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Article

Maxillary Forward Translation and Mandibular Immediate Shift Following 3D-Guided Midpalatal Piezocorticotomy Assisted MARPE in Adults: Lateral Cephalometric Pre- and Post-Treatment Study

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Abstract

Objectives: This study aimed to evaluate the forward translation of the maxillary base in adults undergoing 3D-guided midpalatal piezocorticotomy-assisted Miniscrew-Assisted Rapid Palatal Expansion (MARPE). Furthermore, the research investigated the contributing factors for forward maxillary movement and the subsequent immediate shift of the mandible. **Methods:** In this retrospective quasi-experimental study, cephalometric records of 80 adult patients (mean age 35.23 ± 8.76 years; 52 females, 28 males) were analyzed. Maxillary translation was assessed via SNA and A-Nperp(FH), while intermaxillary changes were measured using the ANB angle. Vertical and rotational changes were tracked through SN-MP, FH-MP, and various occlusal plane angles (OcP-FH, OcP-SN, OcP-GoMe). Facial height dimensions (TAFH, UAFH, LAFH, PFH) and dento-alveolar positions (U1-MP, U1LENGTH) were also recorded. **Results:** Following intervention, significant increases were observed in SNA (0.96°; 95% CI [0.48, 1.43]), ANB (1.42°; 95% CI [1.04, 1.80]), and A-Nperp(FH) (0.81 mm; 95% CI [0.24, 1.39]). The SN-GoMe angle increased by 0.98° and Posterior Facial Height (PFH) increased by 1.57 mm, while upper incisor length (U1LENGTH) significantly decreased by 0.71 mm. **Conclusions:** 3D-Guided midpalatal Piezocorticotomy Assisted MARPE in adults is associated with the increase in SNA, ANB, SN-GoMe, Posterior Facial Height, A-Nperp(FH), and decrease in the maxillary incisor length. The amount of anterior midpalatal separation is not associated with the SNA increase while the latter is associated with the inclination of the maxillary plane (SN-MP).

Keywords: MARPE; adults; 3D- guided piezocorticotomy; 3D-GMP MARPE; downward maxillary rotation; mandibular rotation

Introduction

Maxillary expansion has demonstrated positive effects for treatment of both Class II [1] and Class III malocclusions [2] in growing individuals. Maxillary expansion was associated with increase in pharyngeal airway volume [3] in growing individuals and improved quality of life in adults diagnosed with Obstructive Sleep Apnea (OSA) [4].

Maxillary forward movement has been one of the desired outcomes when treating both growing and non-growing individuals. Combination of facemask and hybrid-hyrax has become a widely described treatment modality in the late mixed dentition [5,6] in Class III malocclusion patients. For Class II growing individuals, where mandibular advancement has been advocated as one of the treatment options, maxillary skeletal expansion is an adjunct increasing its potential. The amount of mandibular advancement is highly dependent on the vertical position and anterior-posterior

inclination of the maxillary incisors, anterior-posterior inclination of mandibular incisors, and the amount of the overjet.

Recent development of custom Miniscrew-Assisted Rapid Palatal Expansion devices has proven predictable maxillary skeletal separation in adult patients. Multiple protocols were introduced to increase the success rate of adult maxillary expansion including slow-turn protocol (MASPE) [7], polycyclic turns [8], 3D- Guided Midpalatal Piezocorticotomy Assisted MARPE (3D-GMP MARPE) [9].

The 3D-GMP MARPE protocol has shown high success rate of midpalatal suture separation in both sexes regardless of age, minimum side effects (skeletal fractures, soft tissue impingement etc), low post-procedural pain level.

This study has aimed at evaluating the effects of maxillary forward translation associated with the 3D-GMP MARPE procedure alone, without the use of facemask or similar devices, evaluated with lateral cephalometric measurements. Authors hypothesized that pre- and post-treatment lateral cephalometric measurements would show evidence of forward maxillary translation following the 3D-GMP MARPE protocol. Gender and Skeletal Classification differences were evaluated between pre- and post-expansion measurements.

Methods

Study design. This quasi-experimental study retrospectively evaluated the records of 80 patients who underwent 3D- GMP MARPE procedure in the clinical setting of the orthodontic practice DrKoval Orthodontics located in Boca Raton, FL, USA. This study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by Solutions Institutional Review Board (Solutions IRB) (Approval No. 0846). Written informed consent was obtained from all participants.

