Original Article

Evaluation of miniscrew-assisted rapid palatal expansion success by comparing width of circummaxillary sutures before expansion in adult male patients

Ji-Min Lee[a]; Sung-Hwan Choi[b]; Yoon Jeong Choi[c]; Kee-Joon Lee[c]; Hyung-Seog Yu[c]

ABSTRACT

Objectives: To investigate the relationship between circummaxillary sutures and miniscrew-assisted rapid palatal expansion (MARPE) success in adult male patients and to evaluate the correlation between the width of the sutures and the maxilla expansion ratio.

Materials and Methods: This retrospective study comprised 40 adult male patients treated with MARPE divided into a separation group (N = 20, mean age, 21.9 years) consisting of subjects with midpalatal suture opening and a nonseparation group (N = 20, mean age, 21.7 years) consisting of subjects with no midpalatal suture opening. Cone-beam computed tomography images were obtained before MARPE expansion for both groups and after expansion for the separation group. Vertical and horizontal skeletal relationships, palate length, and widths of 10 circummaxillary sutures before expansion were compared. The correlation between maxilla expansion ratio (jackscrew expansion to maxillary expansion ratio) and circummaxillary suture widths was also analyzed in the separation group.

Results: There were no significant differences in age, vertical and horizontal skeletal relationships, and palate length between the two groups. Zygomaticomaxillary, pterygomaxillary, midpalatal, and transverse palatine sutures showed significantly greater width in the separation group ($P < .05$). The zygomaticomaxillary suture showed the greatest difference ($\Delta = 0.36$ mm) between the groups. The zygomaticomaxillary and pterygomaxillary sutures showed significant positive correlation with the maxilla expansion ratio ($P < .01$).

Conclusions: In adult male patients, greater circummaxillary suture widths before MARPE expansion, especially zygomaticomaxillary and pterygomaxillary sutures, resulted in a better chance of successful suture separation and more maxillary expansion. (*Angle Orthod.* 2023;93:176–184.)

KEY WORDS: Miniscrew-assisted rapid palatal expansion (MARPE); Circummaxillary sutures; CBCT

INTRODUCTION

Since the bony resistance of the maxillary complex increases in adult patients, miniscrew-assisted rapid palatal expanders have been proposed as a good alternative to rapid palatal expanders. The mean success rate of miniscrew-assisted rapid palatal expansion (MARPE) has been reported as 92.5% in a recent systematic review,[1] a rate that is relatively high, but the midpalatal suture (MP) fails to open in some patients, leading to irreversible iatrogenic effects.

It is therefore important to determine factors related to the success of MARPE prior to treatment. Since the success rate of maxillary expansion is greater in adolescents, it can be implied that the host factor is more important than appliance or procedural factors.

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Age, sex, horizontal and vertical skeletal relationships, palate length, and characteristics related to MP have been proposed[2–6] as relevant host factors.

Recently, Jeon et al.[4] showed that older patients, particularly males, have a higher chance of failure when subjected to MP separation. However, in clinical settings, some patients succeed with suture separation and others do not, even when matched in terms of age and sex, implying that other important factors are relevant to MARPE success.

Previous studies[7] have shown that resistance to maxillary expansion comes from various combinations of circummaxillary sutures. Cho et al.[8] showed that the width of circummaxillary sutures in skeletally mature patients, measured from cone-beam computed tomography (CBCT) images, increased after MARPE expansion. Zygomaticomaxillary sutures showed small amounts of width changes, indicating high resistance to maxillary expansion.[8] In addition, a finite element analysis study[9] showed that the stress was more concentrated on thinner sutures, so it can be reasonably implied that the width of circummaxillary sutures before expansion can be a factor associated with MARPE success. To date, however, no study has compared pretreatment circummaxillary suture widths between subjects in which the MP separated with MARPE and nonseparated subjects. Therefore, this study aimed to investigate the difference in circummaxillary suture widths before expansion in adult male patients according to the success or failure of MARPE and to determine the correlation between the suture widths and the maxilla expansion ratio. The null hypothesis was that there would be no difference in the width of the circummaxillary sutures before expansion between the two groups and no correlation with the maxilla expansion ratio.

MATERIALS AND METHODS

Subjects

This retrospective study included 73 male patients who underwent MARPE treatment between 2016 and 2021 at the Department of Orthodontics, Yonsei University Dental Hospital, Seoul, Korea. The study protocol complied with the Declaration of Helsinki and was approved by the Institutional Review Board of Yonsei University Dental Hospital (IRB No. 2-2021-0099).

The inclusion criteria were age between 17 and 40 years; treatment with MARPE because of transverse discrepancy; presence of lateral cephalometric images, CBCT images, and maxillary anterior periapical radiographic images before MARPE (T0); absence of dentofacial anomalies and systemic diseases; no previous history of orthodontic treatment or expansion; and healthy periodontal tissues.

