Original Article

Comparison of arch width, alveolar width and buccolingual inclination of teeth between Class II division 1 malocclusion and Class I occlusion

Rui Shu[a]; Xianglong Han[b]; Yating Wang[a]; Hui Xu[a]; Dongqing Ai[c]; Lufei Wang[c]; Yeke Wu[c]; Ding Bai[d]

ABSTRACT

Objective: To compare the arch width, alveolar width, and buccolingual inclination of maxillary and mandibular posterior teeth between Class II division 1 malocclusion and Class I occlusion.

Materials and Methods: Forty-five subjects with Class I occlusion and 45 subjects with Class II division 1 malocclusion were selected to measure the maxillary and mandibular arch width and alveolar width of premolars and first molars with digital caliper. Buccolingual inclination of maxillary and mandibular premolars and first molars were measured with a modified universal bevel protractor.

Results: All of the posterior teeth in both groups were lingually tilted. The maxillary premolars and first molars were significantly more lingually tilted ($P < .05$) in Class II division 1 malocclusion than in Class I occlusion. Mandibular first premolars were significantly less lingually tilted in Class II division 1 malocclusion than in Class I occlusion. No significant difference of buccolingual inclination was found in mandibular second premolars and first molars between the two groups. No significant difference in maxillary and mandibular arch width and alveolar width was found between the two groups.

Conclusions: Buccolingual inclination rather than arch width and alveolar width plays an important role in transverse discrepancy of Class II division 1 malocclusion. (*Angle Orthod.* 2013;83:246–252.)

KEY WORDS: Class II division 1 malocclusion; Buccolingual inclination; Arch width; Alveolar width

INTRODUCTION

Class II division 1 malocclusion is one of the most common problems in orthodontic clinical practice.[1–4] In the past, orthodontists focused mostly on the sagittal relationship of Class II malocclusion. Today, more and more studies have been focused on the transverse discrepancy in Class II division 1 malocclusion, and the results have been controversial. Staley et al.,[5] Tollaro et al.,[6] and Sayin and Turkkahraman[4] proposed that Class II malocclusion had a narrower maxillary arch width than Class I or normal occlusion, but the arch is narrow at different posterior teeth positions in these studies. At the same time, Frohlich[7] compared 51 Class II malocclusion children with normal occlusion and found that there were no differences in maxillary arch width.

The alveolar bone width has also been studied and shows no difference between Class II division I malocclusion and Class I occlusion.[4,5,8,9] Andrews[10] has defined the term WALA ridge, which was considered to be the band of keratinized soft tissue directly adjacent to the mucogingival junction. Researchers[9,11,12] have identified that there was significant

[a] PhD candidate, Department of Orthodontics, West China Stomatology Hospital of Sichuan University, State Key Laboratory of Oral Diseases (Sichuan University), Chengdu, Sichuan, PR China.

[b] Lecturer, Department of Orthodontics, West China Stomatology Hospital of Sichuan University, State Key Laboratory of Oral Diseases (Sichuan University), Chengdu, Sichuan, PR China.

[c] Student, Department of Orthodontics, West China Stomatology Hospital of Sichuan University, State Key Laboratory of Oral Diseases (Sichuan University), Chengdu, Sichuan, PR China.

[d] Professor and Chair, State Key Laboratory of Oral Diseases (Sichuan University), Department of Orthodontics, West China Stomatology Hospital of Sichuan University Chengdu, Sichuan, PR China.

Corresponding author: Ding Bai, DDS, PhD, Professor and Chair, State Key Laboratory of Oral Diseases (Sichuan University), Department of Orthodontics, West China Stomatology Hospital of Sichuan University. 14#, 3rd section of Renmin South Road, Chengdu, Sichuan, PR China, 610041
(e-mail: baiding@scu.edu.cn)

Accepted: July 2012. Submitted: May 2012.
Published Online: September 4, 2012

relationship between the dental arch form and the WALA curve both in Class I occlusion and Class II division 1 malocclusion. In these studies, the WALA ridge was also considered as the mark of mandibular alveolar basal bone.