Participants. 89 participants entered the study. After initial review, the records of 80 participants with the mean age of 35.23 ± 8.76 years were evaluated. Inclusion criteria for the study included adults 19 years old and older with no history of maxillary skeletal expansion, orthognathic surgery, connective tissue diseases, autoimmune conditions, chemotherapy. The study population included 52 females (65%) and 28 (35%) males who underwent 3D-GMP MARPE procedure as a part of the initially recommended treatment. The descriptive characteristics of the study population are included in Table 1.

Table 1. Characteristics of the study participants. Mean values and standard deviations are presented for each continuous variable.

	Gender		
	Females	Males	Total
Number	52 (65%)	28 (35%)	80 (100%)
Age	37.94 (7.71)	30.18 (8.45)	35.23 (8.76)
Anterior Midplaatal Separation, mm	5.55 (1.34)	6.65 (1.95)	5.94 (1.65)
ANB before Tx, degrees	4.07 (2.34)	3.12 (2.99)	3.74 (2.61)
SNA before Tx, degrees	80.59 (4.22)	81.26 (3.38)	80.82 (3.94)
SN- ANSPNS before Tx, degrees	8.31 (3.35)	7.73 (3.85)	8.11 (3.52)

Data sources/measurements. Lateral cephalometric radiographs were rendered from the CBCT volumes of each patient. The CBCT images were obtained with Planmeca G7 Viso (FOV 022x021 cm, Planmeca, Helsinki, Finland) with Ultra Low Dose protocol (ULD), 100 kV, 6.3 msA, 30 mkmSv, 600 voxel size. The exported lateral cephalometric radiographs processed in Romexis (Planmeca, Helsinki, Finland) were further traced manually in WebCeph (Seongnam-si, South Korea) by the

Principal Investigator (SK). The lateral cephalometric radiographs were retraced again in 2 weeks for the increase intra-examiner reliability.

Variables. Fifteen measurements were identified for the purpose of this study. (Table 2). Maxillary forward translation was evaluated using angular (SNA) and linear measurements (A-Nperp(FH)), intermaxillary relationship was measured using angular ANB measurement. Angles SN-MP and FH-MP were used to evaluate the direction and amount of maxillary plane rotation. Occlusal plane rotation and cant was measured with OcP-FH, OcP-SN, and OcP-GoMe angles. Linear measurements of the facial heights were evaluated with TAFH (Total Anterior Facial Height, NaMe), UAFH (Upper Anterior Facial Height (Na-ANS), LAFH (Lower Anterior Facial Height, ANS-Me), and PFH (Posterior Facial Height, S-Go). Dento-alveolar measurements of the maxillary incisors position included angular U1-MP and linear U1LENGTH measurement.

Bias. CBCT images taken with open mouth posture were eliminated from the study. The CBCT volumes taken in a standing position with no head or chin support were evaluated.

Study size. The sample size was determined a priori to estimate the mean SNA angle with a 95% confidence level. Based on the previous literature showing a standard deviation of 3.93°, a sample of 60 subjects was required to achieve a margin of error of 1°. Our study evaluated total of 80 subjects.

Intervention. The 3D guide for the midpalatal piezocorticotomy (Figure 1) was fabricated based on the initial CBCT volume merged with the intraoral scans taken with iTero intraoral scanner (iTero, Align Technology, San Jose, California, USA). The piezocorticotomy guide was used to precisely place the piezocorticotomy cuts followed by the custom MARPE placement (Figure 3). The activation of the custom MARPE was initiated 7 days after its placement. Further activation was kept at 1 turn a day (0.11 mm) for both males and females after the midpalatal split was confirmed. The activation of the Powerscrew (TigerDental, Hörbranz, Austria.) was 0.11 mm per turn. The complete (from ANS to PNS) midpalatal suture separation was then confirmed with the CBCT. (Figure 4).

Statistical methods. All statistical analyses were conducted in StataNow/SE 19.5 (Stata Corp, College Station, TX, USA). Descriptive statistics were used to summarize studied population. To test the data normality, Shapiro-Wilk test and Quantile-Quantile plots were used for every measured variable. Paired t-tests and two-sample t-test was used to identify differences between groups for all measured variables. To demonstrate statistical significance and P-value of <.05 was used.

