ORIGINAL ARTICLE

Relationship between vertical skeletal pattern and success rate of orthodontic mini-implants

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Introduction: The objective of this research was to determine which clinical and skeletal factors are related to the success rate of orthodontic mini-implants in the maxillary and mandibular posterior buccal areas. **Methods:** A total of 778 orthodontic mini-implants (Dual-Top Anchor System, Jeil Medical, Seoul, Korea; 1.6 mm diameter, 8 mm length, cylinder shape, self-drilling type) in 306 patients were retrospectively examined. The success rate was calculated according to clinical variables (sex, age, soft-tissue management, placement position, sagittal skeletal classification, arch-length discrepancy, and side) and skeletal variables (articular angle, mandibular plane to palatal plane angle, Frankfort-mandibular plane angle, mandibular plane angle, gonial angle, upper gonial angle, and lower gonial angle). Analysis of variance (ANOVA), chi-square tests, and multiple logistic regression analysis were used for statistical analysis. **Results:** The overall success rate was 79.0%. Almost 80% of the failures occurred within the first 4 months. The clinical variables sex, age, soft-tissue management, sagittal skeletal classification, arch-length discrepancy, and side did not show significant differences in the success rate. Although the success rates were significantly different according to placement position ($P < 0.01$), there was no significant difference in the odds ratios among placement positions. In the skeletal variables, average upper gonial angle (84.2%) had a significantly higher success rate than low (75.7%) and high (71.2%) upper gonial angles ($P < 0.01$). High Frankfort-mandibular plane angle ($P < 0.05$) and low upper gonial angle groups ($P < 0.05$) showed significant lower odds ratios than did the other types. **Conclusions:** Vertical skeletal pattern might be an important factor for the success of orthodontic mini-implants placed in posterior buccal areas. (Am J Orthod Dentofacial Orthop 2010;138:51-7)

Anchorage reinforcement is an important issue in orthodontic treatment. The orthodontic mini-implant (OMI; also called temporary anchorage device) has been popularized because of its simplicity of placement and removal, low cost, and noncompliance from patients.[1-6]

Recently, several studies have been done to determine factors that could be related to the success rates of OMIs.[7-13]

Park et al[10] suggested that inflammation around the OMI, especially on the right side of the mandible, must be controlled to minimize the failure of the OMI. However, Moon et al[13] reported that sex, age, jaw, soft-tissue management, and placement side might not be important factors in success rate of OMIs, but placement position could be. Kuroda et al[12] insisted that the proximity of an OMI to the root was a major risk factor for the failure of the OMI, especially in the mandible.

Miyawaki et al[8] suggested that an OMI diameter of 1.0 mm or less, inflammation of the peri-OMI tissue, and a high mandibular plane angle (ie, thin cortical bone) were associated with failure of OMIs placed in buccal alveolar bone of the posterior region for orthodontic anchorage. However, Kuroda et al[11] found no significant correlation between success rate and age, sex, mandibular plane angle, anteroposterior jaw-base relationship, control of periodontitis, temporomandibular disorder symptoms, loading, and screw length.

Thickness and density of the cortical bone and the facial skeletal pattern are known to have a close relationship.[14-17] Because characteristics of the cortical bone seem to be an important factor in the stability of OMIs, the relationship between the success rate of OMIs and facial skeletal patterns needs to be studied.

However, there has been controversy about the role of placement position and skeletal pattern, especially in the vertical aspect, in the stability of OMIs.[8,11] Therefore, the purpose of this study was to determine

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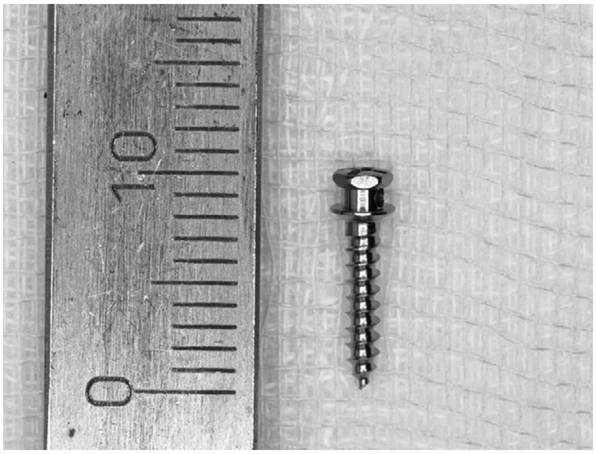

Fig 1. The OMI used in this study.

