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Complications Reported in Maxillary Skeletal Expansion

Jacqueline Payne

University of the Pacific, j_payne2@u.pacific.edu

Audrey Yoon

University of the Pacific, jungdds@gmail.com

Heeyeon Suh

University of the Pacific, hsuh1@pacific.edu

Joorok Park

University of the Pacific, jpark3@pacific.edu

Heesoo Oh

University of the Pacific, hoh@pacific.edu

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COMPLICATIONS RELATED TO MICROIMPLANT-ASSISTED RAPID
PALATAL EXPANDERS

by

Jacqueline Payne

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Jacqueline Payne

APPROVED BY:

Thesis Advisor: Heesoo Oh, DDS, MSD, PhD

Committee Member: Audrey Yoon DDS, MSD

Committee Member: Joorok Park, DDS, MSD

Department Chair: Heesoo Oh, DDS, MSD, PhD

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Abstract:

Introduction: The aim of this study was to determine the types and prevalence of complications following MARPE protocol at University of the Pacific and to investigate the complication of asymmetry using CBCT analysis.

Methods: In the first portion of this study, 97 patients who started treatment prior to July 2020 and who had MARPE expander treatment at the University of the Pacific were included. Chart review and evaluation of progress clinical photographs were used to report the following complications: inflammation, pain, appliance malfunction, broken microscrew, and pulpitis. In the second portion of this study, 77 patients from a private practice orthodontist who started treatment prior to January 2021 were included in this study. The complication of asymmetry was measured using CBCT measurements from T1 (prior to treatment start) and T2 (immediately following MARPE expansion). The change in U6 molar angulation changes was also assessed.

Results: It was determined in the first portion of this study that the most common complication was inflammation around the MARPE site, with 82% of the study population exhibiting any severity of inflammation. 3 patients exhibited severe inflammation requiring removal of MARPE. 18% reported pain in the MARPE area. 9 patients exhibited appliance malfunction, 1 patient exhibited broken microscrew, and 1 patient exhibited pulpitis. It was determined in the second portion of this study that 47% of patients exhibited asymmetry greater than 1 mm and the average asymmetry at ANS was 1.47 mm. No correlation was exhibited between amount of asymmetric expansion and the following measures: age, molar inclination, palatal thickness, posterior screw expansion and palatal vault height.

Conclusions: Inflammation of the MARPE is the most common complication that can result in early removal of the expander. Other complications such as asymmetry and pain are common as well.

Introduction:

Microimplant-Assisted Rapid Palatal Expanders (MARPEs) were introduced around 2010 by Lee et al. to solve the difficulty of skeletal expansion in the post-pubertal patient.¹ Typically, skeletal expansion can be achieved using rapid palatal expanders or Hyrax appliance in pre-pubertal patients whose maxillary sutures have not interdigitated and fused. Post-puberty, as the palatal suture becomes more interdigitated, skeletal expansion of the maxilla is not as reliable and can result in side effects such as: alveolar bone bending, tooth tipping, limited expansion, periodontal loss, tooth resorption and limited stability.^{2,3}

Prior to the advent of MARPE, the only way to gain true skeletal expansion in adults with a greatly interdigitated palatal suture was through surgery: SARPE (surgically assisted rapid palatal expansion) or segmental Le Fort osteotomies.⁴ MARPE offers a non-surgical approach to skeletal expansion in the maxilla in those patients who are past their pubertal peak. Although the MARPE can result in non-surgical skeletal expansion of the maxilla, which was not previously possible in the post-pubertal patient, some complications have been observed. These complications need to be considered and better understood in order that these complications can be avoided.

Although there has not been a paper reporting comprehensively on the complications of MARPE protocol, comprehensive studies on SARPE complications have been published. Verquin et al. looked at short term complications after SARPE and found that more than half of the cohort experienced complications such as paresthesia, severe post-op pain, post-op hemorrhage and dental complications.⁵ Smeets et al. identified long term complications after SARPE and found similar complications with neurosensory deficit being the most common long-term complication.⁶

Asymmetric expansion, dental tipping, and inflammation have independently been reported as complications of MARPE. The aim of this study was to comprehensively determine the types and prevalence of MARPE complications through clinical records review. An additional aim was to quantify the prevalence of asymmetry using CBCT analysis.