Two deficiencies exist in the previous studies. (1) Most of the studies concerning transverse problems with Class II division 1 malocclusion were limited to arch width and alveolar width, neglecting another important transverse problem, the buccolingual inclination of posterior teeth. Inclination, the term presented by Andrews,[13] was one of the six keys of normal occlusion. Studies showed that buccolingual inclination of posterior teeth was important not only to interdigitate occlusion, but also to frontal smile esthetics.[14,15] (2) Inclusion criteria of Class II division 1 in these studies did not consider the skeletal relationship. As transverse discrepancy in Class II malocclusion might be compensation to anteroposterior displacement of jaws,[5] the sagittal skeletal relationship should be considered in sample selection.

Thus, studies on the transverse discrepancy of Class II division 1 malocclusion, with selected samples according to both dental and skeletal relationships, are required. The aim of this research is to study whether there is transverse discrepancy in Class II division 1 malocclusion and the role arch width, alveolar width, and buccolingual inclination play in such a discrepancy. The null hypothesis is that there is no difference in arch width, alveolar width, and buccolingual inclination of posterior teeth between Class I occlusion and Class II division 1 malocclusion.

MATERIALS AND METHODS

Pretreatment lateral cephalometric radiographs and casts of 45 samples with Class II division 1 malocclusion (28 female and 17 male, average 15.6 $\pm$ 2.36 years old) and 45 samples with Class I occlusion (28 female and 17 male, average 16.2 $\pm$ 2.83 years old) were selected from the Department of Orthodontics, West China Stomatology College, Sichuan University. Paired *t*-test was applied to compare the sample ages between the two groups and showed that there was no difference. Ethical approval was obtained from every patient before making the primary casts and taking cephalometric radiographs. Ethical approval was also obtained from the university.

The inclusion criterion for Class II division 1 malocclusion was bilateral Class II molar relationship in centric occlusion with protrusive maxillary incisors. Class II molar relationship was determined by (1) whether the mesial cusps of bilateral maxillary first molars were mesial to the centric groove of the corresponding mandibular first molars; (2) Class II skeletal relationship with ANB angle $> 5^\circ$ in cephalometric analysis;[16] (3) patients without orthodontic, prosthodontic, or orthognathic treatment; (4) no crowding, crossbite, or scissor bite in the posterior teeth; (5) occlusion without missing teeth; (6) fully erupted first premolars, second premolars, and first molars; and (7) no abrasion or defect on the buccal surface of the premolars and first molars under the naked eye.

The inclusion criteria for Class I occlusion were (1) bilateral Class I molars and canines in centric occlusion relationship; (2) Class I skeletal relationship with $0^\circ <$ ANB angle $< 5^\circ$ in cephalometric analysis;[16] (3) patients without orthodontic, prosthodontic, or orthognathic treatment; (4) no crowding, crossbite, or scissor bite in the posterior teeth region; (5) no missing teeth; (6) fully erupted first premolars, second premolars, and first molars; and (7) no abrasion or defect on the buccal crown of premolars and first molars under the naked eye.

The samples we chose in this research were based on prior studies that the canine and molar arch width would not increase after age 13 years in girls and 16 in boys.[17–20]

All of the selected pretreatment study casts were duplicated with alginate and reperfused. The posterior occlusal plane (POP) was determined according to the methods introduced by Janson et al.[21] and Ross et al.[22] Briefly, a glass plane was seated on at least the three most prominent cusps in the first molar and premolar region. The cusp below could identify two points on the lateral wall of the casts by adjusting the direction of the glass plane. In the same way, one point on another side wall can be identified (Figure 1A). The bases of the casts were trimmed to the plane formed by the three points on the lateral wall, which was parallel to the POP (Figure 1B). The buccolingual inclination of posterior teeth measurement was the buccolingual angle between teeth and the POP. The facial axis of clinical crown (FACC) and its midpoint, the facial-axis point (FA point) point, were marked on the buccal surface as described by Andrews[13] and were used to measure the buccolingual inclination.

These measurements were taken from the trimmed casts:

- buccolingual inclination of bilateral maxillary and mandibular first molars;
- buccolingual inclination of bilateral maxillary and mandibular first and second premolars;
- intermolar width between the FA point of bilateral maxillary and mandibular first molars;
- first premolar width between the FA point of bilateral maxillary and mandibular first premolars;
- second premolar width between the FA point of bilateral maxillary and mandibular second premolars;

