RESEARCH ARTICLE

Ultrasonography in the evaluation of the mid-palatal suture in rapid palatal expansion

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Objectives: Orthodontists usually evaluate the mid-palatal sutural opening with occlusal radiography. The purpose of this article is to evaluate the sutural opening with ultrasonography (USG) in a series of patients undergoing rapid palatal expansion (RPE).

Methods: The study included 87 USG images and 87 occlusal radiographs from 29 healthy patients (mean age, 13.9 years; range, 11–20 years; boys, 12; girls, 17) who required RPE treatment. The sutural opening was assessed with USG, and the amount of sutural expansion as mesiodistal length was measured immediately after appliance practice (T_0), 10 turns (T_1) and 20 turns (T_2) during the expansion period. Sutural expansion evaluated by occlusal radiographs was scored at every stage. Measurements obtained by USG and scores observed in the occlusal radiographs were compared by non-parametric Kendall's tau test.

Results: Both USG and radiographic images revealed normal anatomical structure during pre-expansion (stage T_0). On USG, sutural expansion was seen in 19 patients at stage T_1 . There was no expansion at this stage in ten patients. At stage T_2 , on USG and radiography, an increase in the amount of expansion was observed in 19 patients with sutural expansion at stage T_1 and sutural expansion was observed in 5 patients without sutural expansion at stage T_1 . No expansion was observed at both stages T_1 and T_2 in five patients. USG measurements and occlusal scores in both T_1 and T_2 turns showed statistically significant correlation ($p < 0.001$).

Conclusions: The results indicate that USG might be a useful method to assess mid-palatal sutural opening in patients undergoing RPE.

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Introduction

Rapid palatal expansion (RPE) was first introduced in the 1860s by Angell¹ for the treatment of maxillary constriction. It later became a conventional orthodontic treatment. RPE is used in orthodontic practice to correct posterior crossbite and dental crowding and to facilitate correction of Angle Class II² and Class III^{3,4} malocclusions. The overall objective of RPE is to widen the maxilla by separating the mid-palatal suture and the circumaxillary sutural system.⁵

Oral radiographs and CT are commonly used methods to assess the palatal expansion zone, but radiography/CT involves radiation. Especially, CT involves the repeated exposure to high-dose ionizing radiation during the active expansion period and the use of CT is limited by the presence of metal artefacts and the expense.

Sumer et al⁶ indicated that ultrasonography (USG) might be a useful and accurate method to evaluate bone fill in the mid-palatal suture in patients undergoing surgically assisted RPE. In the orthopaedic literature, USG has been shown to be accurate and reliable for the evaluation of distraction osteogenesis wounds in long

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bones.^{7,8} Studies also showed that USG was useful for the evaluation of mandibles treated with distraction osteogenesis.^{9,10}

The purpose of this article is to evaluate the sutural opening with USG in a series of patients undergoing RPE.

Methods and materials

Patients

The study sample consisted of 29 non-surgical patients (mean age, 13.9 years; range, 11–20 years; males, 12; females, 17) with mixed or permanent dentition who underwent RPE therapy as part of the comprehensive orthodontic treatment. Informed consent was obtained from all patients in our study before their participation. Subjects with craniofacial anomalies that would have required any type of surgical intervention were not included in the study. Individuals with orthodontic treatment history, such as phase I treatment, were also excluded from the sample.

Distraction protocol

Each patient had a two-banded Haas appliance, which was supported by the bilateral maxillary first molars, with the extension of expansion arms along the gingiva of the pre-molars. Maxillary expansion started at the beginning of the orthodontic treatment for all patients, and the appliance was activated by one-quarter turns per day, corresponding to 0.2 mm of daily expansion, until the maxillary constriction was corrected. Depending on the amount of the expansion, the activation period ranged from 21 to 25 days. USG examinations were performed immediately after the appliance practice (T_0), 10 turns (T_1) and 20 turns (T_2) during the expansion period and the assessment of mid-palatal suture was confirmed by plain radiographs at every stage. If plain radiography is the regular procedure followed for every patient with this treatment in Turkey, we do not require ethical approval. In total, 87 USG images and 87 occlusal radiographs of 29 patients were independently evaluated by two radiologists (IG and ISB).