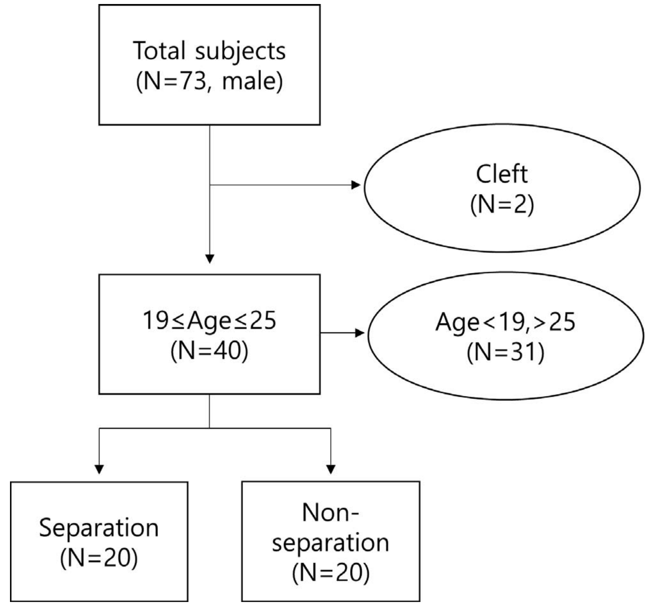

Figure 1. Flow chart of recruitment of subjects.

From the 71 patients meeting the inclusion criteria, in order to exclude age as a factor, the age range was narrowed to between 19 and 25 years. Forty patients were divided into two groups: a separation group and a nonseparation group (Figure 1). The separation group (N = 20) consisted of subjects with MP opening, considered as "success"; the nonseparation group (N = 20) consisted of subjects with no findings of MP opening, considered as "failure." MP opening was confirmed from the maxillary anterior periapical images after total MARPE expansion (T1).

The subjects in the two groups were further classified into subgroups by vertical skeletal pattern (sella-nasion to mandibular plane [SN-MP] angle: low [<27°]; normal [27–37°]; high [>37°]) and horizontal skeletal classification (A point–nasion–B point [ANB] angle: Class I [0–4°]; Class II [>4°]; Class III [<0°]) measured from T0 lateral cephalometric images.[5]

Appliance and Activation Protocol

The hyrax-type MARPE appliance (Kee's Bone Expander, Biomaterials Korea, Seoul, Korea) was used. The MARPE was placed with four miniscrews (2.0-mm diameter, 9.0-mm length in the anterior rugae region and 7.0-mm length in the posterior parasagittal area, self-drilled type; BMK, Ortholution, Seoul, Korea) monocortically incorporated in holes connected with the jackscrew (Figure 2). The maxillary first premolars and first molars were used as anchor teeth.

