9-30-2022

Assessment of skeletal changes and mandibular plane in growing patients treated with miniscrew assisted (MARPE) and conventional rapid palatal expansion using CBCT images

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A Thesis Submitted to the Graduate Committee
of the Department of Orthodontics
University of the Pacific
Arthur A. Dugoni School of Dentistry

In Partial Fulfillment of the Requirements for the Degree
Master of Science in Dentistry

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Abstract:

Background: Maxillary expansion has long been used in children and adolescents for transverse discrepancies and dental crowding. With age, the mid-palatal suture becomes increasingly mature, requiring heavy, rapid force in order to achieve skeletal expansion. As an individual grows into adulthood, it has been demonstrated that a skeletally anchored expander can be used in order to achieve successful sutural separation. The side effects between these two types of expanders, including dental tipping with relative extrusion of buccal segments and clockwise mandibular rotation, have been demonstrated to have differences in their degrees of severity. However, most of the studies have evaluated the effects immediately following the expansion and not through a prolonged period in which growth may occur. The purpose of the present study was to investigate long-term skeletal differences in two types of expansion (RPE vs MARPE) on a growing population. **Methods:** This retrospective study included 39 adolescent subjects (mean age = 13.8 years) who had received maxillary expansion (20 RPE, 19 MARPE) with subsequent completion of orthodontic treatment. Initial and final CBCTs were used to analyze cephalometric and transversal changes between the two groups. Transverse measurements were repeated two weeks apart to test intra-observer reliability. **Results:** Cephalometric analysis demonstrated no significant differences in changes of FMA ($p = 0.549$) or MP-SN ($p = 0.722$) between the two groups following expansion and completion of orthodontic treatment. There were statistically significant differences in transverse changes between the two groups, with the MARPE group displaying more skeletal expansion. **Conclusions:** The results of the present study suggest that skeletally anchored expander - MARPE and conventional expander have similar skeletal effects in adolescents.

Keywords: Mini-screw Assisted Rapid Palatal Expansion; MARPE; Rapid Palatal Expansion;

INTRODUCTION

The maxillary expansion has long been used in children and adolescents for transverse discrepancies and dental crowding. For younger subjects, in primary and early mixed dentition, the mid-palatal suture is in an immature state, and appliances with continuous light force are considered efficient and safe for sutural separation, resulting in palatal expansion.[1] With age, the mid-palatal suture becomes increasingly interdigitated.[2] Therefore, a rapid palatal expander (RPE) appliance with heavier, more rapid force to overcome the maturing suture in adolescence is necessary. Although the sutural separation with RPE is almost always accomplished through mid-adolescence, it is often followed by dental tipping in the posterior segments.[3] This occurs due to the pull of the palatal soft tissue and simultaneous orthodontic buccal movement of the posterior dentition. Not only does this dental effect make post-treatment retention more crucial, but it also poses potential for other side effects – secondary to relative extrusion of maxillary dentition.[4] (2)

For those reasons, skeletally anchored expanders, such as the miniscrew-assisted rapid palatal expander (MARPE,) were developed for better controlled skeletal expansion with less skeletal relapse and dental expansion, and for achieving skeletal expansion in more mature patients.[5-8] (3-5) However, some rotation still occurs as evidenced by a pyramidal expansion pattern, posing the potential for relative extrusion of maxillary dentition and mandibular clockwise rotation.[9, 10] It has been demonstrated in the literature that conventional RPE produces a significant increase in maxillary transverse dimensions.[11, 12] However, this increase may be due more to dental tipping than it is to pure skeletal expansion.[12] The use of miniscrew-assisted RPE, on the other hand, has demonstrated more skeletal expansion at the level of the maxilla, with the center of rotation occurring more superiorly and laterally at the frontozygomatic suture.[10] Nonetheless, as a result of this rotation, there is a relative extrusion of the maxillary posterior dentition in both types of expansion. This can cause the mandible to move down and back in a clockwise rotation, especially in growing patients.[11]

The differences observed in conventional RPE and miniscrew-assisted RPE have revealed a need for studies directly comparing the two different types of maxillary expansion. One such study has demonstrated skeletal and dental differences between RPE and MARPE immediately

following maxillary expansion.[5] Another such study compared a type of mini-implant supported expander with two other conventional expanders, and observed differences in mandibular position.[6] These studies, however, only analyzed differences soon after the completion of expansion, and not through completion of orthodontic treatment in growing patients. Evaluation in the comparison of the long-term skeletal effects from conventional RPE and MARPE is still lacking. Therefore, a study analyzing the side effects resulting from palatal expansion, including mandibular position, following the completion of orthodontic treatment in growing patients is needed. Additional information in this area is potentially beneficial in orthodontics, especially in patients with a vertical growth pattern which may potentially be worsened from treatment. Long-term skeletal changes from RPE and MARPE therapy can be demonstrated with the use of cone beam computed tomography.

Nowadays, cone beam computed tomography (CBCT) images are considered routine exams and can be used for three dimensional assessment of the skeletal and dental changes, respecting the ALARA[13] and ALDA principles.[14] The additional information gained from a CBCT often outweighs the radiation used in conventional cephalograms and panoramic radiographs. CBCT's provide a three-dimensional view of the anatomic and dental structures, and slices can be made to further evaluate specific areas of interest. Particularly, CBCT's are useful in illustrating transverse dimensions, dental anomalies, root positions, impacted teeth locations, alveolar boundary conditions, condyle anatomy and position, pathology, and other information that cannot be shown in two-dimensional radiographs.[15]

The purpose of this study was to evaluate the long-term skeletal changes following maxillary expansion with RPE vs mini-screw assisted RPE in adolescent patients with remaining growth potential, using CBCT images in two different time points (T1 before treatment, and T3 at the completion of orthodontic treatment.) The primary objective was to observe the differences in changes of the vertical mandibular position between the two groups. The null hypothesis was that there would be no significant differences in the position of the mandible in adolescent patients treated with RPE vs mini-screw assisted RPE.

MATERIALS AND METHODS

This retrospective longitudinal observational study was approved by the Institutional Review Board at the University of the Pacific in June 2021 (number IRB2021-97). The inclusion criteria were subjects aged 11 to 16 years receiving orthodontic treatment with RPE or MARPE, and who had a vertical skeletal classification of normo- to hyperdivergent. A pre-treatment and final CBCT were also required for inclusion. Exclusion criteria were poor image quality, subjects that received adjunct facemask or headgear therapy, and/or RPE prior to MARPE treatment. The initial enrollment included 94 subjects – 20 RPE patients treated at the University of Alberta Graduate Orthodontic program, and 74 MARPE patients treated at the University of the Pacific Graduate Orthodontic program. After applying exclusion criteria, 19 MARPE subjects remained, as well as the 20 RPE patients. The CBCT images were acquired from the i-CAT with voxel size $0.3mm^2$ before expansion was initiated and at the completion of orthodontic treatment. For each subject, lateral cephalograms were extracted from DICOM files and traced for comparative cephalometric analysis between the two groups at both time points (Figure 1.) Transverse linear measurements were taken from cross sections in a coronal plane that coincided with the trifurcation of the upper right maxillary molar (Figure 2.) In this plane, the maxillary width at the level of the furcation of right first molar, the width between the CEJs of maxillary first molars, the width of the nasal floor, and the width of the palate were all measured at the two time points (Figure 3.) Using the frontal view on the DICOM, angular measurements of maxillary first molars were made by creating an angle between a reference line between right and left Orbitale, and a line drawn through the center of the crown and the furcation between distobuccal and palatal roots (Figure 4.) Due to the nasal cavity floor and palate not having landmarks considered to be repeatable, a method was developed in order to make consistent measurements. In the coronal plane, a vertical reference line was placed tangent to the most lateral radiolucent aspect of the nasal cavity, and a horizontal reference line placed tangent to the most inferior radiolucent aspect of the nasal cavity (Figure 5.) The 90-degree angle created by the two reference lines was bisected at 45 degrees, and a landmark placed at the point where the bisector crossed the cortical outline of the nasal floor. This was performed for right and left sides to create a linear measurement of the nasal cavity floor width (Figure 6.) With the same reference lines in place,