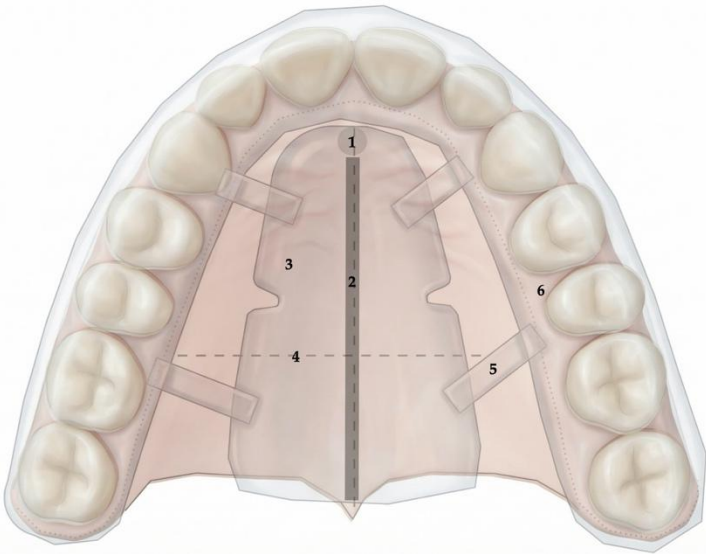


Figure 1. Schematic image of the 3D- printed midpalatal piezocorticotomy guide: 1- incisive foramen, 2 – incision notch for the midpalatal piezocorticotomy, 3 – guide base covering the hard palate, 4 – location of the transverse palatal suture, 5 – 3D printed guide connector, 6 – 3D printed guide occlusal splint covering occlusal surfaces of the maxillary teeth.

Table 2. Descriptions of the parameters measured in the study.

ANTERSEP	Separation of the midpalatal suture at the level of ANS, mm
SKCLASS	Skeletal Class
SNA	SNA before treatment, degrees
ANB	ANB angle degrees
A-Nperp(FH)	Distance between point A to the perpendicular to FH constructed through point N , mm
SN-MP	SN-ANS-PNS angle before treatment, degrees
FH- MP (PPA)	Palatal Plane angle to FH, degrees
SN-GoMe	Angle between the SN and GoMe, degrees
OcP-SN	Angle between the SN plane and the Occlusal plane, degrees
OcP-GoMe	Angle between the GoMe plane and the Occlusal plane, degrees
OcP-FH	Angle between the FH plane and the Occlusal plane, degrees
TAFH	Total anterior facial height, mm
PFH	Posterior Facial Height mm
LAFH	Lower anterior facial height, mm
UAFH	Upper anterior facial height, mm
U1MP	Angle between the axis of the maxillary central incisor and ANS-PNS plane, degrees
U1LENGTH	Lenth of the maxillary central incisor to the ANS-PNS plane mm

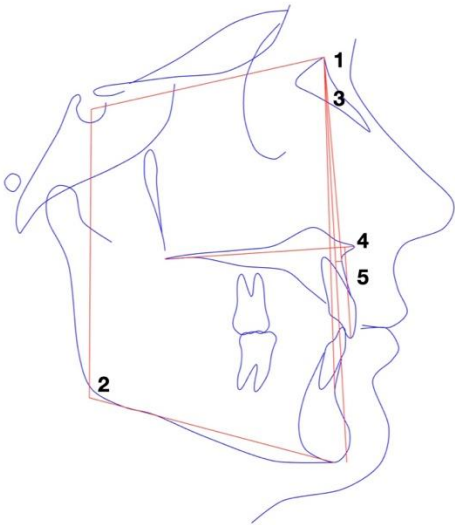


Figure 2. Lateral cephalometric tracing and measurements used for pre- and posttreatment analysis: 1 – SNA, 2- Posterior Facial Height (PFH), 3 – ANB, 4 – A-N perp(FH), 5 – U1LENGTH.

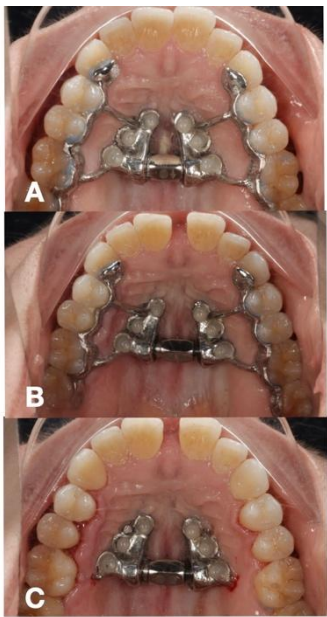


Figure 3. Design of the custom MARPE used: A- after 3D-Guided Midplaatal Piezocorticotomy and installation (TAD screwheads are covered with composite), B – 6 weeks into expansion, C – completed expansion with tooth-anchored parts of the milled framework removed.