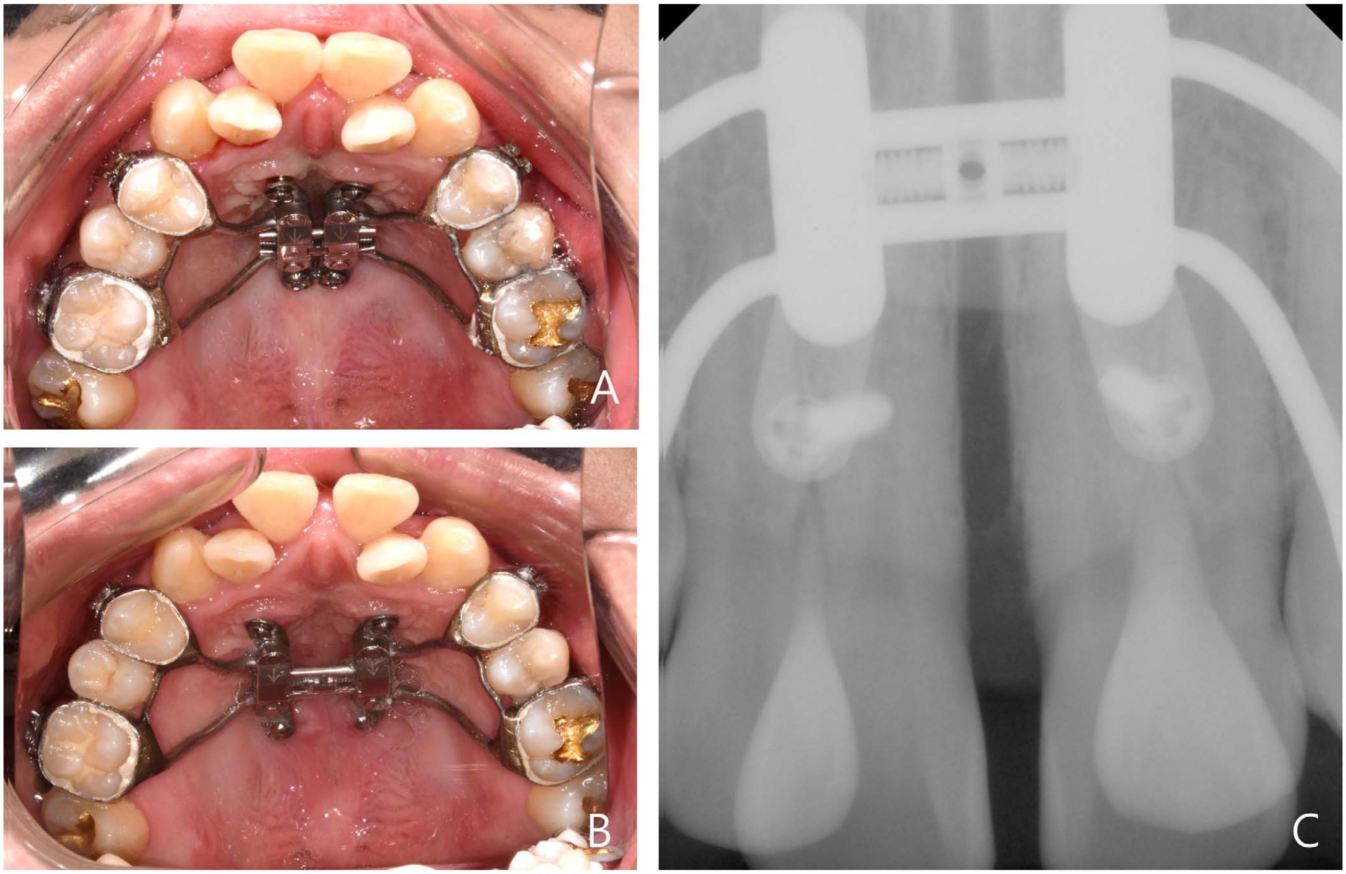

Figure 2. Design of miniscrew-assisted rapid palatal expansion (MARPE). (A) Before expansion. (B) After expansion. (C) Confirmation of midpalatal suture opening by periapical radiographs.

The MARPE appliance was activated through one turn per day (0.2 mm/turn). After 14 days, if MP opening was confirmed, expansion was continued until the palatal cusp of the maxillary first molars came into contact with the buccal cusp of the mandibular first molars. Three to four months of consolidation followed. If the MP did not separate, the following protocol was performed: rest for 4 weeks, after which expansion was resumed. If the suture was still not open after expansion was performed for 14 additional days, expansion was discontinued.[4]

Measurements

Maxillary anterior periapical images, lateral cephalometric images, and CBCT images were taken before MARPE (T0) for all subjects. Maxillary anterior periapical images and CBCT images were taken after maximum expansion (T1) in the separation group. A CBCT scanner (Alphard-3030; ASAHI Roentgen IND, Kyoto, Japan) was set at 10.0 mA and 80 kV, with a field of view of 200×200 mm^2 and a voxel size of 390 μm. Images were taken for 17 seconds and saved as Digital Imaging and Communications in Medicine (DICOM) files using the Zetta PACS program (Taeyoung Soft Company, Anyang, Korea). The DICOM files were imported to InVivo6® software (version 6.5.0; Anatomage, Santa Clara, Calif).

DICOM images were reoriented using a line connecting both infraorbital lower borders in the frontal view, Frankfort horizontal plane in the sagittal view, and midsagittal plane in the axial view. The Frankfort horizontal plane was defined as the plane passing through the center of the porion bilaterally and the left orbitale, and midsagittal plane was defined as a perpendicular plane passing through nasion and basion.[10]

The widths of 10 circummaxillary sutures at T0 were investigated (Figure 3). Each suture was measured from different sections with a slice interval of 0.050 mm in the InVivo6® software, based on the methods of previous studies.[8,11]

The widths of the frontonasal suture (FN), frontomaxillary suture (FM), nasomaxillary suture (NM), frontozygomatic suture (FZ), and zygomaticomaxillary suture (ZM) were measured in coronal sections (Figure