inverse bisectors were used to measure the palatal width where they crossed the cortical outline of the palate. All transverse and molar angle measurements were repeated two weeks after initial measurements in order to test repeatability. The variables included in this study were 26 cephalometric measurements, 4 maxillary transverse measurements, and 2 angular measurements of the first maxillary molars.

STATISTICAL ANALYSIS

To test normality, a Shapiro-Wilk Normality Test was performed. Intra-observer reproducibility was measured by calculating intraclass correlation coefficients. To analyze differences and changes between groups, multiple Student's t-test were used. Pearson correlation coefficients were calculated to test correlation between variables.

RESULTS

Table 1 shows an excellent intraobserver reliability with an ICC ranging from 0.94 to 0.99. The baseline (T1) and post-treatment (T3) descriptive characteristics of each group are shown in the Table 2 and Table 3 respectively. Analysis of the two groups before the start of treatment demonstrated that the RPE and MARPE subjects were similar in age, phenotype and cephalometric measurements as seen in Table 4. However, the MARPE group started with significant difference in the transverse dimensions having greater widths values at the levels of the nasal cavity floor, palate, maxillary width at the trifurcation level, and cementoenamel junctions. The variable of most concern with respect to this study, the mandibular plane angle, had no significant difference between RPE and MARPE groups (Figure 7.) It should be noted that there was a significant difference in treatment time, with the RPE group averaging approximately 12.5 more months than the MARPE group. Analysis of variables at T3 demonstrated that the time between expansion and orthodontic treatment created more significant difference between the MARPE and RPE groups. Most of these differences were among variables of little importance. However, it was observed that the transverse values of the MARPE group remained significantly greater than the RPE group. Additionally, the upper right first molar was significantly more upright in the MARPE group. The upper left molar of the MARPE group was more upright though not to a statistically significant degree. An important finding was that the mandibular plane

angles are still similar between the two groups with a difference of about 2 degrees (Figure 8, Table 5.) When evaluating changes from T1 to T3 within each group, only a small number of variables showed statistical significant variables as seen in Figure 9. Both groups had notable expansion which is demonstrated in statistically significant changes in all transverse measurements. The upper molars in the MARPE group became more upright by a significant degree, while they remained relatively unchanged in inclination in the RPE group. Neither group had a significant change in the mandibular plane angle (Table 6.) Table 7 shows the comparison of the changes from T1 to T3 between the two groups. Analysis of the compared changes demonstrated that the MARPE group had significantly more expansion in each of the transverse variables. Additionally, the difference in the changes of molar inclinations was greater than 4 degrees and was statistically significant, which was mostly due to the changes observed in the MARPE group. There were no significant differences in the amount of change of the mandibular plane between the two groups. The Pearson correlation test (Table 8) provided a few correlations of statistical significance. In the MARPE group, width of the nasal cavity floor had a negative correlation with age. This is thought to be a random result, and one of little importance regarding the present study. One interesting finding was the negative correlation between the inclination of the upper right molar and mandibular plane angle in the MARPE group. Meaning the mandibular plane angle increased as the molar decreased in inclination or became more upright. In the RPE group, the only correlation of significant value was a positive correlation in palatal width and treatment time. This may be attributed to more growth potential with the longer treatment interval.

DISCUSSION

The present study was predicated on discoveries of previous findings showing the difference in side effects from maxillary expansion between MARPE and RPE in growing patients. The latter of the two appliances causing a greater increase in buccal tipping of the maxillary dentition and clockwise rotation of the mandible immediately following expansion. However, these analyses are over the short-term without follow-up on the potential changes that occur from remaining orthodontic treatment and growth potential. With this in consideration, the present study was designed and conducted to investigate the potential changes that occur after

maxillary expansion and through completion of orthodontic treatment in adolescent patients. We found that there was no long-term difference between MARPE and RPE groups regarding changes in the mandibular plane angle. We did however find significant differences in maxillary molar inclinations and the amount of skeletal expansion between the two groups. With the MARPE group having both a significant decrease in molar inclination, and a greater amount of skeletal expansion. The latter was an expected finding given the results of previous studies. In the RPE group, molar inclination remained almost the same as the start of treatment.

There may be several reasons the present study found no long-term difference in the change of mandibular plane angle following expansion with RPE compared to MARPE. The first of which could be that there is a relapse in the buccal tipping that occurs with maxillary expansion. In a systematic review, Chhutani et al.[16] demonstrated that the side effects from expansion are transient in nature and concluded that the mandible eventually returns to its original position. In another study, Kartalian et al.[17] found that the upper molars return to their initial inclination with less than one degree of change. These reports agree with the results of our study, where the mandibular plane of the RPE group increased less than one degree, and the molar inclinations increased less than 1.5 degrees. Our study lacked records from a time point immediately following expansion, so it is impossible to determine if buccal tipping took place. However, significant expansion did take place, and based off numerous other studies, we can assume the RPE group had buccal tipping following expansion that later relapsed by the time orthodontic treatment was completed.

Another potential variable influencing the outcomes of this study is the maxillary displacement in the sagittal plane. Chung et al. [11] demonstrated that both ANS and PNS move downward over one millimeter immediately following expansion with RPE. Given that we observe greater skeletal expansion in MARPE, it is possible that greater circummaxillary suture separation occurs along with greater displacement of the maxilla. Currently, to the best of our knowledge, there are no studies comparing the vertical and A-P displacement of the maxilla from RPE and MARPE in growing patients. A future study using three-dimensional analysis is needed to compare maxillary displacement from the two appliances.

A third potential variable affecting changes in the mandibular plane following expansion is the inclination change of the mandibular first molars. It has been demonstrated that MARPE has less skeletal relapse than RPE. Considering the widely used protocol of expanding the maxilla until upper palatal cusps approximate the lower buccal cusps, and the lesser degree of relapse in skeletally anchored expansion, MARPE may cause more expansion than required to correct a transverse deficiency or crossbite. In which case, uprighting of the upper dentition, lower dental expansion and/or uprighting may be required to achieve satisfactory buccal overjet. This inclination change of the lower dentition may be in the form of buccal tipping with relative extrusion and potentially cause a clockwise rotation of the mandible. It should be noted that one observation of the present study was the upper molars of the MARPE group finished with significantly more upright inclination, which also had a significant correlation with increase in mandibular plane angle. Although, this increase in mandibular plane angle was not significant. Nonetheless, lower molar inclination is a variable that should be explored in order to detect potential significant change and correlation to mandibular plane angle change.