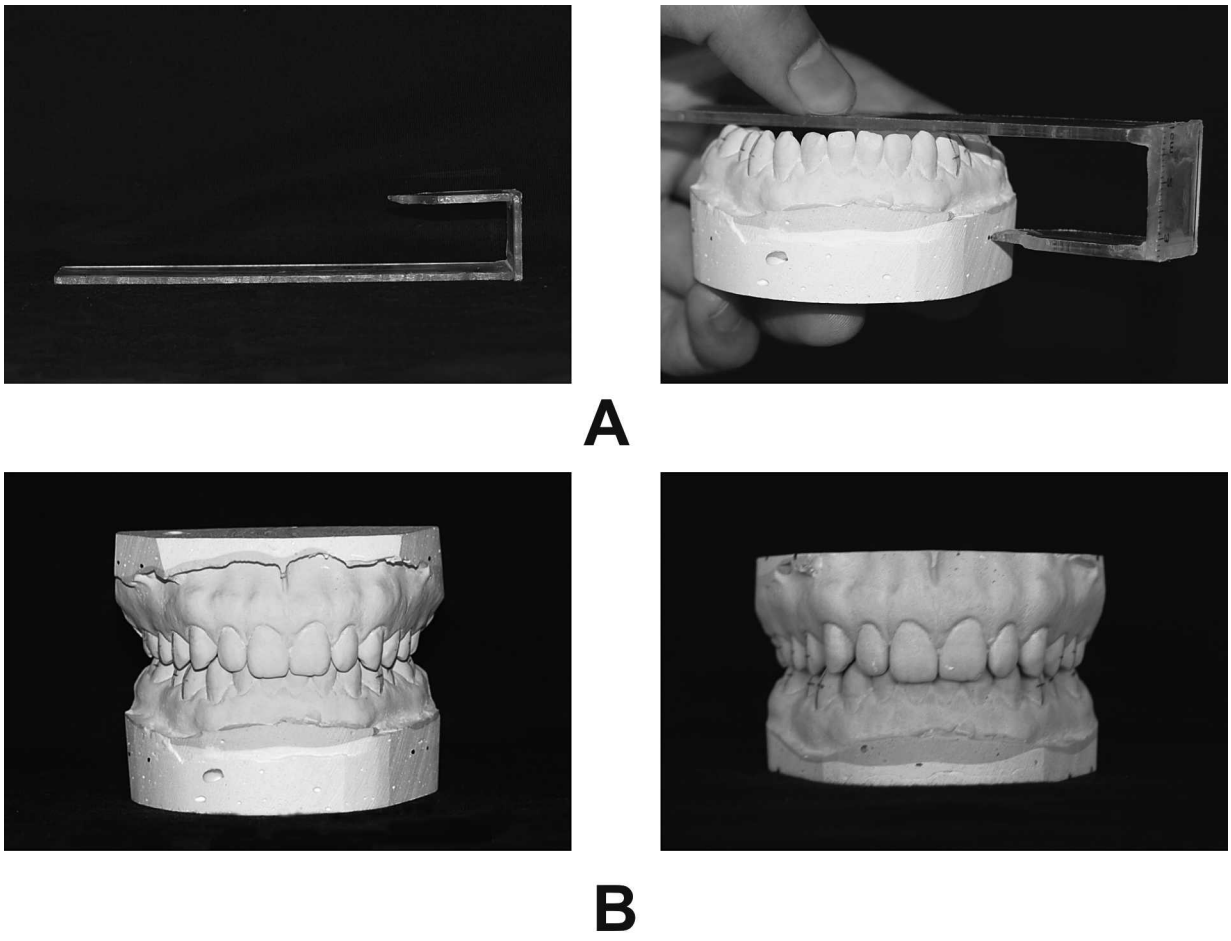

Figure 1. (A) The identifying of the three points for base trimming. (B) Cast before (left) and after (right) trimming.

- maxillary alveolar width between the mucogingival junctions below the FA point of bilateral first maxillary molars;
- maxillary alveolar width between the mucogingival junctions below the FA point of bilateral first and second maxillary premolars;
- mandibular alveolar width between the WALA point below the FA point of bilateral first mandibular molars; and
- mandibular alveolar width between the WALA point below the FA point of bilateral first and second premolars.

The admeasuring apparatus for measurement of the buccolingual inclination was a modified universal bevel protractor (Shanghai, China) (Figure 2A), and the measuring philosophy was similar to the method of Andrews.[13] Casts were put on the platform of the apparatus and the measuring limb was adjusted tangential to the FA point along the FACC. The buccolingual inclination between the teeth crown and the POP could be detected on the data panel (Figure 2B). Each inclination was measured three times, and the average value was adopted for statistical analysis. A digital caliper with minimal accuracy of 0.02 mm was used to measure the arch width and alveolar width (Figure 3).