Part I. Complications Related to MARPE: Clinical Records Review

Materials and Methods:

This retrospective study was approved by the institutional review board of the University of the Pacific (IRB 2020-74). The first portion of the study, which identified complications through review of clinician notes and clinical photos, comprised a patient pool of 97. The mean age was 16.07 ± 5.32 (57 Males/ 40 Females) and included University of the Pacific Orthodontic patients who started MARPE treatment prior to July 2020.

Patients were prescribed an 8mm, 10 mm, or 12 mm MARPE size depending on width and depth of the patient's palate. Most common design of MARPE was tooth-borne expander sutured to maxillary first molar bands with four bicortically engaged 1.8 mm diameter screws. The length of the screws was prescribed on a case by case basis, based off pre-treatment CBCT to engage microimplants bicortically. Total expansion of the jackscrew was based on clinical evaluation and initial maxillary transverse discrepancy. Velocity of expansion and initiation of turns was also based on case by case basis prescribed by the clinician based on patient age and initial stability of the screws.

One rater read through all chart notes for these patients. The following complications were tallied from chart notes: inflammation requiring early removal of expander, appliance

breakage, broken microscrew, and pulpitis related to expansion. Total expansion, adequate expansion, velocity of turns, and the presence of a diastema were other MARPE outcomes recorded from chart notes.

The complication of inflammation was further investigated by compiling intraoral maxillary photos of the MARPE in place. Two raters were calibrated, and rated progress photos taken immediately following MARPE expansion and pre-removal of MARPE. Ratings of MARPE arms versus MARPE body were taken separately.

Results:

The average velocity of expansion for this sample was 0.23 mm per day with an average of 7.24 mm of expansion recorded in chart notes. 91% of patients exhibited diastema in either 1st or 2nd attempt. The presence of a diastema is usually a clinical indication of successful mid-palatal suture split. 30% of patients did not get adequate expansion on the first attempt. 32% of patients who had 2nd MARPE attempt still did not get adequate expansion.

3 patients reported severe pain in the MARPE area that required early removal of the appliance. 18% of patients reported transient pain in the MARPE area, 2% within the nose, 3% reported headaches, and 4% reported pain in the upper dentition. (Table 2)

Regarding inflammation, 6.5% of patients had severe inflammation requiring removal. 18% had moderate inflammation and 57% had mild inflammation, indicating inflammation was more common than not. Other complications included 1% pulpitis associated with MARPE expansion, 9% appliance breakage prohibiting continued expansion or expansion retention, and 1% broken microscrew upon placement or removal of MARPE. (Table 2)

Discussion

Maxillary skeletal expanders offer many benefits in resolving maxillary transverse discrepancies along with dental crossbites. Clinical record review elucidates some of the complications that can occur with this appliance, such as inflammation, pain, appliance breakage, pulpitis associated with expansion, and broken microcrew upon placement or removal.

The majority of patients who received MARPE developed some level of inflammation during treatment. This was by far the most common complication that was determined. Due to the proximity of the expander to the roof of the mouth, hypertrophy around the screws and arms of the MARPE was common. One study reported hyperplasia in 22% of MARPE patients using photos to rate inflammation.⁷ Their photographic definition of hyperplasia most closely matched this study's definition of moderate inflammation. However, they used cortico-punctures along the suture, which could account for their slightly greater prevalence of hyperplasia compared to our 18% prevalence of moderate inflammation. Our study's definition of mild inflammation seemed to be more sensitive, accounting for a greater overall prevalence of inflammation.

Appliance breakage was more common in the earlier version of the Maxillary Skeletal Expander- Type 1 (MSE), developed by Dr. Won Moon. With improvements to the MSE -Type 2, less appliance breakage and malfunction seems to have been experienced. Only one patient exhibited microcrew breakage upon placement of the MARPE. Broken microcrew either during placement or removal may have been more of a concern with the Type 1 expander which used 1.6 mm diameter microcrews. Most commonly the Type 2 expander uses 1.8 mm diameter microcrews. From previous studies, it is understood that as a general rule smaller diameter (<1.5 mm) temporary anchorage devices (TADs) have a greater likelihood to fracture.⁸ Only one patient exhibited endodontic sensitivity that began once the patient started turning the expander.