Fig 2. OMIs placed in the posterior buccal areas for anchorage reinforcement.

which clinical and skeletal variables are related to the success rate of OMIs placed in the maxillary and mandibular posterior buccal areas. The null hypothesis was that there was no difference in the success rate of OMIs according to placement position and vertical skeletal pattern.

MATERIAL AND METHODS

The samples in this retrospective study consisted of 778 OMIs (Dual-Top Anchor System, Jeil Medical, Seoul, Korea; 1.6 mm diameter, 8 mm length, self-drilling type; Fig 1) in 306 patients (110 male, 196 female) treated in the Department of Orthodontics at Gachon Dental Hospital, Inchon, Korea. The OMIs were placed in the maxillary and mandibular posterior buccal areas (427 OMIs in 155 extraction patients and 351 OMIs in 151 nonextraction patients) for anchorage reinforcement between January 2003 and November 2006. Before placement of the OMIs, informed consent about the purposes, advantages, disadvantages, and possibility of dislodgement was obtained from the patients or parents.

The OMIs were placed at the attached gingiva just adjacent to the mucogingival junction (Fig 2) with a 70° to 80° angle to the long axis of the teeth (Fig 3). Placement of the OMIs was done by 4 clinicians and checked by a supervisor (C.H.M.). To reduce the possibility of failure and give enough experience for OMI placement, the first 10 OMIs of each clinician were not included in this study.

Orthodontic loading (150-200 g) was applied to the OMIs 2 to 3 weeks after placement by using elastomerics (Energy chain, Rocky Mountain Orthodontics, Denver, Colo) or nickel-titanium closed coil springs (Super-elastic Coil Springs, yellow, Tomy, Tokyo, Japan). The OMI was judged a success when orthodontic force could be applied for at least 10 months without pain or clinically detectable mobility, or its purpose was accomplished.

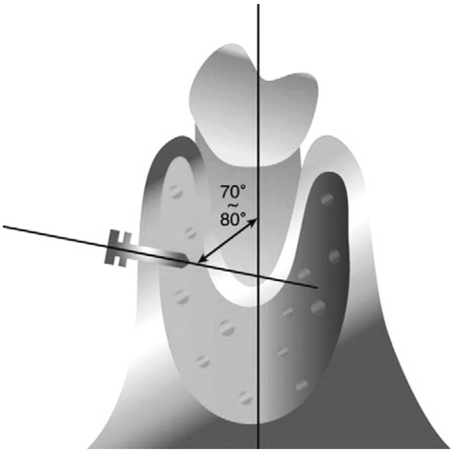

Fig 3. The OMI was placed with 70° to 80° angle to the long axis of tooth.

To analyze the effect of clinical variables such as patients' sex and age, soft-tissue management, placement position, sagittal skeletal classification, arch-length discrepancy, and placement side on the success rate of the OMIs, the samples were divided as follows.

1. According to sex: male (n =110, 257 OMIs) and female (n = 196, 521 OMIs).
2. According to age: teenagers (n = 168; mean age, 14.45 ± 2.65 years; range, 10-19 years; 422 OMIs), twenties (n = 114; mean age, 23.73 ± 2.70 years; range, 20-29 years; 301 OMIs), and