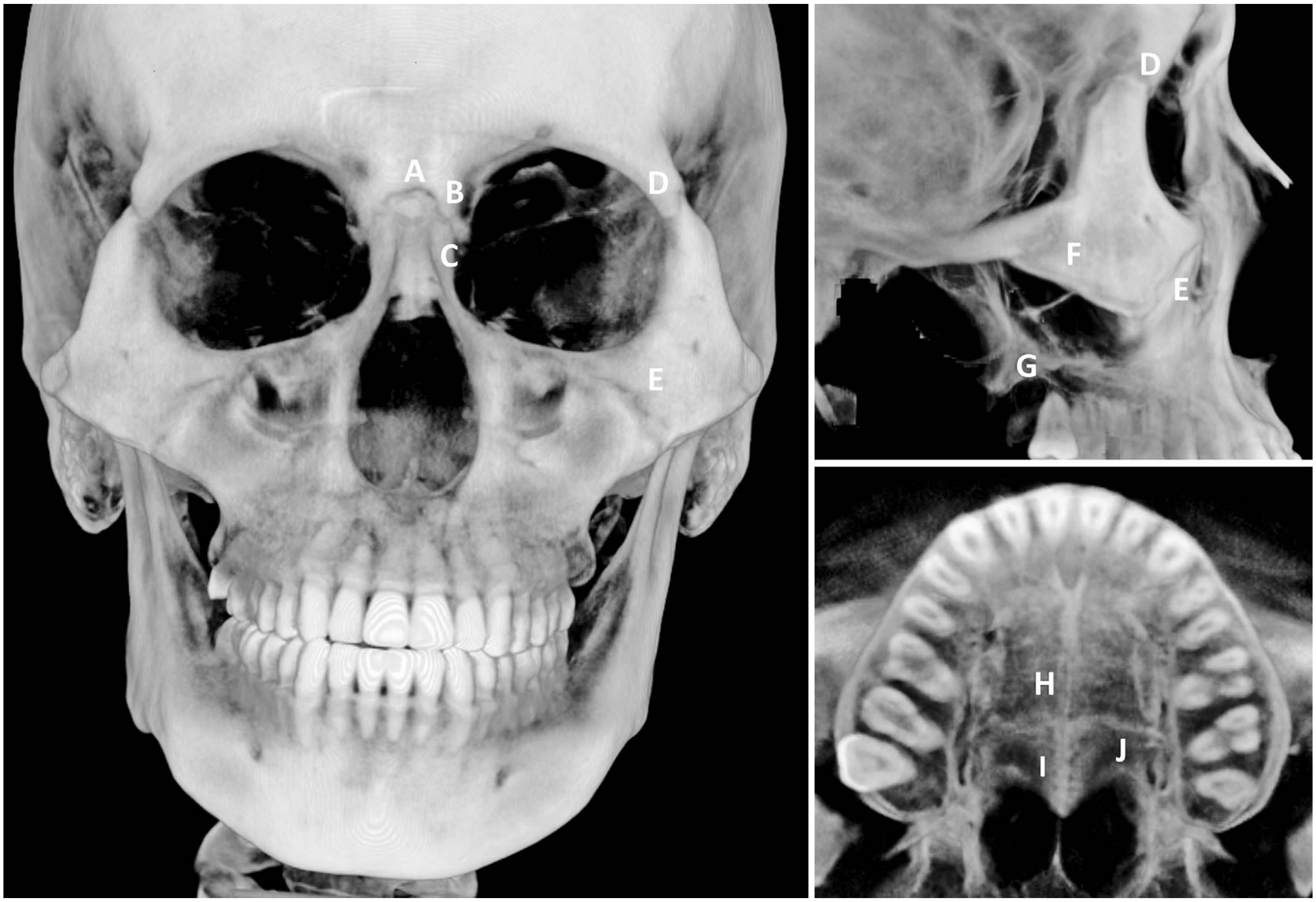

Figure 3. Volume rendering image of the skull showing the circummaxillary sutures evaluated. (A) Frontonasal. (B) Frontomaxillary. (C) Nasomaxillary. (D) Frontozygomatic. (E) Zygomaticomaxillary. (F) Zygomaticotemporal. (G) Pterygomaxillary. (H) Midpalatal. (I) Interpalatine. (J) Transverse palatine.

4). Since the sutures exist bilaterally, the mean was determined after measuring both sides. The slice section that showed the greatest width on each side was chosen, and the minimum distance between the bony edges was measured.

The width of the zygomaticotemporal suture (ZT), midpalatal suture (MP), interpalatine suture (IP), and transverse palatine suture (TP) were measured in axial sections (Figure 4). ZT was measured bilaterally, and the mean value was used.

Sagittal sections were used to measure the width of the pterygomaxillary suture (PM) (Figure 4) and the palate length. PM was measured on both sides, and the mean value was used. Palate length was defined as the distance between the anterior nasal spine (ANS) and the posterior nasal spine (PNS).

In the separation group, to evaluate the difference in efficiency of MARPE expansion, the correlation between maxilla expansion ratio and the width of circummaxillary sutures was further investigated.[4] Maxilla expansion width was defined as the difference of interjugular width measured from the frontal view between T0 and T1.[12] Jackscrew expansion width was measured by the number of turns recorded in the dental record.[5] Maxilla expansion ratio was defined as the ratio between the amount of jackscrew expansion width and maxilla expansion width.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows (version 26.0; IBM Corp, Armonk, NY). A 95% confidence level ($P < .05$) was considered statistically significant. All linear measurements were repeated after a 2-week interval for 20% of the subjects randomly selected to evaluate intraexaminer reliability. Intraclass correlation coefficient (ICC) values ranged from 0.755 to 0.967; the first data set was used in the study.

The minimum sample size to determine correlations between maxilla expansion ratio and suture widths was 13 by power analysis (G*Power, version 3.1.9.7; Düsseldorf, Germany) using a two-tailed significance