Imaging procedure

Sonograms were obtained in the horizontal planes using an Aplio™ 300 (Toshiba Corporation, Tokyo, Japan) 8-MHz linear array transducer. To ensure the standardization of the USG examination of the RPE, patients sat upright, with the sagittal plane perpendicular to the floor and the occlusal plane horizontal. The ultrasound probe was positioned outside the mouth on the skin overlying the mid-palatal suture (a region between the nasal columella–labial junction and the upper lip), and the USG beam was oriented perpendicular to the bone surface. A real-time survey of the mid-palatal suture was then performed, producing axial slices (Figure 1).

Maxillary occlusal radiographs were taken using a Belmont Photo X-II dental X-ray machine (Takara Belmont, Somerset, NJ), set at 60 kVp and 7 mA with

Figure 1 Ultrasonography examination of a patient.

an exposure time of 0.50 s. Kodak D-speed film (Eastman Kodak, Rochester, NY) and a Velopex Extra-X dental film processor (Medivance Instruments Ltd, London, UK) were used. To ensure the standardization of the occlusal radiographs of the maxillary region, patients sat upright, with the sagittal plane perpendicular to the floor and the occlusal plane horizontal. The occlusal film was placed with the long dimension perpendicular to the sagittal plane, crosswise in the mouth. The central ray was directed at a vertical angulation of $+65^\circ$ and a horizontal angulation of 0° , the bridge of the nose was just below the nasion and towards the centre of the film. The central ray entered the patient's face through the bridge of the nose.

Image evaluation

On USG images, normal anatomical structures were evaluated at the beginning of the treatment prior to expansion (Figure 2). If the maxillary cortical bone border as a hyperechoic line was seen continuously and the needle-like hyperechoic, non-homogeneous zone was not seen on the mid-palatal suture region, we decided that there was no sutural expansion in the assessment of USG images at stages T_1 and T_2 (Figure 3a). If the maxillary cortical bone border as a hyperechoic line was seen discontinuously and the needle-like hyperechoic, non-homogeneous zone was seen on the mid-palatal suture region, we decided that there was sutural expansion (Figure 4a). To detect if there is an increase in the sutural expansion or not, we measured the amount of sutural expansion as mesiodistal length from the starting point of the needle-like hyperechoic, non-homogeneous zone on the horizontal plane (Figure 5).

On occlusal images, normal anatomical structures were evaluated at the beginning of the treatment prior to

Figure 2 Ultrasonography image of normal anatomical structures at pre-expansion. Black arrows show superior orbicularis oris muscle, white arrow shows vestibulum oris, black arrowheads show border maxillary cortical bone.

expansion. Before the expansion, the median palatine suture appears on the occlusal radiographs as a thin radiolucent line in the midline between the two portions of the pre-maxilla (Figure 3b). As the mid-palatal suture was opened, the radiographic image showed a larger radiolucent area, parallel to the suture or triangular shape, with its base towards the anterior region of the face (Figure 4b). To detect if there is an increase in the sutural expansion on the occlusal radiography or not, radiographs were evaluated and scored subjectively by the same two radiologists (Figure 6). Occlusal radiographs were scored as 0 (there is no opening), 1 (the presence of sutural expansion) and 2 (increase in the amount of sutural expansion).

Statistical analysis

The variables were analysed using the SPSS® (SPSS Inc., Chicago, IL) (IBM_SPSS_20.iso) program. Measurements obtained by USG and scores observed in the occlusal radiographs were compared by non-parametric Kendall's tau test. A $p < 0.05$ was considered statistically significant.

Results

We performed the USG examination in 29 RPE patients at every stage (T_0 , T_1 and T_2), and measurements were

tabulated (Table 1). Using USG, the surfaces of the bone segments were easily identified, and assessments in the expansion zone could be performed accurately during the active phase of the expansion. The area of expansion was characterized by a non-homogeneous and hyperechoic, sharply demarcated zone.