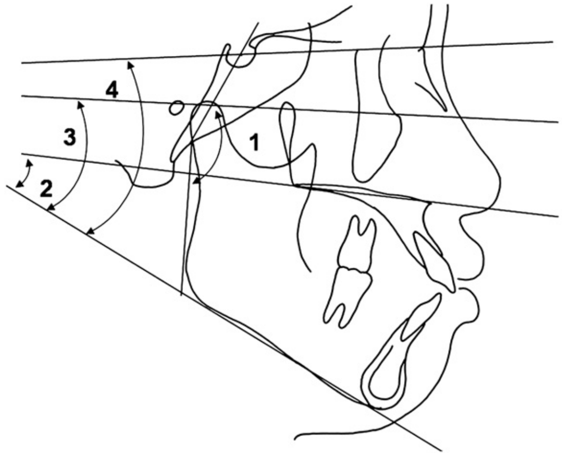

Fig 4. Skeletal variables: *1*, articular angle (S-Ar-Go; low, <141°; average, ≥141° to <151°; high, ≥151°); *2*, mandibular plane to palatal plane angle (Go-Me to ANS-PNS; low, <19°; average, ≥19° to <29°; high, ≥29°); *3*, Frankfort-mandibular plane angle (Po-Or to Go-Me; low, <20°; average, ≥20° to <30°; high, ≥30°); *4*, mandibular plane angle (S-N to Go-Me; low, <29°; average, ≥29° to <39°; high, ≥39°); *5*, gonial angle (Ar-Go-Me; low, <118°; average, ≥118° to <128°; high, ≥128°); *6*, upper gonial angle (Ar-Go-Na; low, <44°; average, ≥44° to <50°; high, ≥50°); *7*, lower gonial angle (Na-Go-Me; low, <71°; average, ≥71° to <81°; high, ≥81°).

adults (n = 24; mean age, 37.04 ± 7.26 years; range, 30-55 years, 55 OMIs).

3. According to soft-tissue management: incision group (cross-shaped stab incision [3-4 mm], reflection of the gingival flaps, placement of the OMI [soft tissue was not sutured]) and nonincision group (the OMI was placed without a soft-tissue incision).
4. According to placement position: U1 (between the maxillary first and second premolars), U2 (between the maxillary second premolar and first molar), U3 (between the maxillary first and second molars), L1 (between the mandibular first and second premolars), L2 (between the mandibular second premolar and first molar), and L3 (between the mandibular first and second molars).
5. According to sagittal skeletal classification: Class I malocclusion (0°<ANB<4°), Class II malocclusion (ANB, ≥4°), and Class III malocclusion (ANB, ≤0°).
6. According to arch-length discrepancy: crowding (<–2 mm), normal (≥–2 to <2 mm), and spacing (>2 mm).
7. According to placement side: right and left.

The skeletal variables such as articular angle, mandibular plane to palatal plane angle, Frankfort-mandibular plane angle, mandibular plane angle, gonial angle, upper gonial angle, and lower gonial angle were measured from the lateral cephalograms at pretreatment (Fig 4). According to Korean norms, each variable was divided into 3 groups: low, average, and high (Fig 4).[18]

Statistical analysis

Analysis of variance (ANOVA), chi-square tests, and multiple logistic regression analysis were used to estimate differences in the success rates and odds ratios of the OMIs according to the clinical and skeletal variables.

RESULTS

The overall success rate was 79.0% with a mean period of 12.21 ± 7.88 months (Table I). The mean period of the failed OMIs was 1.84 ± 2.09 months (Table I). Dislodgement of OMIs occurred most frequently in the first month (32.5%), and 80% of failures occurred within the first 4 months (Table II).

In the clinical variables, age had a marginal significance on the success rate ($P = 0.055$, Table III). Teenagers (76.1%) had a relatively lower success rate than did the twenties (81.7%) and adults (87.3%) (Table III). There was a significant difference in the success rates according to placement position ($P < 0.05$, Table III). The areas between the mandibular second premolar and first molar, and the mandibular first and second molars showed lower success rate than other areas (Table III). However, there were no significant differences in the success rates according to the patients' sex, soft-tissue management, arch-length discrepancy, sagittal skeletal classification, and placement side (Table III). In addition, age, sex, soft-tissue management, placement position, arch-length

Table I. Distribution of the OMIs according to success and failure

	Number of OMIs (percentage)	Duration	
		Mean (mo)	SD (mo)
Success	615 (79.0%)	12.21	7.88
Failure	163 (21.0%)	1.84	2.09

Table II. Distribution of the durations of OMI failures

Duration (mo)	Number of OMIs	Percentage (%)	Cumulative percentage (%)
<1	53	32.5	32.5
≥1, <2	44	27	59.5
≥2, <3	22	13.5	73.0
≥3, <4	12	7.4	80.4
≥4, <5	9	5.5	85.9
≥5, <6	7	4.2	90.2
≥6, <7	10	6.1	96.3
≥7, <8	4	2.5	98.8
≥8, <9	1	0.6	99.4
9	1	0.6	100
Total	163	100.0	100

discrepancy, sagittal skeletal classification, and placement side had no significant differences in the odds ratios of success rates (Table IV).