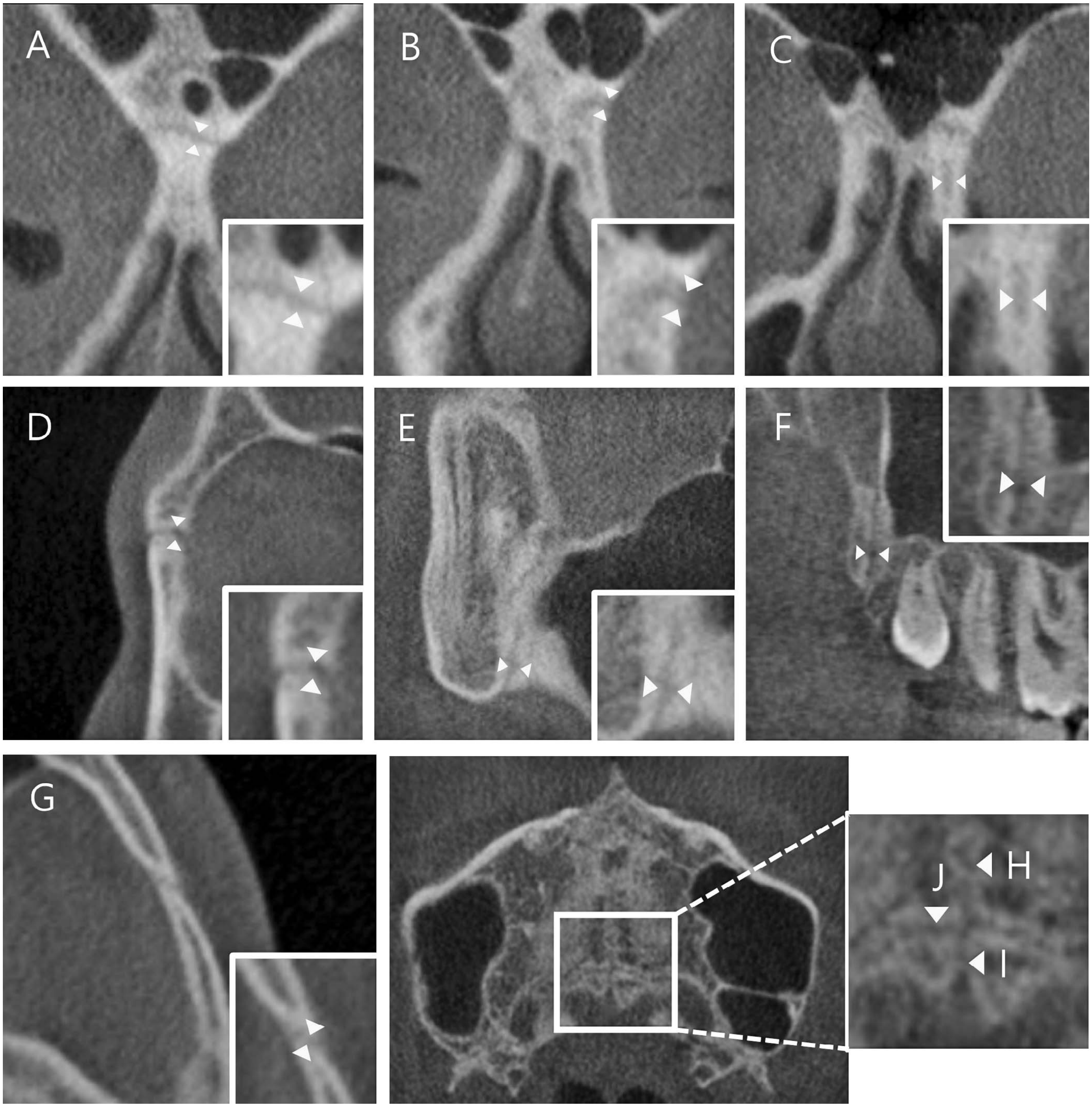

Figure 4. Sections of CBCT images showing the width of circummaxillary sutures. (A–E) Coronal sections: (A) Frontonasal; (B) Frontomaxillary; (C) Nasomaxillary; (D) Frontozygomatic; (E) Zygomaticomaxillary; (F) Pterygomaxillary, sagittal section. (G–J) Axial sections: (G) Zygomaticotemporal; (H) Midpalatal; (I) Interpalatine; (J) Transverse palatine. The arrows indicate the bony edges of the suture that show the greatest width.

level of .05, with a power of 80% and an effect size of 0.7.

The Shapiro-Wilk test was used to verify the normality of each subgroup. Independent *t*-tests or Mann-Whitney *U*-tests were used to compare the mean values between the separation and nonseparation groups. The comparison of the number of subjects in each skeletal classification (horizontal and vertical) was validated using a linear-by-linear association test. Pearson's correlation analysis was used to identify the correlations between maxilla expansion ratio and width of the circummaxillary sutures. Lastly, a simple regression model was developed on sutures that showed statistically significant correlation with maxilla expansion ratio.

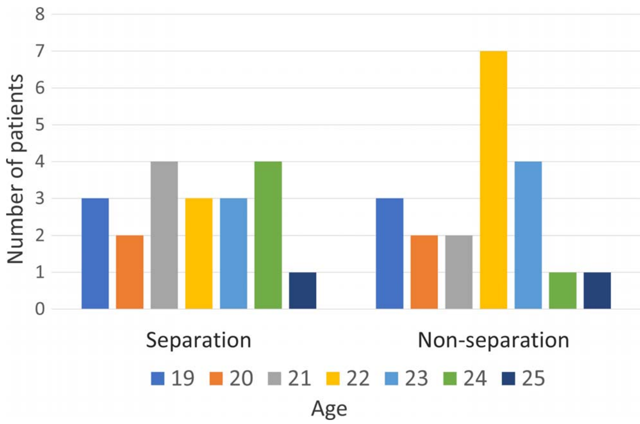

Figure 5. Age distribution of the subjects.

