HC, Miller J, *et al*. Changes in the midpalatal and pterygopalatine sutures induced by micro-implant-supported skeletal expander, analyzed with a novel 3D method based on CBCT imaging. Prog Orthod 2017;18:34.
27. Brooks SL. CBCT dosimetry: Orthodontic considerations. Semin Orthod 2009;15:14-8.
28. Marcu LG, Chau M, Bezak E. How much is too much? Systematic review of cumulative doses from radiological imaging and the risk of cancer in children and young adults. Crit Rev Oncol Hematol 2021;160:103292.
29. Shin HS, Nam KC, Park H, Choi HU, Kim HY, Park CS. Effective doses from panoramic radiography and CBCT (cone beam CT) using dose area product (DAP) in dentistry. Dentomaxillofac Radiol 2014;43:20130439.
30. da Silva Moura W, Chiqueto K, Pithon GM, Neves LS, Castro R, Henriques JF. Factors influencing the effective dose associated with CBCT: A systematic review. Clin Oral Investig 2019;23:1319-30.
31. Fokas G, Vaughn VM, Scarfe WC, Bornstein MM. Accuracy of linear measurements on CBCT images related to presurgical implant treatment planning: A systematic review. Clin Oral Implants Res 2018;29 Suppl 16:393-415.
32. Liu S, Xu T, Zou W. Effects of rapid maxillary expansion on the midpalatal suture: A systematic review. Eur J Orthod 2015;37:651-5.