The final potential factor in the results of this study was the difference in treatment time between the RPE and MARPE groups. On average, the RPE group had a longer treatment time at 41.5 months compared to 29 months in the MARPE group. This difference of 12.5 months represents a confounding factor in that the RPE group may have had more growth which can overcome an iatrogenic increase in mandibular plane angle. This represents a limitation of the present study. Another limitation includes the risk of bias in that examiners were not blinded to the to the treatment groups.

A future study designed as a randomized clinical trial is warranted. This would potentially allow for more similarity in treatment times and documentation of the expansion protocols used between the two groups. Three dimensional analysis of maxillary displacement and changes of lower molar inclinations should also be studied.

CONCLUSIONS

From the results of the present study, the null hypothesis was not rejected in that there were no significant differences in mandibular plane angle changes between MARPE and RPE groups. We were also able to draw the following conclusions:

1) Conventional RPE may be a suitable appliance for transverse discrepancy regardless of vertical skeletal classification in growing patients.
2) MARPE treatment leads to uprighting of the upper molars.
3) MARPE provides greater maxillary skeletal expansion compared to RPE.

ACKNOWLEDGMENTS

The author would like to thank Drs. Jonas Bianchi, Dr. Heesoo Oh, Dr. Manuel Lagravère and Dr. Joorok Park for the support during the development of this project.

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FIGURES CAPTIONS

Figure 1. Lateral cephalogram tracings for RPE and MARPE at T1 and T3.
Figure 2. Locating the trifurcation of upper right first molar in horizontal and sagittal planes.
Figure 3. Transverse mesaurements in coronal plane at T1 and T3.
Figure 4. Angular measurements of upper first molars.
Figure 5. Reference lines at lateral and inferior aspects of nasal cavity.
Figure 6. Reference line bisectors for transverse measurements of nasal floor and palate.
Figure 7. Comparison of variables between MARPE vs RPE at T1.
Figure 8. Comparison of variables between MARPE vs RPE at T3.
Figure 9. Changes for each variable T3-T1 in each group.

TABLES

Table 1. Intra-observer reliability values

Table 1 - ICC test for comparison of reability for the same observer with an interval of 2 weeks				
Variable		ICC value	lower	upper
Mx Transverse UR6	78	0.997	0.99	0.99
Nasal floor	78	0.99	0.99	0.99
Palate	78	0.98	0.98	0.99
CEJ-CEJ	78	0.94	0.91	0.96
UR6 inclination	78	0.94	0.92	0.96
UL6 inclination	78	0.97	0.95	0.98

Table 2. Descriptive values MARPE and RPE at T1

	MARPE (T1)			RPE (T1)		
	95% CI			95% CI		
Variables	Mean	SD	SE	Mean	SD	SE
Age (yrs)	13.72	1.46	0.33	13.98	1.42	0.32
Tx Months	28.89	10.35	2.38	41.45	12.28	2.75
FMA (°)	25.70	4.73	1.08	28.33	6.03	1.35
FMIA (°)	62.63	6.57	1.51	65.89	8.34	1.87
IMPA (°)	91.68	4.83	1.11	85.78	9.17	2.05
SNA (°)	80.57	4.21	0.97	79.32	3.67	0.82
SNB (°)	76.62	4.37	1.00	76.99	2.57	0.57
ANB (°)	3.96	2.47	0.57	2.35	2.57	0.57
FH-SN (°)	11.61	2.39	0.55	10.70	2.72	0.61
Occ Plane to SN (°)	20.72	5.49	1.26	19.10	4.04	0.90
Wits Appraisal (mm)	-0.94	3.31	0.76	-2.20	4.39	0.98
U1-NA (°)	19.91	11.01	2.53	21.79	5.07	1.13
U1-NA (mm)	3.77	3.78	0.87	4.22	1.98	0.44
L1-NB (°)	25.57	5.64	1.29	21.79	7.85	1.75
L1-NB (mm)	5.91	2.33	0.53	4.65	3.02	0.67
Holdaway Ratio (%)	0.21	0.36	0.08	0.16	1.18	0.26
MP-SN (°)	37.29	5.83	1.34	39.03	6.60	1.48
Upper Lip to E-Plane (mm)	-0.97	2.51	0.57	-4.71	2.88	0.64
Lower Lip to E-Plane (mm)	0.65	3.09	0.71	-1.46	3.38	0.76
Upper Face Height (N-ANS) (mm)	51.68	3.59	0.82	49.71	3.55	0.80
Lower Face Height (ANS-Gn) (mm)	65.43	5.93	1.36	69.02	5.43	1.21
Interincisal Angle (U1-L1) (°)	130.57	12.46	2.86	134.09	12.13	2.71
Vertical Face Height Ratio (%)	99.93	10.89	2.50	91.52	6.19	1.39
Stm-1 (mm)	4.00	1.52	0.35	6.60	1.13	0.25
U1-SN (°)	100.47	10.39	2.38	101.11	5.90	1.32
H-Angle (Pg'UL-Pg'Na') (°)	16.86	4.00	0.92	10.94	3.83	0.86
Anterior Face Height (NaMe) (mm)	113.75	7.84	1.80	114.90	6.90	1.55
Pog-NB (mm)	0.67	1.63	0.37	1.18	1.83	0.41
Mx Transverse U6 furcation (mm)	29.20	1.97	0.45	27.00	2.16	0.48
Nasal Floor (mm)	24.40	1.76	0.40	23.13	1.98	0.44
Palate (mm)	22.96	2.78	0.64	20.91	2.49	0.56
CEJ-CEJ (mm)	34.46	2.73	0.63	31.38	2.81	0.63
UR6 (°)	96.27	5.36	1.23	96.20	3.75	0.84
UL6 (°)	96.38	4.95	1.14	94.98	5.23	1.17

Table 3. Descriptive values MARPE and RPE at T3.

	MARPE (T3)			RPE (T3)		
	95% CI			95% CI		
Variables	Mean	SD	SE	Mean	SD	SE
FMA	26.22	5.66	1.30	28.41	6.50	1.45
FMIA	58.11	7.11	1.63	63.92	7.76	1.73
IMPA	95.67	6.37	1.46	87.69	8.46	1.89
SNA	80.96	4.33	0.99	79.65	3.81	0.85
SNB	76.70	4.65	1.07	77.19	3.40	0.76
ANB	4.26	1.93	0.44	2.48	1.94	0.43
FH-SN	11.47	2.60	0.60	11.29	2.80	0.63
Occ Plane to SN	21.83	5.44	1.25	19.52	4.33	0.97
Wits Appraisal	-1.35	3.08	0.71	-2.59	3.07	0.69
U1-NA	21.51	6.74	1.55	27.71	4.74	1.06
U1-NA	3.90	2.49	0.57	5.83	1.84	0.41
L1-NB	30.03	5.89	1.35	24.57	7.08	1.58
L1-NB	7.17	2.28	0.52	5.89	3.18	0.71
Holdaway Ratio	0.21	0.36	0.08	0.66	1.29	0.29
MP-SN	37.70	6.71	1.54	39.69	7.61	1.70
Upper Lip to E-Plane	-2.07	2.28	0.52	-4.84	3.12	0.70
Lower Lip to E-Plane	0.48	2.84	0.65	-1.25	3.15	0.70
Upper Face Height (N-ANS)	52.69	3.16	0.73	51.06	3.18	0.71
Lower Face Height (ANS-Gn)	67.52	6.36	1.46	71.50	5.28	1.18
Interincisal Angle (U1-L1)	124.17	6.61	1.52	125.24	9.89	2.21
Vertical Face Height Ratio	101.13	9.68	2.22	91.31	5.28	1.18
Stm-1 (mm)	4.03	1.38	0.32	5.59	2.17	0.49
U1-SN	102.47	7.25	1.66	107.38	5.62	1.26
H-Angle (Pg'UL-Pg'Na')	16.13	3.26	0.75	11.42	4.16	0.93
Anterior Face Height (NaMe)	116.49	7.74	1.78	118.20	6.03	1.35
Pog-NB	0.83	1.86	0.43	1.17	2.23	0.50
Mx Transverse U6 furcation	34.13	2.98	0.68	29.58	2.55	0.57
Nasal Floor	28.25	2.37	0.54	24.83	2.09	0.47
Palate	27.19	2.86	0.66	22.82	2.76	0.62
CEJ-CEJ	38.29	2.73	0.63	34.83	2.43	0.54
UR6	93.45	4.70	1.08	97.59	4.43	0.99
UL6	93.26	4.58	1.05	96.21	6.56	1.47