Pre-expansion— T_0 stage

Using USG, we saw the normal anatomical structures in all 29 patients. The surfaces of the cortical bone were easily identified. However, the assessment of the mid-palatal suture was impossible at that time owing to the presence of intact and thick vestibular cortical bone, which reflects ultrasound beams, making it impossible for the beams to penetrate the bone structure.

The radiographs revealed a normal anatomical structure at the beginning of the treatment. The median palatine suture appeared on the occlusal radiographs as a thin radiolucent line in the midline between the two portions of the pre-maxilla.

T_1 stage

On USG, sutural expansion was seen in 19 patients. Gap margins were clearly identified by USG in these patients. The area of expansion was characterized by a non-homogeneous and hyperechoic, sharply demarcated zone. Buccal cortex was discontinuous. Gap margins in between were measured on USG, and these patients' radiographic images showed a larger radiolucent area, parallel to the mid-palatal suture or triangular shape, with its base towards the anterior region of the face.

There was no expansion at this stage in ten patients. We saw the same images in these patients at stage T_0 on USG and radiographic evaluation.

T_2 stage

On USG and radiography, an increase in the amount of expansion was observed in 19 patients with sutural expansion at stage T_1 and sutural expansion was observed in 5 patients without sutural expansion at stage T_1 . No expansion was observed at both stages T_1 and T_2 in five patients. On USG, the amount of expansion was measured again at this stage.

Figure 3 (a) Before expansion, mid-palatal suture (black arrowheads) shown on ultrasonography. (b) Before expansion, mid-palatal suture (black arrowheads) shown on occlusal radiography.

Figure 4 (a) During treatment, sutural expansion (arrowheads) shown on ultrasonography. (b) During treatment, sutural expansion (arrowheads) shown on occlusal radiography.

USG measurements and occlusal scores in both T₁ and T₂ turns showed statistically significant correlation ($p < 0.001$).

Discussion

RPE is used in subjects with transverse maxillary deficiencies.^{11,12} A great deal of research has been carried out since Angell¹ first introduced the RPE method in the 1860s to expand the maxillary mid-palatal suture. In the early orthodontic literature (1860–1930), there was disagreement about whether it was possible to widen the hard palate at the mid-palatal suture. The landmark works of Haas^{12,13} made RPE a routine in many orthodontic practices, beginning in the 1960s.

As a part of an initial evaluation of a patient, McNamara¹⁴ recommended that the distance between the closest points of the upper first molars (*i.e.* the transpalatal width) should be measured. According to this author¹⁴ and Howe et al,¹⁵ a maxillary arch with a transpalatal width of 36–39 mm can usually accommodate the dentition of an average size without crowding or spacing, whereas maxillary arches <31 mm in width may be crowded and thus require orthopaedic or surgically assisted expansion. Evidently, other factors, such as facial type, soft-tissue profile and the level of muscle tone, must also be considered when making a decision about expansion. Routinely, orthodontists correct these

deficiencies with orthopaedic RPE appliances, which separate the maxillary suture and create skeletal orthopaedic expansion. In the course of the treatment, the patient is instructed to activate the screws as one-quarter turn twice a day, with the activation time varying according to individual needs.

Although conventional RPE can be used in younger patients, the facial suture lines become significantly more interdigitated and either partially or totally fused with age. After sutural closure or completion of the transverse growth, orthopaedic transverse maxillary expansion is largely unsuccessful because the expansion is primarily composed of alveolar or dental tipping, with little or no basal skeletal movement.¹⁶

Oral radiographs are still widely used as the main diagnostic method to assess the alterations in mineralized tissues during orthodontic treatment. Indeed, occlusal radiographs are essential to analyse the mid-palatal suture throughout RPE.¹⁷ This suture appears on occlusal radiographs as a narrow radiolucent line, which becomes wider and gets separated immediately after RPE.¹⁸ In the present study, we used both USG and plain radiography.