Ross-Fedele et al. published a systematic review of endodontic complications associated with orthodontic temporary anchorage devices. The authors reported that complications can occur whether or not the root is contacted. When damage is solely to the periodontal ligament and not to the root itself, repair normally occurs within 12 weeks.⁹

The chart review portion of this study had limitations in that different resident providers treated different patients of the orthodontic clinic and therefore had different levels of omission or inclusion of information regarding MARPE expansion in his or her note. Also, patients especially in regard to the complication of pain are subject to respond differently to the same amount of pain, determined by his or her pain threshold.

PART II: CBCT study of Asymmetry as a Complication of MARPE Protocol

Materials and Methods:

One of the significant side effects of the MARPE is asymmetric expansion. This portion of the study focused on quantifying asymmetric expansion, using CBCT Timepoint 1 (T1) and Timepoint 2 (T2). T1 was taken as initial orthodontic record, before the patient had undergone any orthodontic treatment. T2 was taken immediately after expansion when MARPE expander was still in place. For this portion of the study, 71 patients (mean age: 19.07 ± 7.61 years) who began treatment prior to January 2021 and had MARPE treatment from a private practice orthodontist were used due to the consistency of T1 and T2 CBCT. Patients with MARPE protocol were included in this study regardless of success or failure.

Using Invivo 3D tracing, 3 judges were calibrated and traced the same 71 patient scans. Ten landmarks were traced at both T1 and T2 timepoints (Table 3). Traced points were averaged between the 3 judges and distances were calculated between left and right points. A comparison between distances at T1 and T2 was then done. Asymmetry was assessed at ANS. As the palate

is split via the MARPE, ANS becomes ANS Right(ANS_R) and ANS Left (ANS_L). Distance of ANS_R and ANS_L at T2 were determined in respect to initial ANS position at T1 (Figure 2). The definition of asymmetric expansion was based off a previous paper that defined asymmetric expansion as greater than 1 mm difference between change in ANS_R versus change in ANS_L expansion.¹⁰

Molar angulation, palatal thickness, posterior screw expansion and palatal vault height were also measured within slices of the CBCTs (Table 4). Two judges calibrated measurements in the Invivo 6 software. Figure 3 illustrates the measurements that were taken from T1. Figure 4 shows the measurements taken from T2.

Statistical analysis:

Changes in the right and left maxillary first molar inclinations (U6 to palatal plane angle) were evaluated with paired t-tests. Pearson correlation was used to assess correlation between asymmetry and the following measures: age, molar inclination, palatal thickness, amount of posterior screw opening or palatal vault height.

Results:

This sample included 71 patients from a private practice orthodontist and had an average age of 19 years old at treatment start. 3D Invivo tracing revealed that the right-left differences of ANS was on average 1.47 mm in the coronal plane (x-axis). 52% of the patients exhibited symmetric expansion of ANS, indicating a difference of less than or equal to 1 mm. 48% exhibited asymmetric expansion of ANS greater than 1 mm (Table 5).

The average velocity of expansion for this sample was 0.25 mm per day with an average of 8.03 mm of expansion recorded in chart notes compared to the 7.75 mm of expansion measured from the CBCT between the posterior screws. 91% of this sample was reported to have clinical opening of the suture indicated by presence of a diastema. The average change in U6 molar angulation was $3.57 \pm 3.76^\circ$ from T1 to T2 and was statistically significant (Table 6). Average palatal thickness measured between the upper bicuspid was 6.35 mm. The average palatal vault height was 13.51 mm. No correlation was found between asymmetric expansion and the following measures: age, molar inclination, palatal thickness, amount of posterior screw opening or palatal vault height (Table 7).

