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TITLE

Alveolar bone changes after tooth-borne surgically assisted rapid maxillary expansion:

a three-dimensional study

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Alveolar bone changes after tooth-borne surgically assisted rapid maxillary expansion: a three-dimensional study

ABSTRACT

Introduction – Surgically assisted rapid maxillary expansion (SARME) with a dental-anchorage appliance can induce dental and skeletal complications adjacent to the teeth supporting the device. The purpose of this study was to quantify the dentoskeletal changes observed after SARME using a tooth-borne device.

Materials and methods – Cone beam CT images from 39 patients were compared between the preoperative (T1) and the postoperative period (T2). The mean time to complete the second imaging was 13.8 ± 6.9 months after the SARME. Dental and bone parameters were assessed: the vestibular bone height (BH), the bone thickness (BT), the existence of fenestrations, and the root resorption at the level of first upper premolar (P1) and the first upper molar (M1). The maxillary expansion parameters were also collected.

Results – Both vertical and horizontal vestibular bone loss were observed mainly in the first upper molar sectors: The BT decreased from 0.93 ± 0.50 mm to 0.53 ± 0.51 mm ($p < 0.0001$) and the BH decreased from 1.84 ± 1.05 mm to 0.93 ± 1.02 mm ($p < 0.0001$) for tooth #16. The bone loss also affected the first upper premolars but in a more limited manner. Significant fenestrations were observed at the apex of the mesio-vestibular root of teeth #16 and #26. We noted significant root resorption affecting the mesio-, disto-vestibular and palatal roots of tooth #16 (mean reductions of 0.32, 0.35, and 0.55 mm, respectively; $p < 0.05$), and the palatal root of tooth # 26 (loss of 0.58 mm; $p = 0.004$). The mean bone expansion was 3.76 mm and 1.41 mm at the premolar and molar levels, respectively ($p < 0.0001$), while a mean 6.24 mm and 4.23 mm inter-cuspid expansion was noted at the P1 and M1 levels ($p < 0.0001$).

Conclusion – Our results document the vestibular bone changes and low root resorption, mostly in the molar sectors, associated with SARME using dental-anchorage devices.

KEYWORDS

Maxillary expansion; SARME; surgical expansion; dentofacial deformities

INTRODUCTION

Surgically-assisted rapid maxillary expansion (SARME) is indicated in skeletally mature patients to treat transverse discrepancies greater than 5 mm between the molars [1]. Patients with transverse maxillary deficiency usually have a narrow palatal vault, a unilateral or bilateral crossbite, a constricted maxillary arch, anterior crowding, and buccal corridors when smiling. Such anomalies may represent aesthetic and functional issues for patients [2,3]. The purpose of SARME is to remove skeletal impediments to allow transverse expansion of the maxilla by distraction osteogenesis [4]. The procedure is usually performed early during the orthodontic treatment, under general anesthesia. Although several surgical procedures have been described, most frequently, a sub-total Le Fort I osteotomy is combined with a midpalatal osteotomy and release of the nasal septum [5].

Three types of appliances can be used to expand the maxilla after the surgical procedure: tooth-borne, bone-borne, and hybrid devices. Tooth-anchored appliances have been associated with possible root resorption, vestibular version, periodontal ligament compression, and alveolar bone bending [1,6,7]. Dental complications are usually observed weeks or months after the SARME and mostly concern premolars and molars as these teeth anchor the device [8]. It is important to evaluate the periodontal condition of the anchor teeth to prevent complications. Indeed, excessive vestibular inclination can cause bone dehiscence and thus allow the formation of gingival recessions [2]. Bone-borne devices, by transmitting the forces directly to the bone, can avoid these undesirable effects [4].

Although SARME is commonly used to treat maxillary transverse deficiencies, there is no consensus in the literature regarding which type of expander to use. Furthermore, the results of different studies are sometimes contradictory. In a systematic review comparing bone-borne versus tooth-borne devices, Verstraaten *et al.* did not find any significant difference in terms of buccal tipping of the teeth [6]. In a comparative study of SARME with tooth-borne versus bone-borne devices, Zandi *et al.* did not find any significant difference in the incidence of complications between the two devices, and they noted comparable results in terms of skeletal and dental changes [9]. Recent studies have used cone beam computed tomography (CBCT) and validated landmarks as an accurate and reproducible tool to assess dentoskeletal changes after SARME [10].