Table 4. Student's t-test for comparison in T1 between groups (MARPE – RPE).

	MARPE-RPE (T1)				
	95% CI				
Variables	p-value	Mean	SE	Lower	Upper
Age	0.585	-0.25	0.46	-1.19	0.68
Tx Months	0.001	-12.56	3.65	-19.94	-5.17
FMA	0.139	-2.64	1.74	-6.16	0.89
FMIA	0.184	-3.26	2.41	-8.15	1.63
IMPA	0.017	5.90	2.37	1.11	10.70
SNA	0.327	1.25	1.26	-1.30	3.81
SNB	0.745	-0.37	1.14	-2.69	1.94
ANB	0.053	1.61	0.81	-0.02	3.25
FH-SN	0.274	0.91	0.82	-0.75	2.57
Occ Plane to SN	0.299	1.62	1.54	-1.49	4.74
Wits Appraisal	0.321	1.26	1.25	-1.28	3.79
U1-NA	0.493	-1.88	2.72	-7.40	3.63
U1-NA	0.644	-0.45	0.96	-2.39	1.50
L1-NB	0.093	3.78	2.20	-0.67	8.24
L1-NB	0.154	1.26	0.87	-0.50	3.02
Holdaway Ratio	0.859	0.05	0.28	-0.52	0.62
MP-SN	0.391	-1.74	2.00	-5.78	2.31
Upper Lip to E-Plane	0.000	3.74	0.87	1.98	5.49
Lower Lip to E-Plane	0.050	2.10	1.04	0.00	4.21
Upper Face Height (N-ANS)	0.093	1.97	1.14	-0.34	4.29
Lower Face Height (ANS-Gn)	0.056	-3.59	1.82	-7.27	0.10
Interincisal Angle (U1-L1)	0.378	-3.52	3.94	-11.50	4.46
Vertical Face Height Ratio	0.005	8.41	2.82	2.70	14.12
Stm-1 (mm)	0.000	-2.60	0.43	-3.47	-1.73
U1-SN	0.814	-0.64	2.69	-6.08	4.81
H-Angle (Pg'UL-Pg'Na')	0.000	5.92	1.25	3.38	8.46
Anterior Face Height (NaMe)	0.635	-1.13	2.37	-5.93	3.66
Pog-NB	0.364	-0.51	0.56	-1.64	0.62
Mx Transverse U6 furcation	0.002	2.19	0.66	0.85	3.54
Nasal Floor	0.042	1.26	0.60	0.05	2.48
Palate	0.020	2.05	0.84	0.34	3.76
CEJ-CEJ	0.001	3.08	0.89	1.28	4.88
UR6	0.960	0.07	1.48	-2.92	3.06
UL6	0.394	1.41	1.63	-1.90	4.72

Table 5. Student's t-test for comparison in T3 between groups (MARPE – RPE).

	MARPE-RPE (T3)				
	95% CI				
Variables	p-value	Mean	SE	Lower	Upper
FMA	0.271	-2.18	1.96	-6.15	1.78
FMIA	0.020	-5.81	2.39	-10.65	-0.97
IMPA	0.002	7.99	2.41	3.11	12.87
SNA	0.322	1.31	1.30	-1.33	3.95
SNB	0.708	-0.49	1.30	-3.12	2.14
ANB	0.007	1.78	0.62	0.53	3.04
FH-SN	0.838	0.18	0.87	-1.58	1.93
Occ Plane to SN	0.151	2.31	1.57	-0.88	5.49
Wits Appraisal	0.219	1.23	0.99	-0.76	3.23
U1-NA	0.002	-6.20	1.86	-9.96	-2.43
U1-NA	0.009	-1.93	0.70	-3.34	-0.52
L1-NB	0.013	5.46	2.09	1.22	9.70
L1-NB	0.158	1.28	0.89	-0.52	3.09
Holdaway Ratio	0.146	-0.45	0.31	-1.07	0.17
MP-SN	0.393	-1.99	2.30	-6.66	2.68
Upper Lip to E-Plane	0.003	2.76	0.88	0.98	4.54
Lower Lip to E-Plane	0.080	1.73	0.96	-0.22	3.68
Upper Face Height (N-ANS)	0.117	1.63	1.02	-0.43	3.69
Lower Face Height (ANS-Gn)	0.040	-3.98	1.87	-7.76	-0.19
Interincisal Angle (U1-L1)	0.695	-1.07	2.71	-6.56	4.41
Vertical Face Height Ratio	0.000	9.82	2.48	4.80	14.84
Stm-1 (mm)	0.011	-1.56	0.59	-2.75	-0.38
U1-SN	0.023	-4.91	2.07	-9.11	-0.72
H-Angle (Pg'UL-Pg'Na')	0.000	4.71	1.20	2.28	7.15
Anterior Face Height (NaMe)	0.446	-1.71	2.22	-6.19	2.78
Pog-NB	0.616	-0.33	0.66	-1.67	1.00
Mx Transverse U6 furcation	0.000	4.55	0.89	2.76	6.35
Nasal Floor	0.000	3.42	0.71	1.98	4.87
Palate	0.000	4.38	0.90	2.56	6.20
CEJ-CEJ	0.000	3.46	0.83	1.79	5.13
UR6	0.007	-4.14	1.46	-7.10	-1.17
UL6	0.113	-2.95	1.82	-6.64	0.74

Table 6. Student's t-test for comparison in T3 – T1 in each group.