In the skeletal variables, there was no significant difference in the success rate according to upper gonial angle (P <0.01, Table V). Average upper gonial angle (84.2%) had a higher success rate than low (75.7%) and high (71.2%) upper gonial angles (Table V). Multiple logistic regression analysis showed that the subjects with a high Frankfort-mandibular plane angle were likely to have a 20% success rate compared with subjects with a low Frankfort-mandibular plane angle (P <0.05, Table VI), and subjects with an average upper gonial angle had almost a 2-times higher success rate than those with a low upper gonial angle (P <0.05, Table VI).

DISCUSSION

To estimate the success rate of OMIs objectively, we confined the sample to the same type of OMIs from 1 manufacturer. Our overall success rate was 79.0%, and almost 80% of failures occurred within the first 4 months (Tables I and II). Therefore, if an OMI withstands more than 4 months of force application, it will have a greater chance of success. The average time to failure was 1.84 months (Tables I and II); this was shorter than the 3.40 months in the study of Park et al.[10]

In this study, sex was not related to the success rate (Tables III and IV); this agrees with the results of Miyawaki et al,[8] Park et al,[10] and Kuroda et al.[11]

Although there was a marginal difference in the success rates between age groups (P = 0.055), age was not significantly related to the clinical success of OMIs (Tables III and IV). This agrees with the results of Miyawaki et al[8] that there was no significant difference in the success rates of the under-20, 20-to-30, and over-30 age groups. However, Motoyoshi et al[19] insisted that the success rate of the early-loaded group of adolescents was significantly lower to that of the adults. This is similar to the results of our study: the success rate of the teenagers (76.1%) was lower than that of the adults (87.3%) (Table III). Motoyoshi et al[19] also reported that a latent period of 3 months before loading is recommended to improve the success rate of OMIs placed in alveolar bones in adolescent patients. In our study, a 2-to-3 week latent period was used.

Our finding of no significant difference in the success rates between the right and left sides (Tables III and IV) does not agree with the results of Park et al,[10] who reported that the right side had a significantly lower success rate than the left side because of oral hygiene. If the OMIs were placed according to the proper protocol, and oral hygiene was good, the chance of soft-tissue inflammation around the OMI could be decreased. Therefore, there would be no difference in the success rate according to the side.

Soft-tissue impingement during placement of the OMI could be a cause of failure.[10] On the contrary, Miyawaki et al[8] reported that the nonincision group had greater OMI success than did the incision group. In our study, the success rate of the incision group was similar to that of the nonincision group (Tables III and IV). Therefore, soft-tissue management might not be a significant factor for OMI success.

Different success rates have been reported according to placement position of OMIs in several studies.[8,11,13] Miyawaki et al[8] reported no difference in the success rates according to placement position. However, Kuroda et al[11] insisted that the areas between the first and second premolars had higher success rates than the areas between the first and second molars. This agrees with our results, which showed that the area between the mandibular first and second premolars had the highest success rate (89.0%), and the area between the mandibular first and second molars had the lowest rate (69.1%) (Table III). Although there was a significant difference in the success rates according to placement position (P <0.05, Table III), multiple

Table III. Comparisons of success rates according to the clinical variables

Clinical variable		Success rate (%)	Number of OMIs	P value
Age	Teenagers	76.1	321	0.055
	Twenties	81.7	246	
	Adults	87.3	48	
Soft-tissue management	Incision	79.5	171	0.837
	Nonincision	78.9	444	
Sex	Male	78.2	201	0.708
	Female	79.5	414	
Placement position	U1	84.5	71	0.012*
	U2	79.6	191	
	U3	79.8	83	
	L1	89.0	89	
	L2	73.3	143	
	L3	69.1	38	
Arch-length discrepancy	Crowding	80.9	428	0.125
	Normal	76.7	125	
	Spacing	72.1	62	
Sagittal skeletal classification	Class I	78.8	331	0.945
	Class II	78.7	129	
	Class III	79.9	155	
Placement side	Left	80.0	264	0.594
	Right	78.3	351	