Before the expansion, the median palatine suture appears on the occlusal radiographs as a thin radiolucent line in the midline between the two portions of the pre-maxilla. It extends from the alveolar crest between the central incisors superiorly through the anterior nasal spin and continues posteriorly between the maxillary

Figure 5 Measurement of the sutural expansion on ultrasonography. (a) No expansion. (b) Arrowheads show 2.8-mm sutural expansion, tenth of the treatment. (c) Arrowheads show 5.8-mm sutural expansion, 20th of the treatment.

Figure 6 Results of occlusal radiography at the (a) 10th and (b) 20th turns of treatment. Arrowheads show sutural expansion.

palatine processes to the posterior aspect of the hard palate. The suture is limited by two parallel radiopaque borders of thin cortical bone on each side of the maxilla. USG cannot be used to evaluate the mid-palatal suture at this stage owing to the presence of intact and thick vestibular cortical bone, which reflects ultrasound beams, making it impossible for the beams to penetrate the bone structure.

During the RPE period, as patients turn the screw, the mid-palatal suture is opened and appears on the occlusal radiographs as a thick radiolucent line in the midline between the two portions of the maxilla. The thickness

of the radiolucent line increases over time. Likewise, on the USG examination, this structure appears as a hyperechoic line because the ultrasound beam is not reflected and can easily penetrate the expansion gap. Orthodontists continue to take radiographs until the required level of expansion is reached. Repeated radiography exposes patients to higher radiation doses.

Some studies have used CT with modern, fast and precise image acquisition to evaluate the bone and soft-tissue changes, even for the visualization of the posterior area of the mid-palatal suture.^{19–21} However, the use of

Table 1 Measurements of the sutural expansion on ultrasonography (USG) and scores observed in the occlusal radiographs

Patient	Age (years)	Sex	10 turns USG (mm)	10 turns occlusal scores	20 turns USG (mm)	20 turns occlusal scores
1	15	M	2.4	1	5.8	2
2	14	F	3.0	1	4.1	1
3	15	F	0.0	0	0.0	0
4	14	M	2.9	1	5.6	2
5	14	M	2.5	1	5.1	2
6	15	F	0.0	0	3.3	1
7	16	F	0.0	0	0.0	0
8	13	F	2.8	1	4.5	2
9	13	M	1.9	1	3.9	2
10	20	F	0.0	0	0.0	0
11	14	F	1.8	1	4.7	2
12	14	F	0.0	0	0.0	0
13	15	M	0.0	0	4.3	1
14	13	M	2.3	1	4.5	2
15	13	F	2.8	1	5.1	2
16	10	F	2.1	1	4.7	2
17	15	F	2.7	1	4.8	2
18	15	M	2.4	1	5.2	2
19	16	F	0.0	0	4.9	1
20	14	F	0.0	0	4.0	1
21	17	F	1.6	1	4.0	2
22	18	F	0.0	0	0.0	0
23	16	F	2.0	1	4.3	2
24	14	M	2.5	1	5.2	2
25	15	M	0.0	0	3.3	1
26	14	F	2.4	1	3.3	1
27	13	M	2.4	1	4.1	2
28	12	M	2.3	1	4.9	2
29	13	M	3.0	1	4.3	1
Correlation coefficient and <i>p</i> -value			$R = 0.736$ and $p = 0.0001$		$R = 0.672$ and $p = 0.0001$	

F, female; M, male.

CT is limited by the presence of metal artefacts and the expense.⁹ Another major disadvantage of CT is the repeated exposure to high-dose ionizing radiation during the active expansion period.

In some previous studies, ultrasound was successfully used in the follow-up of limb lengthening. Studies reported that it is a reliable, safe and non-invasive method of monitoring callus formation and maturation in distraction osteogenesis.^{22,23} A few studies demonstrated a positive correlation between USG and histological findings.^{24,25} In addition, Hirai *et al*²⁶ utilized 30- and 15-MHz frequency B-mode ultrasound probes in five patients with nasal bone fractures, orbital rim fractures, maxillary fractures and mandibular fractures. They reported that high-resolution USG can be used to diagnose even 0.1-mm wide disruptions of the bony surface, as the callus is not mineralized in the initial few weeks.