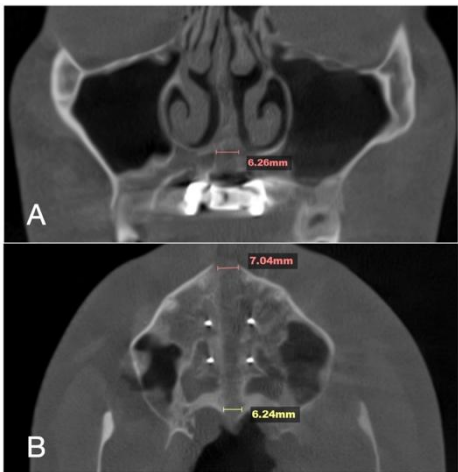


Figure 4. Resulting midpalatal suture separation: A – coronal view at the level of the maxillary first molars indicating 6.26 mm of separation at the level of the nasal base (ANS-PNS plane), B – axial view of the same patient demonstrating 7.04 mm of the midpalatal separation at the level of the ANS and 6.24 mm of the midpalatal suture separation at the level of the PNS (89% parallelism).

Results

Participants. All 80 participants demonstrated successful separation of the midpalatal suture. The mean anterior separation achieved was 5.55 ±1.34 mm in females, 6.65 ±1.95 mm in males, and 5.94 ±1.65 mm in total sample.

Descriptive data. Among 15 measurements compared between pre- (T0) and post-expansion (T1) stages only 6 showed significantly different change (SNA, ANB, A-Nperp(FH), SN-GoMe, PFH, and U1LENGTH). Parameters measuring the inclination of the maxillary plane relative to the Frankfort horizontal (FH-MP) or base of the skull (SN-MP) did not show significantly different change indicating no significant maxillary plane rotation/inclination with the procedure. Occlusal

plane inclination (OcP-FH, OcP-SN, OcP-GoMe) did not significantly change with intervention either.

Outcome data. SNA angle significantly increased by 0.96 degrees with the 95% CI [0.48, 1.43] with intervention, ANB angle significantly increased by 1.42 degrees (95% CI [1.04,1.80]), A-Nperp(FH) significantly increased by 0.81 mm (95% CI [0.24,1.39]), PFH (Posterior Facial Height) significantly decreased by 1.57 mm (95% CI [-2.82, -0.32]), SN-GoMe angle significantly increased by 0.98 degrees (95% CI [0.42, 1.54]), upper incisor length (UILENGTH) significantly decreased by 0.71 mm (95% CI [-1.36, -0.05]).

Other analyses. Interpercentile group analysis of all 15 variables demonstrated significant difference between percentile groups for A-Nperp(FH). Angle Classification group analysis was performed between Class I and Class II groups showing significant intergroup difference for OcP-FH variable, while Class I group individually demonstrated significant difference in SNA, ANB, SN-GoMe, OcP-SN, OcP-FH variables. Skeletal Class II group showed significant difference in SN-GoMe, A-Nperp(FH), PFH variables. Scatter plots with fitted values of SNA increase and A-Nperp(FH) increase demonstrated a steady pattern in the A-point forward movement with expansion at the average level of 2 mm for males and an increasing point A displacement with expansion for females. Crude and adjusted linear regression analyses showed that SNA change is not associated with the amount of expansion but is rather related to the pre-treatment position of the maxillary plane relative to the base of the skull: for every 1 degree increase in pre-treatment SN-MP angle, the difference of pre- and post-expansion SNA will increase by 0.21 degrees in a mixed group of Class I and Class II subjects with mixed pre-expansion composition of maxillary base inclination.

Table 3. Pre- and Post- expansion Comparison.