The aim of this study was to precisely describe the dentoskeletal changes observed on the maxillary first premolars (P1) and the first molars (M1) after tooth-borne SARME using preoperative and postoperative CBCT analysis.

MATERIALS AND METHODS

Study population

This monocentric, retrospective study included patients who had undergone a SARME to correct a transverse deficiency of the maxillary bone. All of the procedures were carried out in the Department of Maxillofacial and Stomatology Surgery of Nantes University Hospital (France) between January 2010 and January 2020. Throughout this retrospective study, there were no changes to the current clinical practice or the randomization. Due to the retrospective nature of the study, it was formally granted exemption from approval by the ethics committee of Nantes University Hospital in accordance with French legislation article L. 1121-1 paragraph 1 and R1121-2 of the Public Health Code.

The inclusion criteria were:

- a maxillary transverse deficiency of 5 mm or greater between the molar sectors,
- the presence of a posterior crossbite,
- availability of a complete medical file with preoperative CBCT (T1) and after the retention period, when the patient attended a follow-up appointment (T2).

The exclusion criteria were:

- patients with previous orthodontic treatment,
- the presence of a congenital craniofacial syndrome including cleft lip and palate,
- missing first molars.

The patient medical charts were reviewed, and data documenting the age of the patients, their gender, the mean follow-up duration, and potential complications were compiled.

Treatment protocol

The surgical technique performed was similar to a conventional Le Fort I osteotomy as described by Bell [11], although there were a certain number of minor variations. An upper vestibular or sulcular incision was performed from one canine to the other. A subperiosteal flap then allowed exposure of the emergence of the infraorbital nerve and the pterygomaxillary junction. The nasal floor was lifted upward, and the piriform orifices were often enlarged and lowered to allow better nasal ventilation. After pterygomaxillary disjunction and release of the nasal septum, a horizontal bone

osteotomy was carried out with an oscillating saw involving the anterior and lateral walls of the maxillary sinus and the pterygoid plates. In most cases, the inter-sinus-nasal septa were left in place, and no downward fracture of the maxilla was performed. A vertical osteotomy passing between the central upper incisors, and performed with thin osteotomes, completed the procedure.

Patients were then treated with two-banded tooth-borne appliances, cemented onto the first molars and premolars, and placed systematically in the days before the surgical procedure. Appliance activation was initiated 7 days postoperatively using two partial revolutions daily. Activation was continued for 2 to 3 weeks, depending on the total amount of expansion needed. A soft food diet was advised during this period.

Radiographic analysis

Image acquisition was performed before the procedure (T1) and a few months later during the follow-up (T2) using a wide-field CBCT device (NewTom VGi, QR, Verona, Italy). The radiographic measurements were performed by the same examiner on multiplanar reconstruction (MPR) with 0.3 mm cuts using a picture archiving communication system (CARESTREAM® View PACS 12.1, Carestream Health, Inc. 2014, Rochester, USA).

Various parameters were measured on the images:

1. **The bone height (BH) and the bone thickness (BT)** for P1 and M1. For this analysis, we relied on the work of Chane-Fane and Darque, and Rungcharassaeng *et al.* [12,13]. In order to obtain a reproducible measurement, the coronal axis of the axial section was positioned perpendicular to the alveolar process (Figure 1). Depending on the tooth studied, the line was placed through the middle of the root for P1 and through the middle of the mesio-vestibular root for M1. On the coronal section obtained, a reference line (RL) was drawn from the vestibular apex to the vestibular cusp for P1, and from the mesio-vestibular apex to the mesio-vestibular cusp for M1. Then two lines were constructed perpendicularly to the RL: the first (PL1) going through the most coronal point of the intersection of the alveolar bone with the tooth; the second (PL2) going through the most vestibular point on the vestibular cortical bone. The distance between PL1 and

PL2 on the RL was defined as the BH. The BT was defined as the distance between the root surface and the vestibular cortical bone on PL2 (Figure 1).