In the present study, USG was used to assess the mid-palatal suture in patients undergoing RPE. To the best of our knowledge, there are no published quantitative or semi-quantitative sonographic comparisons of sutural expansion with oral radiographs and USG in RPE patients. USG was used in one study⁶ of three surgically assisted RPE patients, where it was proven to be accurate in the measurement of the gap across the osteotomy and in the evaluation of callus formation. In that study, which was similar to our evaluation, callus formation was examined after the expansion. By contrast, we observed USG findings of the mid-palatal sutural expansion during the active RPE period and measured the amount of expansion.

The present study contains some limitations. The choice of orthodontic appliance and activation times were not within the control of the authors of the study. In the USG examination, we evaluated the mesiodistal width of the expansion gap on the horizontal plane but not the anteroposterior length of the expansion

gap on the same plane. We have observed that the anteroposterior length of the expansion gap on the horizontal plane and the amount of expansion are not proportional to each other in many patients undergoing RPE. Despite the increasing amount of expansion, the anteroposterior length of the expansion gap could remain the same. The image field of view is restricted by the linear probe and scanning angle. Thus, the system cannot produce a full view of the whole anatomy. Therefore, we decided the scoring that Sumer *et al*⁶ did is not suitable. On the other hand, we have to keep in mind that the amount of expansion in the mesiodistal direction is important for orthodontists in the evaluation of sutural expansion. Measurements were evaluated with millimetric calliper on USG, but measurements could not be performed with millimetric calliper on occlusal radiography because there is magnification on occlusal radiography. If metal artefacts can be eliminated, future studies could focus on the comparison of CT and USG. However, repeated exposure to high-dose ionizing radiation during the active expansion period is a major concern in children/teenagers.

In conclusion, USG is an easy-to-use, inexpensive tool that can provide accurate information on the mid-palatal sutural expansion in patients undergoing RPE. A major advantage of USG is that it is a real-time imaging tool with no ionizing radiation. As our study was not able to provide a rigid golden standard against which ultrasound measurements could be compared owing to its clinical character, future experimental studies should be carried out to assess measurement accuracy of ultrasound imaging for this purpose.

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References

1. Angell EH. Treatment of irregularity of the permanent or adult teeth. *Dent Cosmos* 1860; **1**: 535–44.
2. Guest SS, McNamara JA Jr, Baccetti T, Franchi L. Improving Class II malocclusion as a side-effect of rapid maxillary expansion: a prospective clinical study. *Am J Orthod Dentofacial Orthop* 2010; **138**: 582–91. doi: [10.1016/j.ajodo.2008.12.026](https://doi.org/10.1016/j.ajodo.2008.12.026)
3. da Silva Filho OG, Magro AC, Capelozza Filho L. Early treatment of the Class III malocclusion with rapid maxillary expansion and maxillary protraction. *Am J Orthod Dentofacial Orthop* 1998; **113**: 196–203.
4. McNamara JA Jr, Brudon WL. *Orthodontics and dentofacial orthopedics*. Ann Arbor, MI: Needham Press; 2001. pp. 67–80.
5. McNamara JA Jr. Long-term adaptation to changes in the transverse dimension in children and adolescents: an overview. *Am J Orthod Dentofacial Orthop* 2006; **129**: S71–4.
6. 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.
7. Maffulli N, Hughes T, Fixsen JA. Ultrasonographic monitoring of limb lengthening. *J Bone Joint Surg Br* 1992; **74**: 130–2.
8. Derbyshire ND, Simpson AH. A role for ultrasound in limb lengthening. *Br J Radiol* 1992; **65**: 576–80.
9. Troulis MJ, Coppe C, O'Neill MJ, Kaban LB. Ultrasound: assessment of the distraction osteogenesis wound in patients undergoing mandibular lengthening. *J Oral Maxillofac Surg* 2003; **61**: 1144–9.
10. 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**: 1012–17. doi: [10.1007/s00330-008-0856-6](https://doi.org/10.1007/s00330-008-0856-6)
11. Bell RA. A review of maxillary expansion in relation to rate of expansion and patient's age. *Am J Orthod* 1982; **81**: 32–7.
12. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the mid palatal suture. *Angle Orthod* 1961; **31**: 73–90.
13. Haas AJ. The treatment of maxillary deficiency by opening the dental palatal suture. *Angle Orthod* 1965; **35**: 200–17.
14. McNamara JA. Maxillary transverse deficiency. *Am J Orthod Dentofacial Orthop* 2000; **117**: 567–70.
15. Howe RP, McNamara JA Jr, O'Connor KA. An examination of dental crowding and its relationship to tooth size and arch dimension. *Am J Orthod* 1983; **83**: 363–73.
16. Betts NJ, Vanarsdall RL, Barber HD, Higgins-Barber K, Fonseca RJ. Diagnosis and treatment of transverse maxillary deficiency. *Int J Adult Orthodon Orthognath Surg* 1995; **10**: 75–96.