Chi-square test: *$P < 0.05$.
Age: *teenagers*, <20 years; *twenties*, 20-29 years; *adults*, ≥30 years.
Placement position: *U1*, between the maxillary first and second premolars; *U2*, between the maxillary second premolar and first molar; *U3*, between the maxillary first and second molars; *L1*, between the mandibular first and second premolars; *L2*, between the mandibular second premolar and first molar; *L3*, between the mandibular first and second molars.
Arch-length discrepancy: *crowding,* arch-length discrepancy less than –2 mm; *normal*, arch-length discrepancy between –2 and +2 mm; *spacing*, arch-length discrepancy more than 2 mm.
Sagittal skeletal classification: *Class I*, 0°<ANB<4°; *Class II*, ANB ≥4°; *Class III*, ANB ≤0°.

Table IV. Comparison of odds ratios according to the clinical variables

Clinical variable		Odds ratio	95% CI	P value
Age	Teenagers	Reference		
	Twenties	1.138	0.668-1.937	0.634
	Adults	2.431	0.843-7.008	0.100
Soft-tissue management	Incision	Reference		
	Nonincision	0.86	0.461-1.602	0.634
Sex	Male	Reference		
	Female	1.235	0.729-2.094	0.433
Placement position	U1	Reference		
	U2	0.802	0.378-1.702	0.565
	U3	0.716	0.303-1.694	0.447
	L1	1.791	0.692-4.638	0.230
	L2	0.582	0.274-1.236	0.159
	L3	0.528	0.206-1.356	0.185
Arch-length discrepancy	Crowding	Reference		
	Normal	0.64	0.389-1.054	0.079
	Spacing	0.725	0.385-1.367	0.320
Sagittal skeletal classification	Class I	Reference		
	Class II	1.071	0.621-1.848	0.804
	Class III	0.905	0.513-1.595	0.730
Placement side	Left	Reference		
	Right	0.924	0.533-1.602	0.778

Multiple logistic regression analysis was done.
Age: *teenagers*, <20 years; *twenties*, 20-29 years; *adults*, ≥30 years.
Placement position: *U1*, between the maxillary first and second premolars; *U2*, between the maxillary second premolar and first molar; *U3*, between the maxillary first and second molars; *L1*, between the mandibular first and second premolars; *L2*, between the mandibular second premolar and first molar; *L3*, between the mandibular first and second molars.
Arch-length discrepancy: *crowding,* arch-length discrepancy less than –2 mm; *normal*, arch-length discrepancy between –2 and +2 mm; *spacing*, arch-length discrepancy more than 2 mm.
Sagittal skeletal classification: *Class I*, 0°<ANB<4°; *Class II*, ANB ≥4°; *Class III*, ANB ≤0°.

logistic regression analysis did not show a significant difference in the odds ratios (Table IV). Therefore, more studies are needed concerning the effect of placement position on OMI success.

There was no significant difference in success rates according to arch-length discrepancy (Tables III and IV). This result agrees with the results of Miyawaki et al.[8] However, when considering that the proximity of an OMI to the root is a major risk factor for failure,[12] it seems logical that the area between the first and second premolars, where the bone is most abundant, had the highest success rates in the maxillary and mandibular posterior buccal areas (Table III).[20]

The anteroposterior jaw-base relationship did not show a significant difference in success rates in this study (Tables III and IV). This agreed with the studies of Miyawaki et al[8] and Kuroda et al.[11]

In terms of thickness and density of the cortical bone and facial skeletal pattern, there has been consensus that subjects with brachycephalic faces, with small gonial angles and mandibular plane angles, have thicker cortical bone than average- and long-faced groups.[14-16] Sato et al[17] reported that the density of cortical bone was higher in subjects with small Frankfort-mandibular plane angles and gonial angles. On the other hand, Miyawaki et al[8] reported that average and low mandibular plane angle groups had significantly higher success rates than the high mandibular plane angle group. However, Kuroda et al[11] insisted that there was no correlation between the success rate of OMIs and the mandibular plane angle; this agreed with our results.