2. **Fenestrations.** On the same coronal sections, the presence of fenestration (F) was recorded when present on the vestibular roots of P1 and M1.
3. **External apical root resorption.** On the coronal sections, we measured the distance between the apex and the vestibular dental cusp (Figure 1):
 - of the vestibular root length (VRL) and the palatal root length (PRL) of P1,
 - of the mesio-vestibular root length (MVRL), the disto-vestibular root length (DVRL), and the palatal root length (PRL) of M1.
4. **Maxillary expansion parameters** (Figure 1):
 - The external maxillary width (EMW) was measured on a straight-line tangent to the palatal vault and corresponding to the distance between the external cortical bones with regard to the first upper premolars (EMW4) and the first upper molars (EMW6).
 - The inter-apex distance (IAD) was measured between the two P1 (IAD4) and the two M1 (IAD6)
 - The inter-cuspid distance (ICD) was measured between the two P1 (ICD4) and the two M1 (ICD6)
 - The angle (A4) formed by the straight lines passing through the vestibular cusps and the apex of the P1. The angle had a positive value when the lines converged upwards and a negative value when they converged downwards.
 - The angle (A6) formed by the straight lines passing through the disto-vestibular cusps and the palatal apex of the M1. The angle had a positive value when the lines converged upwards and a negative value when they converged downwards.

Statistical analysis

The statistical analysis was performed using GraphPad Prism 9.0 software for Mac (GraphPad Software, La Jolla, CA, USA). The quantitative data were analyzed using a paired *t*-test. A *p*-value of less than 0.05 was taken to indicate statistical significance. Fisher's test was used to assess fenestrations. Twenty randomly selected CBCTs were evaluated a second time by the same examiner. The methodical error of the cephalometric measurements was assessed using Dahlberg's formula (mean square error (S.E²) = $d^2/2n$, where *d* is the difference between the

relapses in the first and the second measurements, and n is the number of double measurements) [14].

RESULTS

The medical records of 199 patients who underwent SARME in the Maxillofacial Surgery Department at Nantes University Hospital between 2010 and 2020 were collected. Ninety-one patients were eliminated based on the exclusion criteria: 83 patients had received orthodontic treatment, 7 were followed up for a craniofacial syndrome, and one presented with dental agenesis of the first upper molars. Sixty-nine patients were secondarily excluded due to a lack of radiological data (41 and 28 for missing postoperative and preoperative CBCT, respectively). Thirty-nine patients were ultimately included in the study (25 females and 14 males). The patients ranged from 12 to 48 years of age (mean 25.9 ± 9.2 years). The postoperative CBCT was carried out on average 13.8 ± 6.9 months after the surgical procedure.

Efficacy of the SARME

The degree of maxillary expansion was determined by various parameters. Changes were observed in external maxillary width, particularly regarding the first premolars: bone expansion increased from 36.66 ± 4.31 mm to 40.42 ± 4.63 mm for EMW4 ($p < 0.0001$). A more moderate variation was observed for EMW6 (Table 1). The inter-apex distance increased significantly between the preoperative and the postoperative period at both the premolar and the molar levels (Table 1). The inter-cuspid distance increased more (Table 1). The mean Dahlberg standard error for these measurements was 0.59 ± 1.23 for EMW and 2.00 ± 8.05 for the IAD and ICD, respectively.

	<i>T1</i>	<i>T2</i>	<i>p-value</i>
External maxillary width, mean \pm SD			
EMW4	36.66 ± 4.31	40.42 ± 4.63	< 0.0001
EMW6	58.32 ± 4.85	59.73 ± 4.80	< 0.0001
Inter-apex distance, mean \pm SD			
IAD4	35.12 ± 4.26	38.07 ± 4.19	< 0.0001
IAD6	31.27 ± 3.62	35.33 ± 4.39	< 0.0001
Inter-cuspid distance, mean \pm SD			
ICD4	37.71 ± 3.80	43.95 ± 2.70	< 0.0001
ICD6	49.85 ± 3.80	54.08 ± 3.76	< 0.0001

Table 1. Changes in maxillary transversal dimension between T1 and T2. EMW, external maxillary width; IAD, inter-apex distance; ICD, inter-cuspid distance; SD, standard deviation.

Radiographic changes (primary outcomes)

Significant changes occurred in the BH and BT between T1 and T2. We observed a 33% to 43% decrease in the BT in the molar sectors, ranging from 0.93 ± 0.50 mm to 0.53 ± 0.51 mm for tooth #16 and from 0.95 ± 0.53 mm to 0.63 ± 0.60 mm for tooth #26 ($p < 0.0001$). A mean of 21% to 23% of bone loss was noted for the premolar sectors (Table 2). The BH was also significantly reduced, particularly regarding the molar sectors, with a mean of 49.5% of bone loss for tooth #16 and 35.7% for tooth #26. The bone height loss was less significant for the premolars (Table 2). The mean Dahlberg standard errors for the BH and the BT were 0.219 ± 0.35 mm and 0.044 ± 0.55 mm, respectively.