	MARPE (T3-T1) n= 19						RPE (T3-T1) n= 20					
			95% CI						95% CI			
Variables	Mean	SD	SE	Lower	Upper	p-value	Mean	SD	SE	Lower	Upper	p-value
FMA	0.53	2.13	0.49	-0.50	1.55	0.295	0.07	2.50	0.56	-1.09	1.24	0.895
FMIA	-4.52	5.88	1.35	-7.35	-1.68	0.004	-1.97	5.04	1.13	-4.33	0.39	0.097
IMPA	3.99	5.93	1.36	1.13	6.85	0.009	1.91	4.25	0.95	-0.08	3.89	0.060
SNA	0.38	1.15	0.26	-0.17	0.94	0.162	0.33	1.41	0.31	-0.33	0.99	0.307
SNB	0.08	0.97	0.22	-0.38	0.55	0.708	0.20	1.56	0.35	-0.53	0.93	0.573
ANB	0.30	1.18	0.27	-0.27	0.87	0.281	0.13	1.05	0.23	-0.36	0.62	0.585
FH-SN	-0.14	0.87	0.20	-0.55	0.28	0.500	0.59	1.08	0.24	0.09	1.10	0.024
Occ Plane to SN	1.11	2.76	0.63	-0.22	2.44	0.097	0.43	2.69	0.60	-0.83	1.68	0.489
Wits Appraisal	-0.42	1.95	0.45	-1.36	0.52	0.365	-0.39	2.08	0.46	-1.36	0.58	0.411
U1-NA	1.61	9.92	2.28	-3.18	6.39	0.490	5.92	5.61	1.25	3.30	8.54	0.000
U1-NA	0.13	3.39	0.78	-1.50	1.77	0.868	1.62	1.81	0.40	0.77	2.46	0.001
L1-NB	4.46	5.67	1.30	1.72	7.19	0.003	2.78	4.38	0.98	0.73	4.83	0.010
L1-NB	1.26	1.85	0.42	0.37	2.15	0.008	1.24	1.43	0.32	0.56	1.91	0.001
Holdaway Ratio	-0.01	0.18	0.04	-0.09	0.08	0.902	0.50	2.06	0.46	-0.47	1.47	0.292
Upper Lip to E-Plane	-1.10	1.85	0.42	-1.99	-0.21	0.018	-0.12	0.91	0.20	-0.55	0.30	0.548
Lower Lip to E-Plane	-0.16	1.67	0.38	-0.97	0.64	0.675	0.21	1.28	0.29	-0.39	0.81	0.471
Lower Face Height	2.09	3.24	0.74	0.53	3.66	0.011	2.48	2.49	0.56	1.32	3.65	0.000
Interincisal Angle	-6.40	11.86	2.72	-12.12	-0.68	0.030	-8.84	8.17	1.83	-12.67	-5.02	0.000
Vertical Face Height Ratio	1.20	8.49	1.95	-2.89	5.29	0.545	-0.21	4.15	0.93	-2.16	1.73	0.819
Stm-1(mm)	0.03	1.25	0.29	-0.57	0.63	0.913	-1.01	2.07	0.46	-1.97	-0.04	0.042
U1-SN	2.00	10.01	2.30	-2.83	6.83	0.395	6.28	6.32	1.41	3.32	9.23	0.000
H-Angle (Pg'UL-Pg'Na')	-0.73	3.15	0.72	-2.25	0.79	0.324	0.48	1.27	0.28	-0.12	1.08	0.108
Anterior Face Height (NaMe)	2.74	2.98	0.68	1.30	4.18	0.001	3.31	2.96	0.66	1.92	4.70	0.000
Pog-NB	0.16	0.81	0.19	-0.23	0.55	0.391	-0.01	0.78	0.17	-0.38	0.35	0.932
MP-SN	0.41	1.91	0.44	-0.51	1.32	0.367	0.66	2.47	0.55	-0.50	1.82	0.247
Upper Face Height (N-ANS)	1.01	1.94	0.44	0.07	1.94	0.036	1.35	1.28	0.29	0.75	1.95	0.000

	MARPE (T3-T1) n= 19						RPE (T3-T1) n= 20					
			95% CI						95% CI			
Variables	Mean	SD	SE	Lower	Upper	p-value	Mean	SD	SE	Lower	Upper	p-value
Mx Transverse U6 furcation	4.94	1.73	0.40	4.11	5.77	0.000	2.58	1.69	0.38	1.79	3.37	0.000
Nasal floor	3.85	1.14	0.26	3.30	4.40	0.000	1.70	0.78	0.17	1.33	2.06	0.000
Palate	4.23	1.80	0.41	3.36	5.10	0.000	1.91	1.46	0.33	1.22	2.59	0.000
CEJ-CEJ_T	3.83	2.02	0.46	2.86	4.80	0.000	3.45	2.86	0.64	2.11	4.79	0.000
UR6	-2.82	2.91	0.67	-4.22	-1.42	0.001	1.39	4.68	1.05	-0.80	3.58	0.199
UL6	-3.13	2.93	0.67	-4.54	-1.72	0.000	1.24	5.85	1.31	-1.50	3.97	0.357

Table 7. Student t-test for comparison in T3 – T1 between groups (MARPE – RPE).

	MARPE-RPE (T3-T1)				
	95% CI				
Variables	p-value	Mean	SE	Lower	Upper
FMA	0.549	0.45	0.75	-1.06	1.96
FMIA	0.154	-2.55	1.75	-6.09	1.00
IMPA	0.213	2.08	1.65	-1.25	5.42
SNA	0.896	0.05	0.41	-0.78	0.89
SNB	0.783	-0.12	0.42	-0.96	0.73
ANB	0.636	0.17	0.36	-0.55	0.89
FH-SN	0.026	-0.73	0.32	-1.37	-0.09
Occ Plane to SN	0.438	0.69	0.87	-1.08	2.46
Wits Appraisal	0.968	-0.03	0.65	-1.33	1.28
U1-NA	0.101	-4.31	2.56	-9.51	0.88
U1-NA	0.094	-1.48	0.86	-3.23	0.27
L1-NB	0.306	1.68	1.62	-1.60	4.96
L1-NB	0.966	0.02	0.53	-1.05	1.09
Holdaway Ratio	0.295	-0.51	0.48	-1.47	0.46
MP-SN	0.722	-0.25	0.71	-1.69	1.18
Upper Lip to E-Plane	0.042	-0.98	0.46	-1.91	-0.04
Lower Lip to E-Plane	0.437	-0.37	0.47	-1.33	0.59
Upper Face Height (N-ANS)	0.514	-0.34	0.52	-1.41	0.72
Lower Face Height (ANS-Gn)	0.674	-0.39	0.92	-2.26	1.48
Interincisal Angle (U1-L1)	0.456	2.45	3.25	-4.13	9.02
Vertical Face Height Ratio	0.509	1.42	2.12	-2.89	5.72
Stm-1 (mm)	0.067	1.04	0.55	-0.08	2.15
U1-SN	0.117	-4.28	2.67	-9.68	1.13
H-Angle (Pg'UL-Pg'Na')	0.120	-1.21	0.76	-2.75	0.33
Anterior Face Height (NaMe)	0.551	-0.57	0.95	-2.50	1.36
Pog-NB	0.488	0.18	0.25	-0.34	0.69
Mx Transverse U6 furcation	0.000	2.36	0.55	1.25	3.47
Nasal Floor	0.000	2.16	0.31	1.53	2.79
Palate	0.000	2.33	0.52	1.27	3.39
CEJ-CEJ	0.634	0.38	0.80	-1.23	1.99
UR6	0.002	-4.21	1.26	-6.75	-1.67
UL6	0.006	-4.36	1.49	-7.39	-1.34

Table 8. Pearson correlation test within groups between the transversal differences (T3-T1) and Mandibular plane changes in RPE and MARPE Group