RESULTS

The age distribution of the subjects is shown in Figure 5. Descriptive statistics and comparison between the mean values of the separation and nonseparation groups are listed in Table 1. There were no significant differences in age, vertical skeletal pattern, horizontal skeletal classification, and palate length.

Table 2 shows the difference in circummaxillary suture widths between the two groups. ZM, PM, MP, and TP showed significant differences. In particular, ZM ($P < .001$) and PM ($P = .005$) showed highly significant differences, with the separation group showing a greater width than the nonseparation group at T0. ZM had the greatest difference in widths between the two groups ($\Delta = 0.36$ mm). The other sutures did not show a significant difference, but mean values were higher in the separation group, except for FZ and NM.

Of the 20 separation group subjects, four lacked T1 CBCT data. Therefore, for the remaining subjects, the correlation between maxilla expansion ratio and circummaxillary suture widths was further investigated. ZM ($r = .724$, $P = .002$) and PM ($r = .828$, $P < .001$) showed significant positive correlation with maxilla expansion ratio (Table 3), indicating that the wider the suture at T0, the greater the maxilla expansion ratio at T1. Figure 6 shows the scatterplots and best-fit lines of ZM and PM from simple linear regression analysis. The regression equations were as follows: maxilla expansion ratio $= 0.332 \times$ ZM $+ 0.121$ ($R^2 = 0.524$, $P < .01$); maxilla expansion ratio $= 0.442 \times$ PM $+ 0.061$ ($R^2 = 0.686$, $P < .001$).

Table 1. General Characteristics and Comparison Between Separation and Nonseparation Groups[a]

Characteristic	Separation	Nonseparation	*P* Value[b]
No. of Subjects	20	20	
Age, y (mean ± SD)	21.9 ± 1.9	21.7 ± 1.7	.790
Vertical skeletal pattern			
Low	1	1	.596
Normal	6	8	
High	13	11	
SN-MP, ° (mean ± SD)	38.11 ± 1.58	37.12 ± 1.02	.583
Skeletal classification			
Class I	4	5	.707
Class II	3	3	
Class III	13	12	
ANB, ° (mean ± SD)	−1.31 ± 1.17	0.35 ± 0.64	.220
Palate length, mm (mean ± SD)	51.77 ± 3.41	51.33 ± 2.37	.634

[a] SN-MP indicates sella-nasion to mandibular plane; ANB, A point–nasion–B point. Vertical skeletal pattern of the subjects was classified according to SN-MP angle, as follows: low = <27°; normal = 27–37°; and high = >37°. Skeletal classification was classified according to ANB angle, as follows: Class I, 0–4°; Class II, >4°; and Class III, <0°.

[b] Independent *t*-test was performed to compare the mean values. Linear-by-linear association test was performed to compare the number of subjects.

Table 2. Comparison of Circummaxillary Suture Widths Before MARPE (T0) Between Separation and Nonseparation Groups[a]

	Separation		Nonseparation		
Variables (mm)	Mean	SD	Mean	SD	*P* Value[b]
Frontonasal	0.86	0.1	0.77	0.1	.583
Frontomaxillary	0.95	0.12	0.95	0.07	.547
Nasomaxillary	0.51	0.24	0.67	0.34	.108
Frontozygomatic	0.94	0.05	1.03	0.06	.243
Zygomaticomaxillary	0.63	0.21	0.27	0.17	<.001***
Zygomaticotemporal	0.47	0.07	0.32	0.06	.090
Pterygomaxillary	0.59	0.19	0.41	0.19	.005**
Midpalatal	0.36	0.19	0.22	0.21	.030*
Interpalatine	0.38	0.29	0.23	0.22	.096
Transverse palatine	0.49	0.16	0.29	0.26	.011*

[a] SD indicates standard deviation.

[b] Independent *t*-test or Mann-Whitney *U*-test was performed.

* $P < .05$; ** $P < .01$; *** $P < .001$.

Table 3. Correlations Between Maxilla Expansion Ratio and Circummaxillary Suture Widths[a]

	Expansion Ratio	
Variables	*r*	*P* Value
Frontonasal	0.457	.065
Frontomaxillary	0.194	.471
Nasomaxillary	0.516	.068
Frontozygomatic	0.231	.390
Zygomaticomaxillary	0.724	.002**
Zygomaticotemporal	−0.216	.422
Pterygomaxillary	0.828	<.001***
Midpalatal	0.185	.494
Interpalatine	0.49	.054
Transverse palatine	−0.259	.332

[a] Pearson's correlation analysis was performed prior to assessment of normality by Shapiro-Wilk test. Expansion ratio refers to the maxilla expansion ratio.