Discussion:

As determined by this study, the complication of asymmetry is a relatively common side effect of MARPE protocol. Asymmetry is a concern to the patient if it is large enough to be perceived. Asymmetric expansion was defined as the difference between expansion of ANS right versus ANS left because ANS is a clinically impactful hard tissue landmark for soft tissues of the facial complex. For this study, less than 1 mm difference in ANS expansion was defined as symmetric expansion. Greater than 1 mm difference in ANS expansion was determined asymmetric. It is important to note that these definitions may be too sensitive and may not be clinically relevant especially as it pertains to the layperson's perception of asymmetry.

A previous study found that among the asymmetric group, which was defined as greater than 1.1 mm difference, ANS moved 2.22 mm more than the contralateral side.¹¹ This was similar to what we found in our study, which was that ANS moved 2.57 mm more than the contralateral side in the asymmetric group. Kim et al. reported on asymmetry in MARPE expansion and found

that 30% of patients exhibited asymmetric expansion whereas our study reported 48% exhibited asymmetric expansion.¹⁰ Possible differences that could have accounted for greater asymmetric expansion could have been due to increased total amount of expansion. It has been shown that the asymmetric group showed a greater average amount of total expansion as compared to the symmetric group. Perhaps there is correlation between total expansion and asymmetry. However, our study did not find any correlation between asymmetry and total expansion measured at the posterior screws.

Dental tipping and asymmetry complications were purely objective complications that could be identified from measurements taken from CBCT tracings and measurements. Dental tipping was measured as an angle from the palate through the center of the upper first molars and amounted to a statistically significant increase of 3.57 °. However, this change in molar angulation cannot be simply defined as dental tipping because from previous studies it is known that some amount of naso-maxillary complex rotation and alveolar bone bending also occurs during maxillary skeletal expansion. Both alveolar bone bending and naso-maxillary complex rotation centered at the naso-fronto suture, could affect the molar angulation measurement. Moon et al.'s study did isolate pure dental tipping from alveolar bone bending and naso-maxillary complex rotation and found a slightly smaller change of 2.40° in U6 molar tipping.¹² Our value of 3.57° may be slightly larger because alveolar bone bending, and naso-maxillary complex rotation was not isolated from the molar inclination measurement.

Conclusion

In conclusion, the most common complication was inflammation with 82% of patients exhibiting any severity of inflammation. Asymmetric expansion and pain were less common but

presented in 48% and 26% of the populations, respectively. Doctors may want to make patients aware of these complications in his/her informed consent. Also, the importance of keeping the MARPE appliance clean and free of debris should be stressed to the patient.



Figure 1. Inflammation Complication. Clinical photos demonstrate the different degrees of inflammation. Rating 3 (severe inflammation requiring removal) was taken from chart note.