Measur ements	T0						T1						P- value	Me an cha nge	95% CI mean change
	Mean	SD	Min	Max	[95% conf.interv]		Mean	SD	Min	Max	[95% conf.interv]				
SNA, degrees	80.82	3.94	69.9	88.7	79.94	81.70	81.66	4.08	72.7	90.1	80.75	82.56	0.001*	0.96	0.48, 1.43
ANB, degrees	3.74	2.60	-3.9	10	3.16	4.32	5.16	2.67	-1	11.7	4.56	4.56	<0.00 0*	1.42	1.04, 1.80
A-N perp(F H), mm	.03	3.97	-.85	.91	-.85	.91	.84	3.66	.03	1.66	.03	1.66	0.006*	0.81	0.24, 1.39
SN-MP, degrees	8.11	3.52	-.9	15.9	7.33	8.89	8.26	3.37	.6	15.3	7.51	9.01	0.64	0.15	-0.50, 0.81
FH-MP (PPA), degrees	-1.16	3.40	-9.4	9.2	-1.92	-.41	-.98	3.38	-8.5	6.9	-1.73	-.22	0.60	0.19	-0.51, 0.89
SNGo ME, degrees	35.27	8.22	16.5	51.8	33.44	37.10	36.25	8.61	17.6	52.1	34.33	38.16	0.001*	0.98	0.42, 1.54
OcP- SN, degrees	17.89	6.13	.8	41.5	16.52	19.25	18.24	5.70	3.2	31.3	16.97	19.50	0.49	0.35	-0.67, 1.37
OcP - GoMe, degrees	17.38	6.57	-11.6	31.1	15.91	18.84	18.00	6.11	1.2	32.2	16.65	19.36	0.21	0.63	-0.37, 1.63
OcP- FH, degrees	8.63	5.38	-3.8	31.6	7.43	9.82	9.0	5.05	-1.5	22.8	7.87	10.12	.46	0.37	-0.63, 1.37
TAFH, mm	117.47	9.09	77.5	140.3	115.45	119.49	116.08	11.70	79.8	135.2	113.47	118.68	.13	- 1.39	-3.22, 0.43
PFH, mm	76.65	8.03	52.4	99	74.86	78.44	75.08	9.78	50.7	99.1	72.90	77.26	.014*	- 1.57	-2.82, -0.32

LAFH, mm	68.38	6.29	41.9	83.1	66.98	69.78	67.62	7.73	43.2	81.9	65.90	69.34	.23	-	-2.04, 0.52
UAFH, mm	50.90	4.17	35.9	63.9	49.97	51.83	50.63	5.09	37.1	58.9	49.49	51.76	.51	-	-1.10, 0.55
U1MP, degrees	108.76	7.71	91.6	124.8	107.04	110.48	107.76	8.40	82.4	127.3	105.89	109.63	0.07	-	-2.10, 0.09
U1LEN														1.00	
GTH, mm	29.70	2.94	20.2	35.3	29.04	30.35	28.99	3.51	17.8	35.1	28.21	29.77	.03*	-	-1.36, -0.05

* Statistically significant difference.

Table 4. Amount of Midpalatal Separation in Percentile Groups.

Percentile Groups	Min	Max	Mean	SD	Count
1	3.3	4.8	4.10	.55	20
2	4.81	5.7	5.22	.27	21
3	5.71	6.81	6.26	.32	19
4	6.81	10.17	5.89	1.58	20
Total					80

Table 5. Inter percentile group analysis for different variables.

Variable	Group 1		Group 2		Group 3		Group 4		ANOVA	Bartlett's Test	Kruskal-Wallis test
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	A		
SNA	-1.33	2.05	-1.06	2.17	-.99	1.80	.04	3.48	n/a	.02	.66
ANB	-1.63	1.84	-1.29	1.84	-1.54	1.68	-1.24	1.49	.86	.78	n/a
A-N perp(FH)	-1.74	2.53	-.28	1.83	-1.52	2.97	.23	2.54	n/a	.02	.04*
SN-MP	-1.07	2.17	.32	2.11	.88	2.69	-.72	4.11	n/a	.01	.22
FH-MP (PPA)	-.71	3.53	-.43	2.75	1.35	2.86	-.86	3.12	.10	.70	n/a
SNGoME	-1.21	1.54	-.80	2.10	-.93	1.83	-.98	4.01	n/a	<.000	.73
OcP-SN	.11	4.15	-.38	2.16	-.18	7.28	-.93	3.84	n/a	<.000	.52
OcP -GoMe	-1.32	4.41	-.45	2.68	-.75	6.54	-.02	3.99	n/a	<.002	.69
OcP-FH	.48	4.25	-1.11	2.78	.3	6.85	-1.08	3.36	n/a	<.000	.63
TAFH	.25	3.76	-.82	3.85	1.87	8.92	4.41	12.54	n/a	<.000	.87
PFH	1.21	2.37	.22	3.31	1.76	6.11	3.16	8.55	n/a	<.000	.68
LAFH	.50	3.34	-.71	2.60	.27	6.51	3.04	8.39	n/a	<.000	.41
UAFH	-.48	2.53	-.67	2.68	1.32	3.88	1.03	5.08	n/a	<.006	.43
U1MP	-.35	4.42	2.04	4.66	2.89	3.81	-.54	5.92	.06	.29	n/a
U1LENGTH	.89	1.71	.06	1.67	-.20	3.40	2.05	3.98	n/a	<.000	.09

*Statistically significant difference.