** $P < .01$; *** $P < .001$.

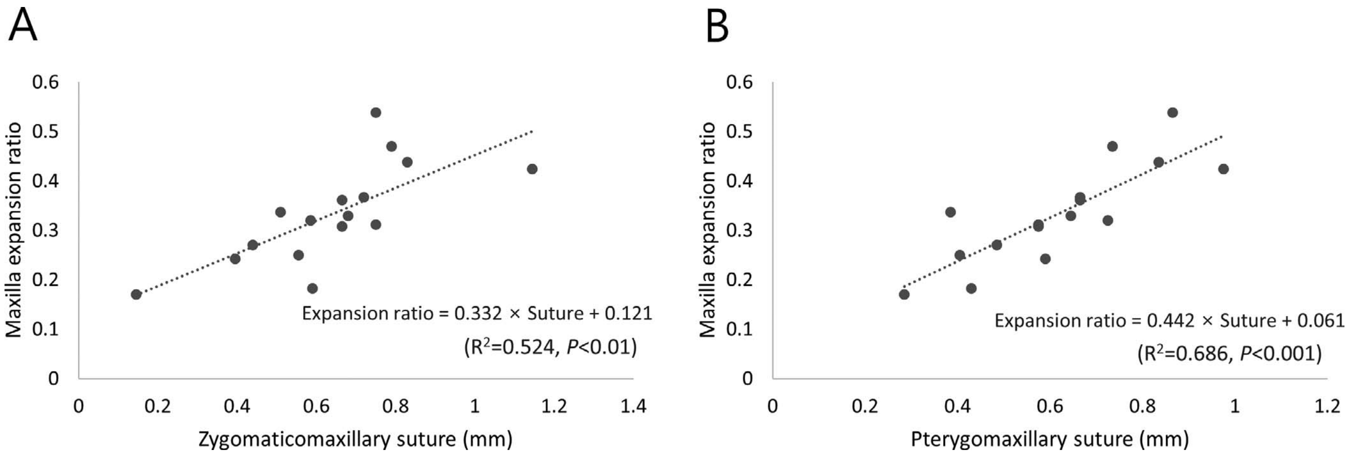

Figure 6. Correlations between maxilla expansion ratio and zygomaticomaxillary (A) and pterygomaxillary suture (B). Best-fit lines with determinant coefficient; R^2 from simple linear regression analysis.

DISCUSSION

The present study showed that in adult male patients, the greater the width of circummaxillary sutures before expansion, the better the chance of successful suture separation and the greater the maxillary basal bone expansion.

Even though circummaxillary sutures are known to provide major resistance to maxillary expansion,[8,13] previous studies[2,3,5,6] that investigated factors related to MARPE success generally concentrated on only MP itself. Specifically, MP maturation staging has been proposed[2,3,5] as a potential factor; however, Isfeld et al.[14] showed that suture staging is nonintuitive, with slight to poor interexaminer agreement. Therefore, this factor was not included in the current study.

Generally, chronological age and sex seem to be important factors. A recent retrospective study[4] of 215 subjects suggested that in the age subgroup of 21 to 25 years, males were more likely to fail in MARPE. Males tend to have higher bone density and content after puberty,[15] which can lead to differences in skeletal elasticity or stiffness. Therefore, to exclude diverse sex-related endocrine factors, only males were included as subjects in this study. However, even in males of similar ages using the same MARPE appliance, there are patients who differ in success in clinical settings. Therefore, it is reasonable to assume that there are other underlying host factors that affect MARPE success.

Age between the separation and nonseparation groups showed no significant difference (21.9 $\pm$ 1.9 and 21.7 $\pm$ 1.7 years, respectively; Table 1), so it was verified that age was controlled. There was also no significant difference in vertical and horizontal skeletal relationships, nor was there a significant different in palate length, between the two groups, implying that these factors were not the reason for the difference in MARPE outcomes.

In this study, ZM, PM, MP, and TP showed significantly greater widths in the separation group (Table 2). A greater width before expansion can imply less resistance.[9] Out of the four sutures, ZM showed the greatest difference ($\Delta = 0.36$ mm), followed by PM ($\Delta = 0.18$ mm), implying greatest difference in resistance between the two groups. Cho et al.[7] and Ghoneima et al.[11] suggested that ZM and PM showed smaller changes in width than did other sutures after expansion, which indicated their higher resistance to expansion. Since the force of the MARPE appliance counteracts the existing anatomical resistance from the MP and circummaxillary sutures,[16] the greater the resistance on ZM and PM, the less the stress concentrated to MP itself, which leads to a lower success rate.

Even though other circummaxillary sutures did not show statistically significant differences, the mean values were generally higher in the separation group. When the sutures were viewed in the InVivo6® software, subjects in the separation group generally showed more clearly visible sutures (Figure 7), which might have contributed to successful expansion.