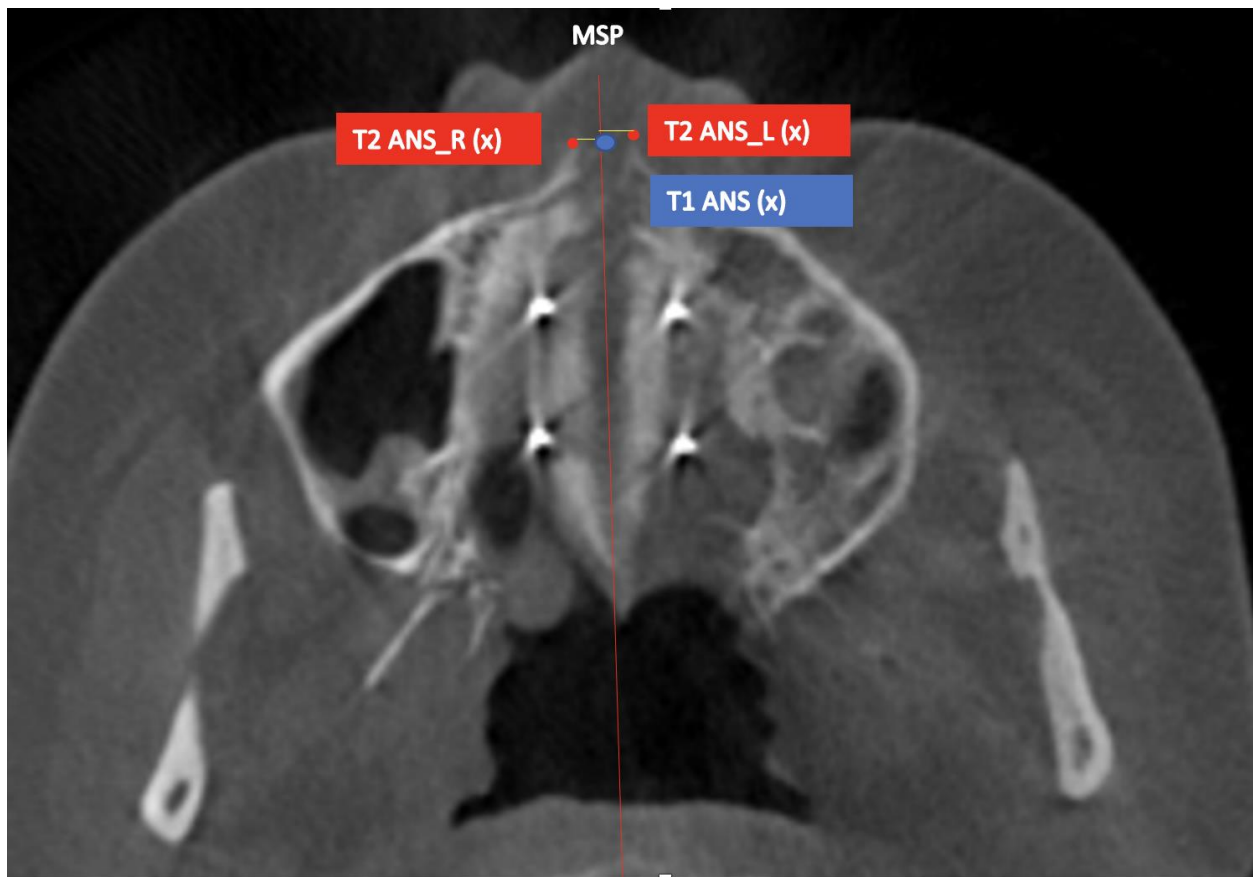


Figure 2. ANS_R versus ANS_L expansion. This measurement was determined by first determining x-distance of T1 ANS from the mid-sagittal plane. Then, the distance from T1 ANS to T2 ANS_R and from T1 ANS to T2 ANS_L could be determined through the following equations: $\Delta\text{ANS_R} = \text{distance of ANS_R to MSP} + \text{distance of T1 ANS to MSP}$, $\Delta\text{ANS_L} = \text{distance of ANS_L to MSP} - \text{distance of T1 ANS to MSP}$.