Subgroup analysis based on skeletal classification is presented in Tables 6 and 7.

Table 6. Skeletal Class I and Class II Subgroups Characteristics before Treatment.

Skeletal Class			
	I	II	Total
N	38 (50.7%)	37 (49.3%)	75 (100.0%)
MEANSEP	5.844 (1.682)	5.875 (1.462)	5.859 (1.567)
ANB	2.284 (1.081)	5.965 (1.428)	4.100 (2.238)
TAFH	118.400 (10.975)	116.892 (6.788)	117.656 (9.122)
PPA	-1.153 (3.655)	-0.997 (3.150)	-1.076 (3.393)
PFH	76.992 (8.728)	75.727 (7.451)	76.368 (8.093)
SNA	79.876 (3.911)	81.722 (3.842)	80.787 (3.961)

SNGoMe	35.253 (8.179)	36.389 (7.848)	35.813 (7.984)
SN-MP	8.366 (3.439)	8.014 (3.735)	8.192 (3.568)
U1-MP	110.011 (6.069)	106.273 (8.397)	108.167 (7.501)
OcP-SN	17.668 (4.638)	19.051 (6.951)	18.351 (5.895)
OcP-GoMe	17.576 (5.889)	17.332 (7.509)	17.456 (6.692)
OcP_FH	8.161 (4.261)	10.043 (5.783)	9.089 (5.123)
ANperpFH	-0.726 (3.652)	0.749 (3.908)	0.001 (3.827)
LAFH	68.424 (7.594)	68.630 (4.652)	68.525 (6.275)
UAFH	51.318 (4.545)	50.722 (3.957)	51.024 (4.247)
U1-length	29.521 (3.128)	30.127 (2.638)	29.820 (2.893)

Table 7. Skeletal Class I and II Subgroup Comparative Analysis.

Variable	I					II					Intergr oup P value
	T0		T1		P value	T0		T1			
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		
SNA	79.88	3.91	81.00	4.03	.004*	81.72	3.84	81.98	4.00	.16	.13
ANB	2.28	1.08	3.93	2.01	.0052*	5.96	1.43	6.95	1.99	.16	.08
A-N perp(FH)	-.73	3.65	-.084	3.39	.15	.75	3.91	1.62	3.21	.027*	.07
SN-MP	8.37	3.44	8.33	2.87	.92	8.01	3.73	8.77	3.59	.12	.22
FH-MP (PPA)	-1.15	3.66	-.70	3.48	.36	-.10	3.15	-.83	3.20	.74	.687
SNGoME	35.25	8.18	36.03	8.28	.01*	36.39	7.85	37.68	8.49	.004*	.69
OcP-SN	17.67	4.64	18.53	4.98	.025*	19.05	6.95	18.78	6.00	.45	.29
OcP -GoMe	17.58	5.89	17.49	5.62	.50	17.33	7.51	18.89	6.55	.19	.12
OcP-FH	8.16	4.26	9.49	4.96	.016*	10.04	5.78	9.19	4.95	.98	.04*
TAFH	118.4	10.97	118.23	11.44	.096	116.89	6.79	114.53	10.91	.35	.23
PFH	76.99	8.73	76.64	9.29	.36	75.73	7.45	72.98	9.77	.001*	.052
LAFH	68.42	7.59	68.67	7.94	.10	68.63	4.65	66.97	6.65	.32	.13
UAFH	51.32	4.54	51.37	4.56	.319	50.72	3.96	50.25	5.48	.86	.53
U1MP	110.01	6.07	109.62	7.79	.616	106.27	8.40	105.19	8.55	.17	.53
U1LENGTH	29.52	3.13	29.04	3.36	.50	30.13	2.64	29.16	3.22	.18	.47

*Statistically significant difference.

Discussion

Maxillary forward translation as an effect of expansion technique remains controversial in adults. Skeletal Class III patients have been the focus for the maxillary forward movement - oriented treatment with combination of the facemask therapy and various expansion techniques. Wilmes and colleagues [10] demonstrated significant benefits of bone-anchored maxillary skeletal expansion devices when combined with facemask treatment for the sagittal maxillary movement.