Correlations

			Age	Tx Months	Mx Transverse U6 furcation	Nasal floor	Palate	CEJ-CEJ	UR6	UL6
MARPE	Age	Pearson Correlation	-	-0.17	-0.32	-.576**	-0.43	0.15	0.28	0.00
		Sig. (2-tailed)	-	0.474	0.175	0.010	0.065	0.551	0.245	0.988
	Tx Months	Pearson Correlation	-0.175	-	-0.18	-0.08	0.08	0.13	-0.15	0.20
		Sig. (2-tailed)	0.474	-	0.453	0.744	0.754	0.603	0.530	0.410
	MP - SN_T3-T1	Pearson Correlation	-0.12	-0.14	0.02	-0.15	0.00	-0.23	-.573*	0.19
		Sig. (2-tailed)	0.621	0.557	0.926	0.534	0.994	0.337	0.010	0.436
	FMA	Pearson Correlation	-0.24	-0.10	0.15	-0.09	0.17	-0.17	-.517*	0.12
		Sig. (2-tailed)	0.321	0.682	0.553	0.711	0.499	0.487	0.024	0.615
RPE	Age	Pearson Correlation	-	0.31	-0.14	-0.14	0.09	0.19	0.18	0.23
		Sig. (2-tailed)	-	0.190	0.554	0.545	0.696	0.434	0.438	0.338
	Tx Months	Pearson Correlation	0.31	-	0.25	-0.01	.513*	0.18	0.16	0.01
		Sig. (2-tailed)	0.190	-	0.296	0.964	0.021	0.449	0.513	0.983
	MP - SN_T3-T1	Pearson Correlation	-0.31	-0.17	-0.15	-0.16	-0.03	0.04	0.19	0.13
		Sig. (2-tailed)	0.179	0.468	0.520	0.490	0.897	0.882	0.412	0.571
	FMA	Pearson Correlation	-0.30	-0.14	-0.31	-0.28	-0.17	-0.08	0.30	0.26
		Sig. (2-tailed)	0.197	0.560	0.188	0.226	0.486	0.736	0.204	0.269

FIGURES

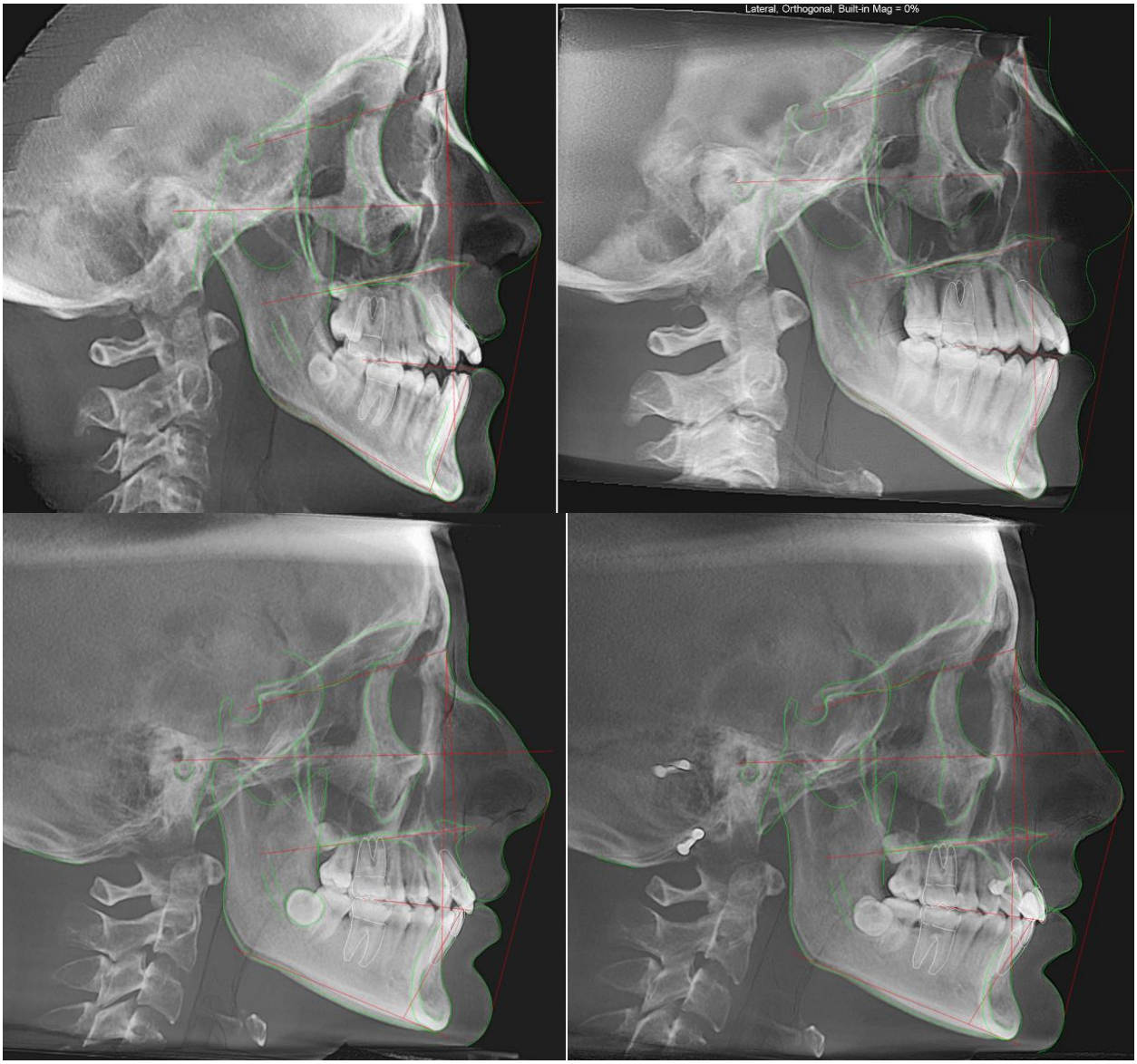

Figure 1. Lateral cephalogram tracings for RPE and MARPE at T1 and T3

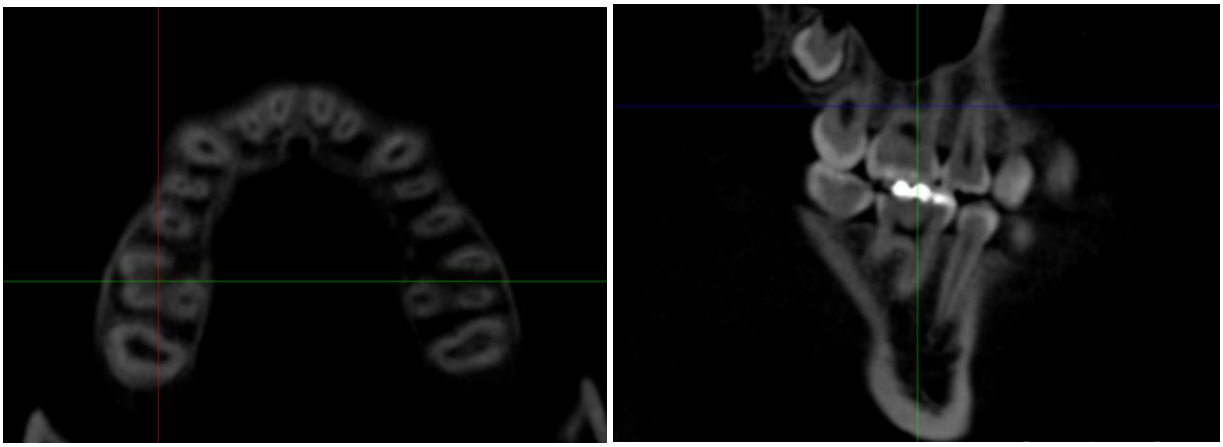

Figure 2. Locating the trifurcation of upper right first molar in horizontal and sagittal planes