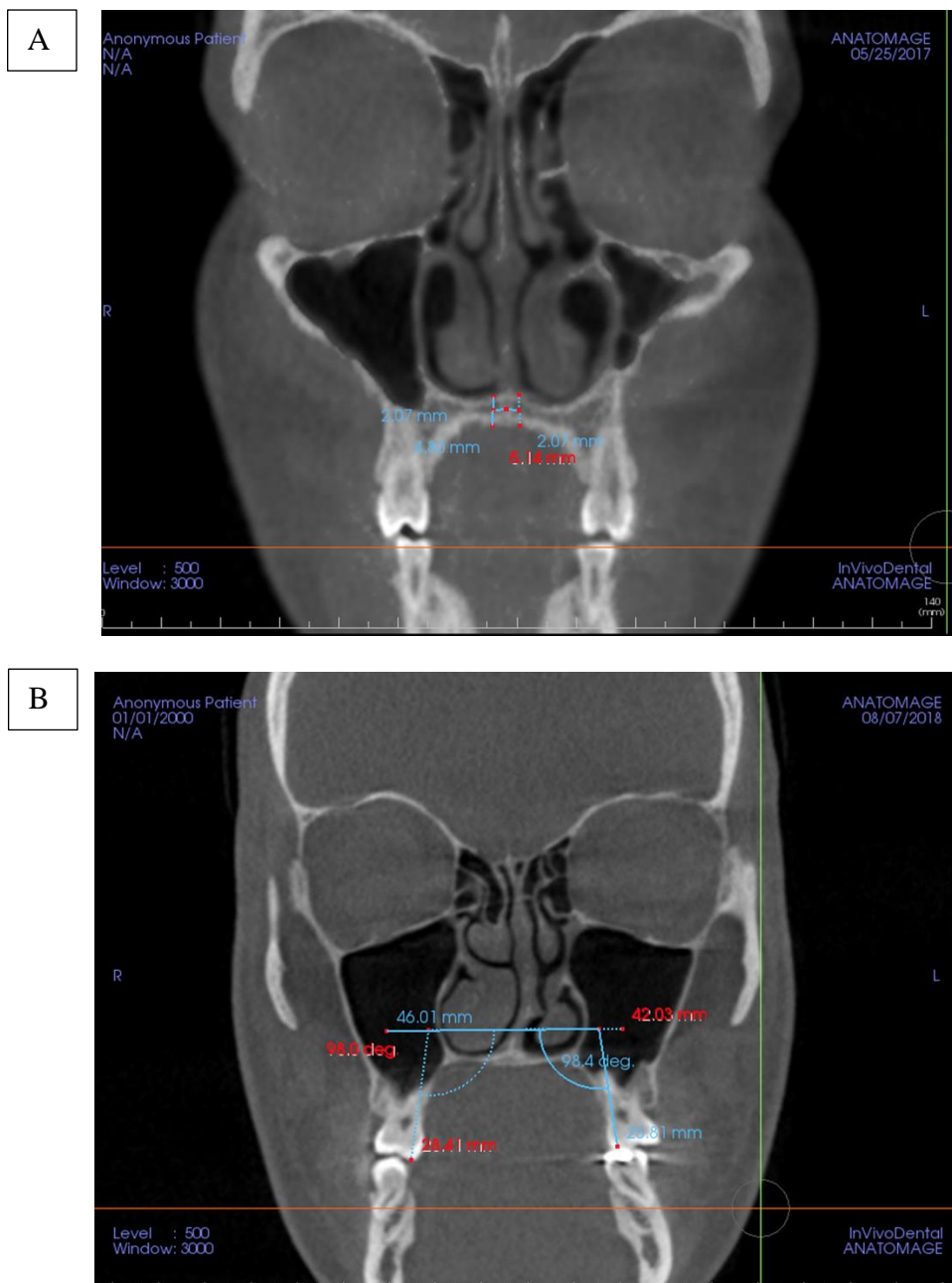


Figure 3. Measurements taken at T1. (A) Palatal thickness. (B) Molar angulation.