Current study showed significant increase in the anterior position of the maxillary base when measured on the lateral cephalometric radiographs. The measurements used in the study included SNA and A-Nperp(FH), both having point A as a reference for the most anterior point of the maxillary base. The average increase in the SNA was 0.96 degrees, with the A-Nperp(FH) increase being 0.81 mm in the study sample of 80 subjects and 5.94 ±1.65 mm of anterior midpalatal suture separation. Evaluation of the maxillary sagittal changes after Surgically-Assisted Rapid Palatal Expansion (SARPE) was published by Jia-Hong Linin a systematic review and meta-analysis [11] reporting a 0.50° ± 0.08° increase in SNA. Several earlier studies reported clockwise maxillary rotation with SARPE [11,12]. Our study did not confirm maxillary downward rotation with 3D-GMP MARPE showing no statistically significant difference between pre- and post-expansion measurements. Iodice and co-authors [13] did not find any statistically significant changes in the sagittal maxillary base

position with SARPE reporting only maxillary incisor inclination change. Our study agrees with this finding reporting dento-alveolar change in the maxillary incisor vertical position (statistically significant decrease in maxillary incisor length) with intervention. Xue and co-authors [14] reported SNA and ANB increase with MARPE treatment in adults (0.54 degrees of increase for SNA angle and 1.54 degrees increase for the ANB angle), while our study showed ANB increase of 1.42 degrees. Thuy and Trang [15] reported no change to the Maxillary Plane Angle and minimal changes to the SNA and ANB angles with MARPE intervention.

McMullen and colleagues evaluated maxillary position changes in growing and non-growing patients treated with MARPE concluding greater downward displacement of ANS in growing patients. [16] Sayar [17] and colleagues evaluated growing and non-growing patients treated with Rapid Palatal Expansion (RPE) devices, and found no difference between groups in skeletal and dental outcomes of RPE.

The SNA increase with facemask- hybrid hyrax combination treatment produced 1.87±1.06 degrees of increase [18], 3.04 mm of forward movement of point A after 10 months of protraction time in growing individuals [19]; Tarraf and colleagues reported 4.26 ± 2.15 degrees of SNA increase with combination of hybrid hyrax and mandibular miniplates treatment in growing subjects [20]. Our data shows that adult maxillary skeletal expansion with 3D-GMP MARPE produces, on average, 0.96± 2.12 degrees of SNA increase.

Factors such as age, sex, suture maturation have been evaluated as contributing to the success of the maxillary skeletal expansion. [21] Chen and Kapetanovic [22] have confirmed that for adult patients the success of midpalatal suture separation is not related to age and gender. Shin [23] and colleagues found a negative correlation between the amount of midpalatal suture separation and subject's age and sex. These varying outcomes are related to the difference in techniques used, amount of midpalatal separation achieved, and study group characteristics. The 3D-GMP MARPE technique has proven to be successful irrespective of the midpalatal suture maturation stage, patient age or gender. The amounts of anterior separation evaluated in this study averaged at 5.94 ±1.95 mm, which is higher than frequently reported amounts of midpalatal separation [24–26]. Additionally, 3D-GMP MARPE did not produce any significant discomfort throughout the expansion stage which is in accordance with the study by Elshehaby [27] who reported lower pain levels when microosteoperforations of the midpalatal suture were combined with MARPE treatment.

Scatter plots (Figure 5 and 6) show visual representation between the amount of anterior separation and the increase in both SNA and A-Nperp(FH). Linear regression analysis did not confirm statistically significant association between two, thus indicating that the amount of anterior midpalatal separation is not directly related to the point A position change with 3D-GMP MARPE. The adjusted linear regression analysis demonstrated that SNA change is dependent on the initial inclination of the maxillary base (SN-MP) rather than the amount of anterior midpalatal separation. (Table 8).