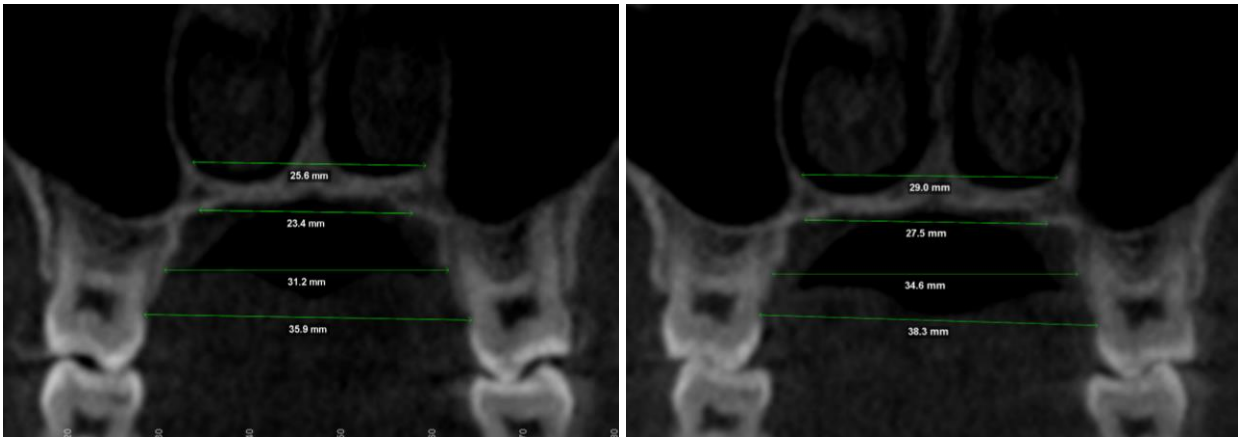

Figure 3. Transverse mesaurements in coronal plane at T1 and T3

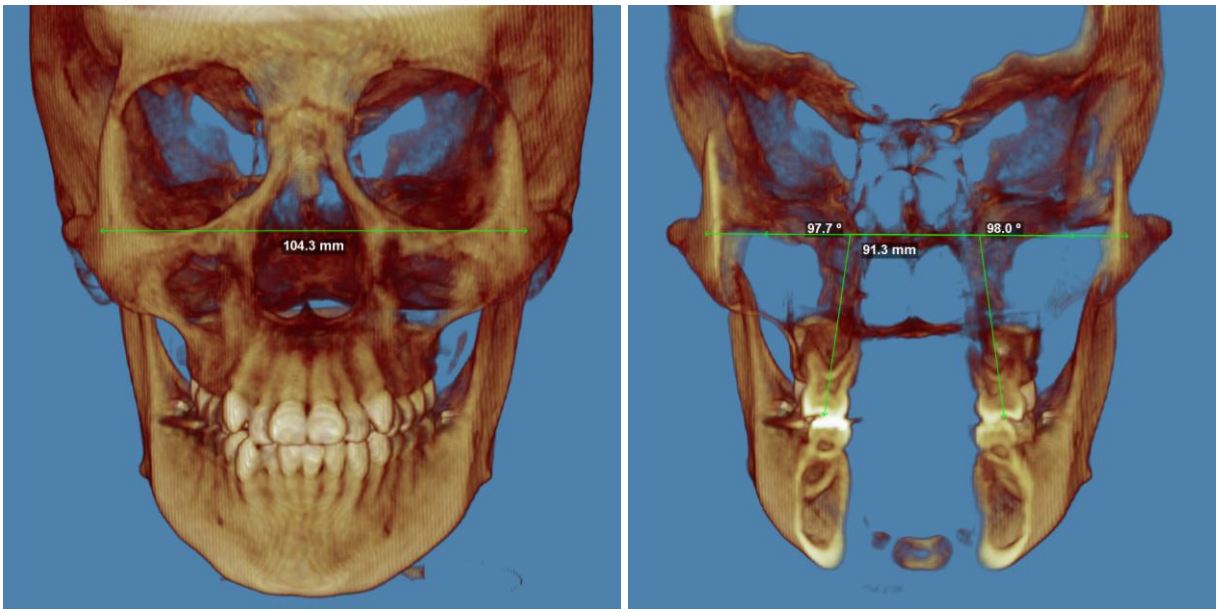

Figure 4. Angular measurements of upper first molars

Figure 5. Reference lines at lateral and inferior aspects of nasal cavity

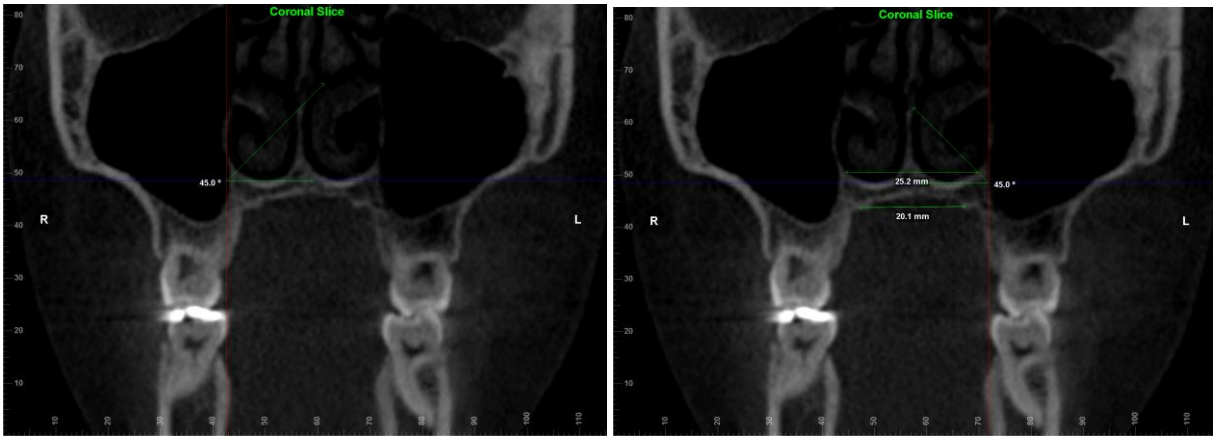

Figure 6. Reference line bisectors for transverse measurements of nasal floor and palate