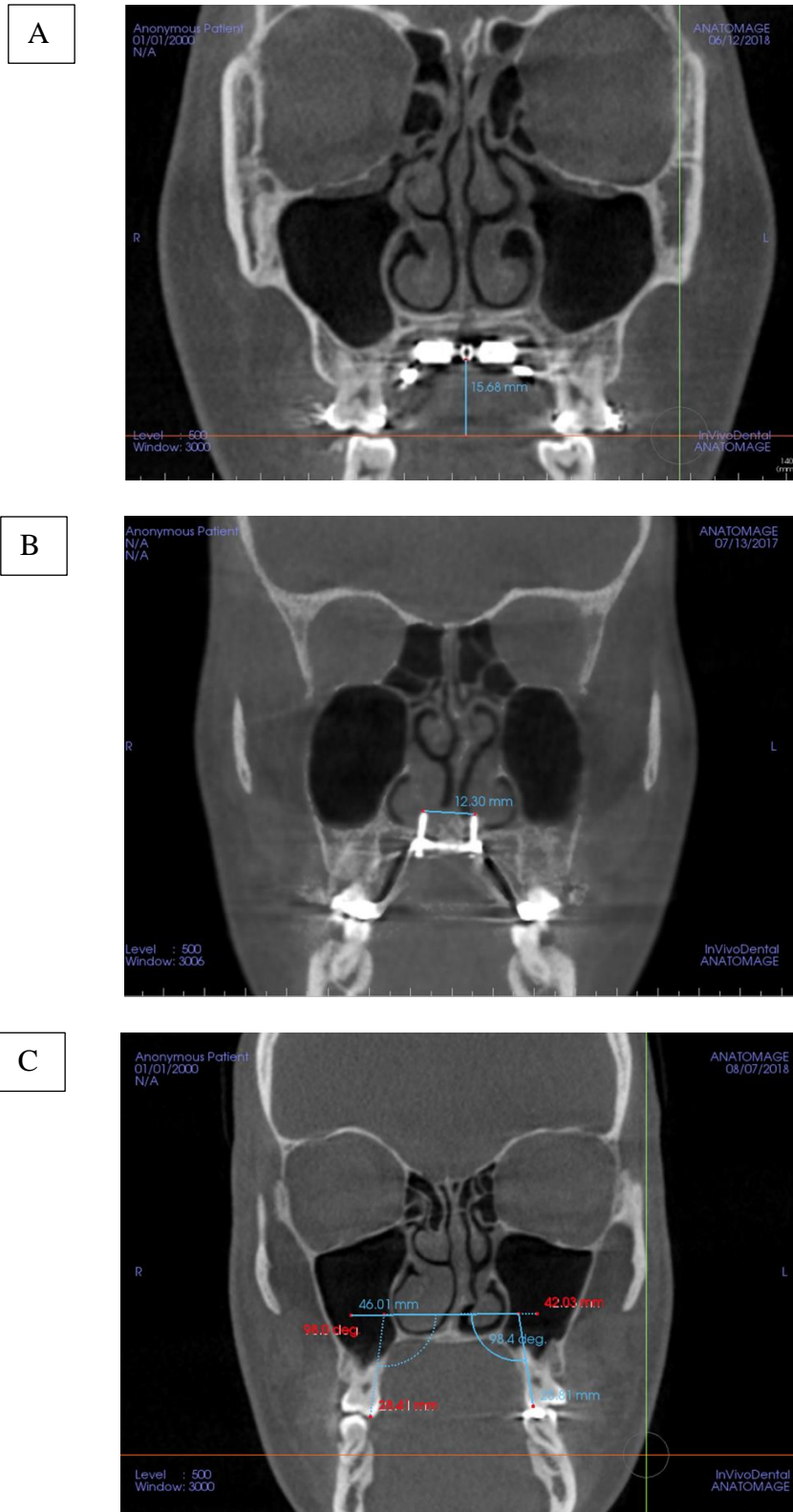


Figure 4. Measurements taken at T2. (A) Palatal Vault Height. (B) Posterior Screw expansion. (C) Post-expansion molar angulation.

Table 1. Complication definitions that were ascertained from either chart notes or clinical photos.

Category	Score	Definition
Diastema		
	0	No
	1	Yes
Inadequate Expansion		
1st Attempt	0	No
	1	Yes
2nd Attempt	0	No
	1	Yes
Inflammation		
Roof of mouth (R)	0	None
	1	Mild (Sign of swelling)
	2	Moderate (Covering screws)
	3	Severe (Recommended to remove)
Arms (A)	0	None
	1	Mild (Sign of swelling)
	2	Moderate (Covering screws)
	3	Severe (Recommended to remove)
Pain-Location		
MARPE area (M)	0	No report
	1	Mild
	2	Severe enough to remove
Nose (N)	0	No report
	1	Mild
	2	Severe enough to remove
Headache (H)	0	No report
	1	Mild
	2	Severe enough to remove
Dentition (D)	0	No report
	1	Mild
	2	Severe enough to remove
Others	0	No report
	1	Mild
	2	Severe enough to remove
Broken Microimplant		
	0	No
	1	Yes
Pulpitis		
	0	No
	1	Yes
Appliance Breakage		
	0	No
	1	Yes

Table 2. Complications reported in MARPE expansion.

Diastema	Patients (n=97)
0	9.28%
1	90.72%
Pain-Location	
MARPE area (M)	
0	81.44%
1	15.46%
2	3.09%
Nose (N)	
0	97.94%
1	2.06%
2	0.00%
Headache (H)	
0	96.91%
1	3.09%
2	0.00%
Dentition (D)	
0	95.88%
1	4.12%
2	0.00%
Reported Any of the Above Types of Pain	25.77%
MARPE Inflammation Rating over Tx	
0	18.1%
1	57.34%
2	18.11%
3	6.49%
Appliance Breakage/ Malfunction	
0	90.72%
1	9.28%
Broken Screw	
0	98.97%
1	1%

Table 3. Definitions of skeletal, dental, and soft tissue landmarks digitized for each case through Invivo 3D Tracing.