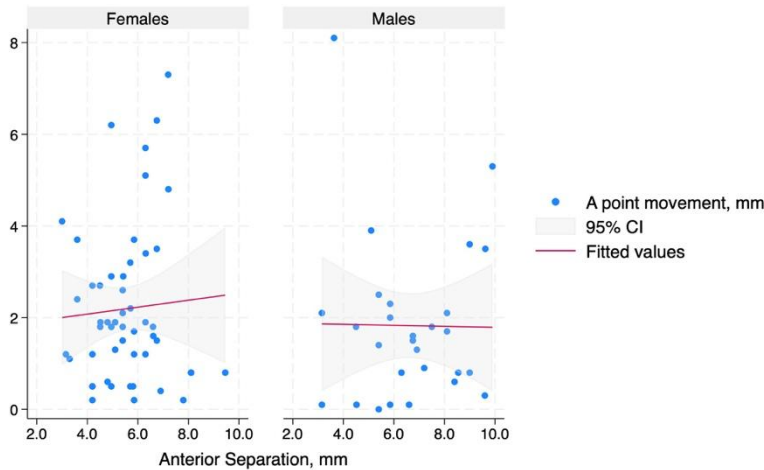


Figure 5. Scatter plot with fitted values with 95% CI of the A-point movement measured as an absolute change of A-Nperp(FH) by gender indicating an increase in forward movement in females with the amount of ANS separation, and a slight decrease of the A-point movement in males as ANS separation increases.

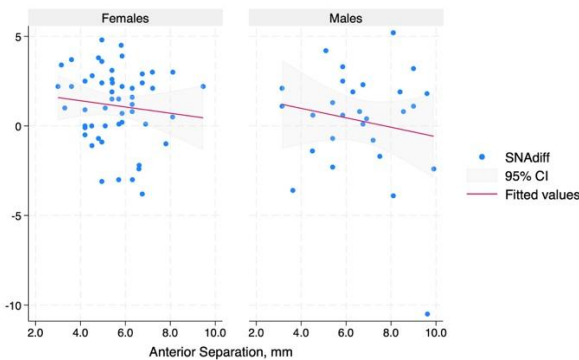


Figure 6. SNA difference with the amount of anterior midpalatal separation by gender. Downward slope of both fitted lines indicates the decrease in the amount of SNA increase with increasing Anterior separation of the midpalatal suture.

Table 8. Crude and adjusted analysis for the SNA change with 3D-GMP MARPE procedure in adults.			
		SNA difference	
		Crude analysis	
	Coefficient	P-value	95% CI
ANT separation, mm	-0.28	0.099	-0.61, 0.05
		Adjusted Analysis	
ANT separation, mm	-0.28	0.08	-0.60, 0.04
U1-MP, degrees	0.001	0.99	-0.07, 0.7
SN-MP, degrees	0.21	0.008*	0.06, 0.37

Posterior Facial Height increase reported in the current study was statistically significant for the total sample with intervention indicating immediate mandibular response to the maxillary skeletal expansion. SN-GoMe angle increase was concomitant with the ANB increase indicating posterior mandibular rotation.

The limitations of the current study included analysis of the restricted sample of patients with pre-existing symptoms of Sleep Disordered Breathing and/or Obstructive Sleep Apnea. The predominant tendency to higher ANB angles before treatment and smaller number of patients with Skeletal Class III base relationship did not allow for the comparison of all skeletal classes.

Current data needs to be carefully interpreted as SNA angle and linear A-Nperp(FH) measurements, which both depend on the position of point A, might not be the accurate representations of the maxillary base position. Point A is located in the trajectory of the apex of the maxillary incisor root also being subject to movement with maxillary skeletal expansion, as shown in the current study. Further 3D cephalometric studies are advised to evaluate maxillary forward position changes using different landmarks.

Reported data has limited generalizability due to the nature of the study sample. Further studies are recommended to increase the generalizability of the current findings.

Conclusions

3D-Guided midpalatal Piezocorototomy Assisted MARPE in adults is associated with the increase in SNA, ANB, SN-GoMe, Posterior Facial Height, A-Nperp(FH), and decrease in the maxillary incisor length. The amount of anterior midpalatal separation is not associated with the SNA increase while the latter is associated with the inclination of the maxillary plane (SN-MP).

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Data availability: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate: The study protocol was reviewed and approved by Solutions Institutional Review Board (Solutions IRB) (Approval No. 0846). Written informed consent was obtained from all participants.

Consent for publication: Written informed consent for publication of anonymized data was obtained from all participants prior to enrollment.

Declaration of competing interest: One author (SK) declares a pending patent: US and Canada Patent Pending: Piezocorticotomy guide for midpalatal skeletal expansion (Application # 18/919,416).

Abbreviations

- MARPE Miniscrew-Assisted Rapid Palatal Expansion
- SARPE Surgically Assisted Rapid Palatal Expansion
- RPE Rapid Palatal Expander
- 3D-GMP 3-Dimensional Guided Midpalatal Piezocorticotomy

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