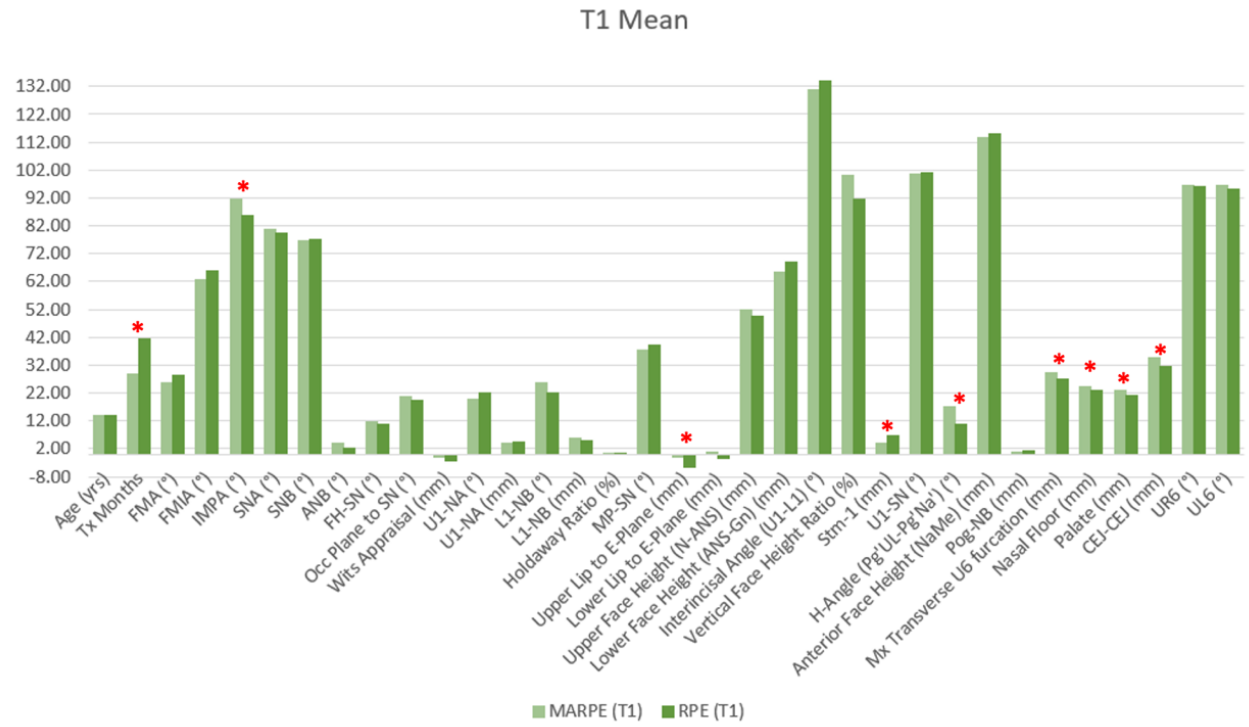

Figure 7. Comparison of variables between MARPE vs RPE at T1

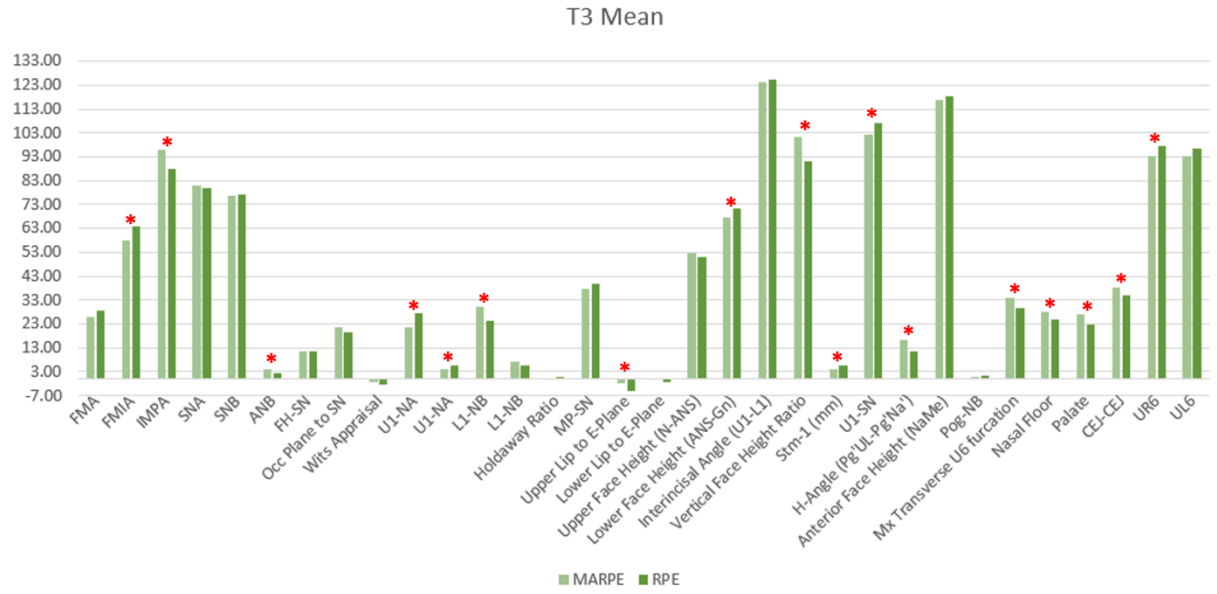

Figure 8. Comparison of variables between MARPE vs RPE at T3.

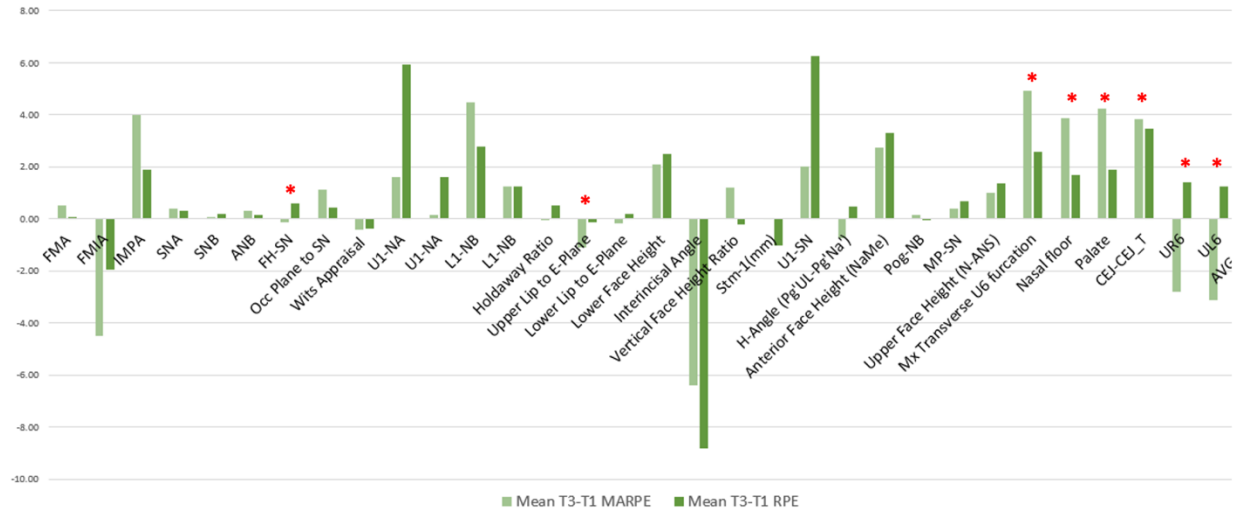

Figure 9. Changes for each variable T3-T1 in each group.