	Landmark	symbol	Definition
Skeletal Landmarks	Nasion	N	Midpoint of the frontonasal suture
	Basion	Ba	Most inferior and posterior point at the anterior margin of the foramen magnum
	Sella	S	Midpoint of the cavity of sella turcica in all three planes
	Orbitale*	Or	Most inferior point along the inferior margin of the orbital rim
	Porion*	Po	Most superior and lateral point of the external auditory meatus
	Anterior nasal spine**	ANS	Most anterior point of the premaxilla along the midline of the maxilla
	Posterior nasal spine**	PNS	Most posterior point of the palatine bone
	Point A**	A	The deepest point on the contour of the maxilla between the anterior nasal spine and the upper incisor
Dental Landmarks	U1 incisal edge*	U1	Most mesial point along the upper central incisor incisal edge
	U1 apex*	U1A	Upper central incisor root apex

*Bilateral landmarks (right and left)

** Landmark becomes bilateral when palatal suture is split by MARPE

Table 4. Measurements taken for each case.

Measurement	Symbol	Definition	Orientation
Molar Angulation	U6_PP	Angle between lingual cusp tip of U6 through the apex and parallel to the hard palate	The coronal slice was oriented around the midpoint of the palatal root where both the lingual cusp and the apex of the palatal root could be visualized
Palatal Thickness	PT	2 mm right and left of the mid-palatal suture from the inferior cortical border to the superior cortical border of the palate	The coronal slice was oriented between the maxillary bicuspid
Posterior Screw Expansion	PScrew_D	Measured as the distance between the most apical tips of the posterior screws. Distance between posterior screws at treatment start was 4mm.	The coronal slice was oriented where the tips of both posterior screw apices could be visualized
Palatal Vault Height	OP_MARPE_Ht	Distance from occlusal plane to the surface of the MARPE jackscrew	The coronal slice was oriented around the midpoint of the palatal root where both the lingual cusp and the apex of the palatal root could be visualized
Change in ANS (Right)	ANS_R_Ch	Measured as the $\Delta(x\text{-coordinate})$ between T1 ANS to T2 ANS (right)	3D tracing oriented using Orbitale (right), Porion (right), and Porion (left) as plane for coordinate system
Change in ANS (Left)	ANS_L_Ch	Measured as the $\Delta(x\text{-coordinate})$ between T1 ANS to T2 ANS (left)	3D tracing oriented using Orbitale (right), Porion (right), and Porion (left) as plane for coordinate system
Asymmetry of ANS Expansion	Dif_ANS_RL	Difference between Change in ANS (Right) and ANS (Left)	3D tracing oriented using Orbitale (right), Porion (right), and Porion (left) as plane for coordinate system

Table 5. Asymmetry at ANS. Difference between expansion of ANS right versus ANS left.

Difference between movement of ANS_R and ANS_L		
<= 1 mm	>1 mm <2	>= 2 mm
35	14	18

Table 6: Change in molar angulation (U6 in relation to palatal plane).

	T1	T2	T2-T1	p-value
U6_PP_R	99.7 ± 6.74	104.01 ± 7.05	4.36 ± 5.06	<.0001
U6_PP_L	99.05 ± 6.05	101.72 ± 6.48	2.77 ± 4.77	<.0001
U6_PP	99.37 ± 5.14	102.86 ± 5.2	3.57 ± 3.76	<.0001

Table 7: Changes in molar angulation has no correlation with age, molar inclination, palatal thickness, amount of posterior screw opening or palatal vault height.

	AVG ± SD	r	p
Age	19.07 ± 7.61	0.08	0.54
UR6_PP_12	4.36 ± 5.06	-0.02	0.89
UL6_PP_12	2.77 ± 4.77	0.01	0.95
PT_Av	6.35 ± 2.35	-0.08	0.55
PScrew_D	11.75 ± 2.39	0.20	0.11
PVaultHt	13.51 ± 2.75	-0.03	0.82

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