The finding that low Frankfort-mandibular plane angles ($P < 0.05$, Table VI) and average upper gonial angles ($P < 0.05$, Table VI) had significantly higher success rates than other variables in this study means

Table V. Comparison of success rates according to the skeletal variables

Skeletal variable		*Success rate (%)*	*Successful OMIs (n)*	P *value*
Articular angle (°)	Low (<141)	78.5	62	0.691
	Average (≥141 to <151)	77.9	304	
	High (≥151)	80.6	249	
Mandibular plane to palatal plane angle (°)	Low (<19)	74.4	32	0.286
	Average (≥19 to <29)	77.5	324	
	High (≥29)	81.7	259	
Frankfort-mandibular plane angle (°)	Low (<20)	75.9	22	0.392
	Average (≥20 to <30)	81.1	297	
	High (≥30)	77.3	296	
Mandibular plane angle (°)	Low (<29)	73.2	52	0.245
	Average (≥29 to <39)	81.0	353	
	High (≥39)	77.5	210	
Gonial angle (°)	Low (<118)	74.5	120	0.207
	Average (≥118 to <128)	80.9	398	
	High (≥128)	77.6	97	
Upper gonial angle (°)	Low (<44)	75.7	227	0.002*
	Average (≥44 to <50)	84.2	309	
	High (≥50)	71.2	79	
Lower gonial angle (°)	Low (<71)	75.9	41	0.761
	Average (≥71 to <81)	79.9	318	
	High (≥81)	78.5	256	

Chi square test: *$P<0.01$.

Table VI. Comparison of odds ratios according to the skeletal variables

Skeletal variable		*Odds ratio*	*95% CI*	P *value*
Articular angle (°)	Low (<141)	Reference		
	Average (≥141 to <151)	0.577	0.269-1.239	0.159
	High (≥151)	1.265	0.524-3.05	0.601
Mandibular plane to palatal plane angle (°)	Low (<19)	Reference		
	Average (≥19 to <29)	0.981	0.351-2.737	0.970
	High (≥29)	1.788	0.572-5.588	0.317
Frankfort-mandibular plane angle (°)	Low (<20)	Reference		
	Average (≥20 to <30)	0.608	0.137-2.7	0.513
	High (≥30)	0.167	0.032-0.883	0.035*
Mandibular plane angle (°)	Low (<29)	Reference		
	Average (≥29 to <39)	1.378	0.529-3.606	0.513
	High (≥39)	1.579	0.468-5.33	0.461
Gonial angle (°)	Low (<118)	Reference		
	Average (≥118 to <128)	1.657	0.825-3.332	0.156
	High (≥128)	2.378	0.796-7.106	0.121
Upper gonial angle (°)	Low (<44)	Reference		
	Average (≥44 to <50)	1.932	1.112-3.357	0.019*
	High (≥50)	0.852	0.37-1.962	0.706
Lower gonial angle (°)	Low (<71)	Reference		
	Average (≥71 to <81)	0.789	0.27-2.312	0.666
	High (≥81)	0.722	0.222-2.347	0.589

Multiple logistic regression analysis: *$P<0.05$.

that these 2 variables might be more important indicators than the mandibular plane angle. A person with a low upper gonial angle will have progressively less horizontal forward movement of the chin and vertical growth with clockwise rotation if the angle is about 40° to 44°.[21] A high Frankfort-mandibular plane angle is known to cause an open-bite tendency or vertical growth. Therefore, high Frankfort-mandibular plane angles and low upper gonial angles could be related to lower odds ratios. However, further studies are needed concerning the effects of the skeletal pattern on OMI success.

CONCLUSIONS

1. In clinical variables, sex, age, soft-tissue management, sagittal skeletal classification, arch-length discrepancy, and side were not related to the success rate of OMIs, but placement position might be.
2. In the skeletal variables, vertical pattern indicators such as Frankfort-mandibular plane angles and upper gonial angles might be important factors for the success rate of OMIs placed in posterior buccal areas.

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