17. Inoue N, Oyama K, Ishiguro K, Azuma M, Ozaki T. Radiographic observation of rapid expansion of human maxilla. *Bull Tokyo Med Dent Univ* 1970; **17**: 249–61.
18. Sannomiya EK, Macedo MM, Siqueira DF, Goldenberg FC, Bommarito S. Evaluation of optical density of the midpalatal suture 3 months after surgically assisted rapid maxillary expansion. *Dentomaxillofac Radiol* 2007; **36**: 97–101.
19. Landes CA, Laudemann K, Schübel F, Petruchin O, Mack M, Kopp S, et al. Comparison of tooth- and bone-borne devices in surgically assisted rapid maxillary expansion by three-dimensional computed tomography monitoring: transverse dental and skeletal maxillary expansion, segmental inclination, dental tipping, and vestibular bone resorption. *J Craniofac Surg* 2009; **20**: 1132–41.
20. Laudemann K, Petruchin O, Mack MG, Kopp S, Sader R, Landes CA. Evaluation of surgically assisted rapid maxillary expansion with or without pterygomaxillary disjunction based upon preoperative and post-expansion 3D computed tomography data. *J Oral Maxillofac Surg* 2009; **13**: 159–69. doi: [10.1007/s10006-009-0167-3](https://doi.org/10.1007/s10006-009-0167-3).
21. Loddi PP, Pereira MD, Wolosker AB, Hino CT, Kreniski TM, Ferreira LM. Transverse effects after surgically assisted rapid maxillary expansion in the midpalatal suture using computed tomography. *J Craniofac Surg* 2008; **19**: 433–8. doi: [10.1097/SCS.0b013e318163e2f5](https://doi.org/10.1097/SCS.0b013e318163e2f5)
22. Thurmüller P, Troulis M, O'Neill MJ, Kaban LB. Use of ultrasound to assess healing of a mandibular distraction wound. *J Oral Maxillofac Surg* 2002; **60**: 1038–44.
23. Hughes CW, Williams RW, Bradley M, Irvine GH. Ultrasound monitoring of distraction osteogenesis. *Br J Oral Maxillofac Surg* 2003; **41**: 256–8.
24. Young JW, Kostrubiak IS, Resnik CS, Paley D. Sonographic evaluation of bone production at the distraction site in Ilizarov limb-lengthening procedures. *AJR Am J Roentgenol* 1990; **154**: 125–8.
25. Moed BR, Kim EC, van Holsbeeck M, Schaffler MB, Subramanian S, Bouffard JA, et al. Ultrasound for the early diagnosis of tibial fracture healing after static interlocked nailing without reaming: histologic correlation using a canine model. *J Orthop Trauma* 1998; **12**: 200–5.
26. Hirai T, Manders EK, Nagamoto TK, Sagers GC. Ultrasonic observation of facial bone fractures: report of cases. *J Oral Maxillofac Surg* 1996; **54**: 776–9.