	T1	T2	p-value
Bone thickness, mean \pm SD			
BT14	1.10 ± 0.48	0.87 ± 0.61	0.011
BT24	1.04 ± 0.48	0.8 ± 0.56	0.006
BT16	0.93 ± 0.50	0.53 ± 0.51	< 0.0001
BT26	0.95 ± 0.53	0.63 ± 0.60	< 0.0001
Bone height, mean \pm SD			
BH14	1.94 ± 0.85	1.59 ± 1.04	0.063
BH24	1.55 ± 0.64	1.26 ± 0.86	0.044
BH16	1.84 ± 1.05	0.93 ± 1.02	< 0.0001
BH26	1.43 ± 0.83	0.92 ± 1.04	0.0007

Table 2. Comparison of the bone thickness and the bone height in the premolar and molar sectors between T1 and T2. BT, bone thickness; BH, bone height; 14, right upper first premolar; 24, left upper first premolar; 16, right first upper molar; 26, left first upper molar; SD, standard deviation.

With regard to the fenestrations, we noted a tendency for these to increase, particularly in the molar sectors at the apex of the mesio-vestibular root of tooth #16 and tooth #26, with the mean number of impacted teeth ranging from 5 to 13 for MVF16 and from 3 to 11 for MVF26 ($p_1=0.05$ and $p_2=0.03$, respectively) (Table 3).

	T1	T2	p-value
F14	3	9	0.114
F24	3	9	0.114
MVF16	5	13	0.058
DVF16	3	8	0.191
MVF26	3	11	0.036
DVF26	1	4	0.358

Table 3. Comparison of fenestrations at T1 and T2. F, fenestration: MV, mesio-vestibular; DV, disto-vestibular.

To investigate the root resorption associated with SARME, we measured the distance between the dental apex and the vestibular/palatal cusps of P1 and M1 on both sides. We did not observe any significant difference in the root length in the premolar regions (Table 4). Whereas significant root shortening was observed in the mesio-, disto-vestibular, and palatal roots of tooth #16 (Table 4). The mean Dahlberg standard error for the root measurement was 0.163 ± 0.31 .

	<i>T1</i>	<i>T2</i>	<i>p-value</i>
Premolar root length, mean \pm SD			
VRL14	20.54 \pm 2.22	20.34 \pm 2.08	0.170
PRL14	18.81 \pm 2.42	18.56 \pm 2.32	0.260
VRL24	20.61 \pm 2.04	20.43 \pm 2.30	0.300
PRL24	18.93 \pm 2.16	18.85 \pm 2.37	0.710
Molar root length, mean \pm SD			
MVRL16	19.24 \pm 1.86	18.92 \pm 1.75	0.032
DVRL16	18.82 \pm 1.79	18.47 \pm 1.72	0.027
PRL16	20.66 \pm 2.09	20.11 \pm 2.17	0.002
MVRL6	18.84 \pm 1.56	18.79 \pm 1.73	0.673
DVRL26	18.7 \pm 1.59	18.50 \pm 1.54	0.160
PRL26	20.56 \pm 2.01	19.98 \pm 2.16	0.004

Table 4. Comparison of the root length in the premolar and molar sectors between T1 and T2. *VRL*, vestibular root length; *PRL*, palatal root length; *MVRL*, mesio-vestibular root length; *DVRL*, disto-vestibular root length; *SD*, standard deviation.

Others results

A significant change was observed in angle A4, which increased from 7.38 ± 14.98 degrees to 17.61 ± 13.19 degrees ($p < 0.0001$). A slight increase was noted regarding angle A6 formed by the first upper molars (increasing from 52.96 ± 11.97 degrees to 54.52 ± 10.43 degrees; $p = 0.34$). The mean Dahlberg error for the angle measurement was 2.16 ± 4.96 degrees.

Five minor complications were noted after the surgical procedure: Three patients complained of hypoesthesia of the superior lip or loss of dental sensitivity in the central upper incisors, with total recovery at 6 months. One patient suffered from signs of dental necrosis of tooth #11, with permanent dyschromia. One patient presented immediate postoperative epistaxis, with spontaneous recovery.