Even if the MP succeeds in separation, if the maxillary expansion ratio was low, there would be fewer clinical benefits. A greater ZM and, especially, PM width, led to an increased maxillary expansion ratio (Table 3; Figure 6). After suture separation, the lateral and medial pterygoid plates, which form PM, still act as a form of resistance to maxilla expansion. MARPE is proposed[16,17] to induce more horizontal translation of the maxilla than RPE. To gain more parallel expansion, it is necessary to disarticulate the PM. Cantarella et al.[17] concluded that MARPE could tear the PM. If the resistance of PM is low, it can be implied that a higher

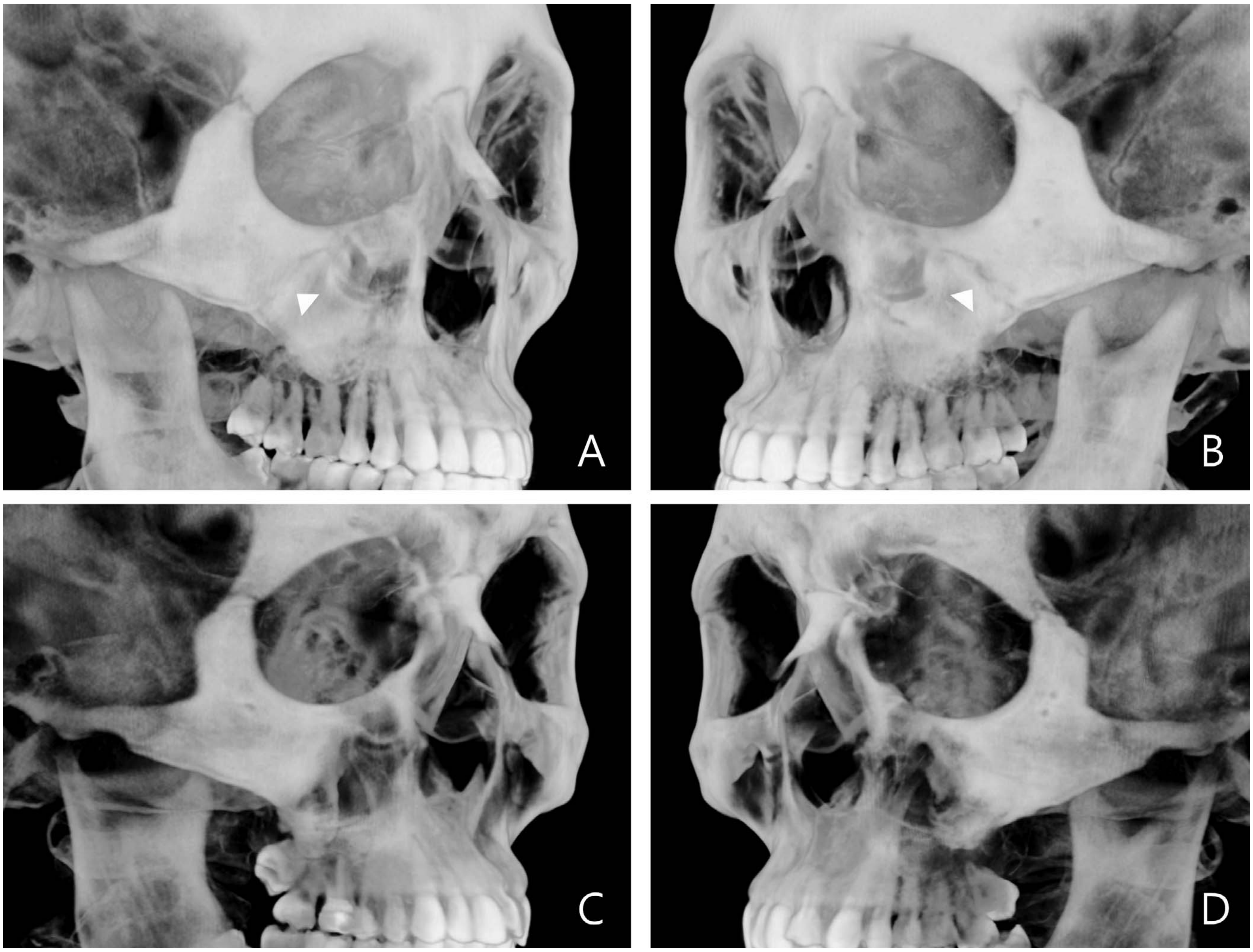

Figure 7. Circummaxillary sutures in volume rendering images of two patients before MARPE expansion. (A, B) A 23-year-old male patient (patient 1). (C, D) A 20-year-old male patient (patient 2). MP separation was successful in patient 1 but failed in patient 2. Although patient 1 was older than patient 2, circummaxillary sutures are generally more clearly visible, especially the ZM (arrows). In patient 2, the ZM is narrow.

maxillary expansion ratio can be achieved. From this point, a larger PM width can also imply less PM resistance and an improved chance of maxillary expansion.

There were a few limitations to this study. Histomorphologic analysis of the sutures would have been more accurate than CBCT.[18] However, since the present study was conducted on living patients, sutural width was evaluated with CBCT. ICC value was relatively low for sutures such as NM (0.755) compared to ZM (0.967) or PM (0.924); therefore, measuring widths of some sutures by CBCT might be relatively ambiguous. Nevertheless, the results of this study can help clinicians gain a better understanding of the factors responsible for successful MARPE expansion, one of which seems to be ZM and PM in young adult males. To generalize the results, a further prospective study with a larger sample size is needed.

CONCLUSIONS

- Male adult patients treated with MARPE who succeeded in MP separation showed a greater width of ZM, PM, MP, and TP before expansion.
- Greater ZM and PM widths before MARPE expansion resulted in more maxillary expansion.

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