DISCUSSION

Very few studies to date have focused on vestibular bone changes in posterior teeth after SARME [15–17]. The purpose of this study was to accurately quantify the effects of maxillary expansion on the alveolar bone involving the use of dental-anchorage devices. The accuracy and reproducibility of measurements on CBCT images have been shown to be greater than on conventional 2D radiographs [18]. Moreover, CBCT analysis is a reliable method for evaluation of dental and skeletal changes in the maxilla after SARME, through specific landmarks, without the superimposition of structures or distortion [19]. For this reason, we based our study on radiographic analysis of different bone and dental landmarks. We included 39 patients, which is more than most of the studies that have reported on this issue [15–17]. Most of the patients in our observation period had to be excluded because of previous orthodontic treatment, mostly in childhood, with recurrence of the dentofacial deformities. The other reason for excluding patients was the lack of pre- or post-operative imaging because, although cone beam CT is now widely used and performed pre-operatively, there is no consensus on whether to perform a post-operative examination. The mean age of the patients was 25.9 years, which is in line with the literature, which reports that patients submitted to SARME are often between 19 and 29 years of age [20]. Indeed, SARME is generally indicated for transverse maxillary hypoplasia and/or crowding of teeth in skeletally mature patients [1]. We observed a significant decrease in bone thickness at the P1 and M1 levels, reaching 0.40 mm for tooth #16. Our results are in agreement with the literature, which reports bone loss of 0.4 to 1 mm on molar sectors [15–17]. The bone height was also reduced after the surgical procedure, particularly regarding the first upper molars; in coherence with other publications [16,17]. We can assume that vestibular bone resorption, either horizontally or vertically, is more pronounced on the molar sectors because they support the appliance and are, therefore subject, to expansion forces. However, we did not observe complete bone loss, and no correlation with a clinical outcome (tooth mobility, gingival retraction) could be established at this stage.

Alveolar fenestration can be defined by a circumscribed defect of the cortical plate that exposes the underlying root surface but does not involve the alveolar margin of the bone [21]. Although fenestrations are encountered in patients without orthodontic treatment, it is widely assumed that application of an orthopedic appliance increases the risk of fenestration, particularly regarding the maxilla [22,23]. Therefore, we

excluded patients who had previously undergone orthodontic treatment. Our study revealed an increase in the number of cases of fenestration on the postoperative observation, particularly regarding the mesio-vestibular root of the first upper molars. In a radiographic comparative study, Romano *et al.* did not find evidence of an increase in fenestrations after SARME, irrespective of the teeth studied (canines, premolars, and molars) [22]. The authors further showed that the presence of fenestrations on the preoperative evaluation was a significant predictor for the development of dehiscence in the postoperative and the after-retention periods [22]. While this was not measured in our study, it is commonly accepted that assessment of alveolar defects is necessary before commencing any orthodontic or surgical treatment [23,24]. However, other causes, such as insufficient oral hygiene, may contribute to fenestrations and dehiscence. Furthermore, some authors argue that fenestrations are hard to diagnose or may be overestimated in CBCT images [25,26]. One of the biases in the measurement of bone defects is that the postoperative cone beam imaging was sometimes performed after the start of the retention phase. So, we can assume that some fenestrations healed if the dental apex were repositioned in the cortex if orthodontic movements were initiated, thus underestimating the number of fenestrations. Although the root length of the premolars was not impacted by SARME, those of the upper first molars were significantly reduced after the procedure. Our results are at the lower range of those observed by Kayalar *et al.*, who noted a loss of 0.3 to 1mm in the maxillary molar sector [15]. These authors also reported more resorption on the palatal root of the maxillary molars [15]. While these root resorptions are significant, they appear to be too small to have a discernible clinical impact. In comparison, resorptions related to orthodontic treatment are considered to be low to moderate when less than 2.5 mm, which may concern 48% to 66% of the teeth treated orthodontically [27]. Our results could be distorted because orthodontic movements could have started by the time the second CBCT was performed. In a systematic review of root resorption, Alqahtani *et al.* highlighted that the percentage of teeth affected by root resorption varied between 1% and 36%, with a higher risk found after SARME [28]. While most studies use 2D imaging to assess root resorption, we chose to use CBCT imaging for greater accuracy. It is well established that the risks of human error and observer variability are influenced most by the landmark-line-based measurement than the imaging modality [29]; for this reason, we used the Dahlberg standard error on double measurements to express this measurement error.

The other results of our study related to the skeletal expansion obtained with SARME which was a mean of 3.8 mm between the first upper premolars and reduced to 1.4 mm with regard to the external maxillary width on the first upper molars sectors. In a systematic review of stability after SARME, Gogna *et al.* reported a mean skeletal expansion of 2.3 to 3.1 mm [30]. In the same study, the authors reported an expansion at the inter-canine level of 4–6 mm and 6–8.9 mm at the inter-molar region [30]. Our results are in line with these data, as we found an increase of 6.2 mm in the inter-cuspid diameter on P1 and 4.2 mm on M1. Another study reported a 1.47 ± 0.64 mm expansion at P1 and 3.70 ± 1.52 mm at M1 after SARME [31]. Other results indicate a V-shaped expansion pattern, with greater expansion at the nasal level than in the posterior sectors [32,33]. One of the factors explaining the diversity of results is the numerous osteotomy techniques used, some with lowering of the maxilla allowing splitting of the posterior wall of the maxilla, some passing through the nasal cavities on both sides of the septum to increase the maxillary enlargement. What is certain is that despite the pterygomaxillary osteotomy, the maxilla remains strongly attached in its posterior portion, which may partially explain the lack of transverse expansion at this level. Furthermore, dental or dentoalveolar points are generally used to measure posterior expansion. However, these points are affected by buccal alveolar bending and do not reflect the skeletal expansion, making comparison difficult between the studies [34]. Relapse was not investigated in our study, although our second imaging procedure was often performed during the retention phase. The relapse rate is estimated to be 0.1 to 2.3 mm at the inter-canine dimension and 0.2 to 3 mm at the inter-molar level [30]. The stability appears to be highly influenced by the post-orthodontic phase in which arch coordination is achieved, and alignment and final vertical adjustments are carried out [35]. Regarding dental movements, the distance between the cusps of P1 increased twice as much as the distance between their apexes. In addition, the angle formed by the first upper premolars increased significantly between the preoperative and the postoperative period. The coronovestibular version of the anchored teeth is a classical effect observed with tooth-borne devices [15]. Gradual straightening of the teeth is usually achieved with the retention phase. We reported a low rate of surgical complications, mostly consisting of sensory disorders in the operated area, with spontaneous recovery. In a systematic review, Muños-Pereira *et al.* highlighted a higher risk of bone resorption with tooth-borne devices compared to bone-borne appliances [35]. Other frequent

surgical complications include pain, nasal bleeding, tooth discoloration, and gingival recession [35,36].

Our study suffers from some limitations. The first relates to the retrospective nature of the study, including the different time points for CBCT imaging, which ranged from 6 to 25 months after the surgical procedure. Only one examiner performed the measurements, but the intra-observer error was assessed by the Dahlberg score. Another limitation relates to the landmarks that we chose for measurement of the EMW, as the highest point of the hard palate, the nasal septum, and the shape of the palatal arch can be modified by the procedure. Finally, the lack of simultaneous clinical evaluation of the results regarding occlusion, inter-arch concordance, and signs of bone resorption (tooth mobility, periodontium) precludes assessment of the clinical consequences of the dentoskeletal changes after SARME.

We have noted very heterogeneous methods for measurement of the changes in skeletal parameters after SARME. This represents an obvious obstacle to the comparison of results. Further randomized control trials with long-term results are needed to address the main question related to SARME: 1/ Which appliance allows the best results to be achieved with the least amount of bone and dental resorption? 2/ What is the best activation protocol? 3/ Which surgical technique allows for maximum expansion while also reducing complications?

CONCLUSION

Our study adds to the limited data in the literature related to objective measurement of the dentoskeletal changes after SARME using dental-anchorage devices. Our results support the trend of vestibular bone resorption and root resorption mostly in the upper molar sectors.

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FIGURE LEGEND

Figure 1: Methods for measurement of the radiographic parameters. Orientation of the coronal axis of the axial section perpendicular to the alveolar process (a). Method for measurement of the BT and the BH on a coronal section of P1 and M1 (b). Measurement of the maxillary expansion on a coronal section of the maxillary bone (c). Measurement of the root resorption between the apex and the mesio-vestibular cusp of M1 and the vestibular cusp of P1 (d).