Paired *t*-test was applied for testing the difference of the buccolingual inclination between the left and the right side at each tooth category. The statistical data showed that there was no difference. Therefore, we adopted the mean value of two sides as the inclination of each tooth category.

Independent *t*-test was applied for the comparison of buccolingual inclination, arch width, and alveolar width between the Class I and Class II division 1 groups. Statistical package for Social Sciences version 17.0 for Windows (SPSS Inc, Chicago, Ill) was used to perform all of the statistical analyses.

RESULTS

Twenty-five casts were randomly selected to be measured twice at an interval of 4 weeks. Paired *t*-test was applied to determine the systematic error. The comparison showed that the differences between the

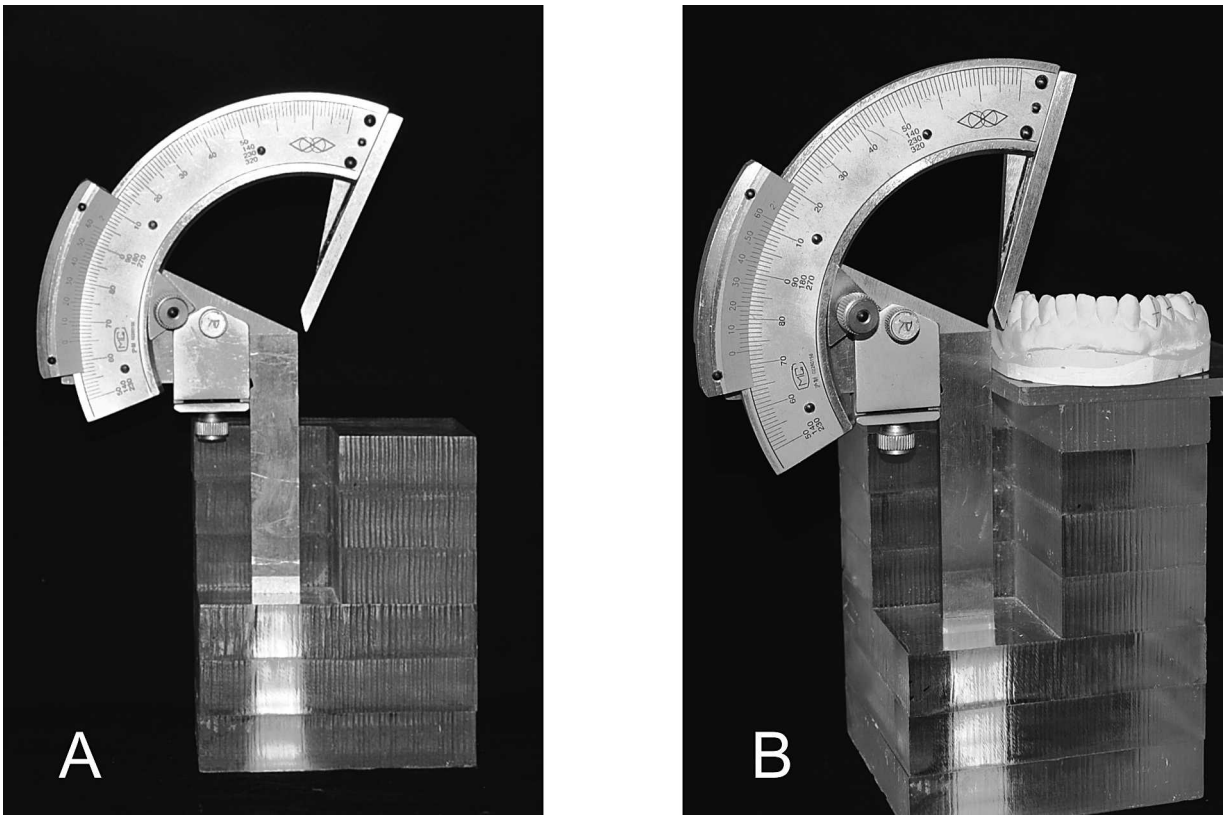

Figure 2. (A) Apparatus for inclination measurement. (B) Measurement of buccolingual inclination.

first and second measurements for arch and alveolar width and buccolingual inclination were insignificant. Random error was calculated by Dahlberg formula.[23] Values for arch width varied from 0.346 to 0.410; values for alveolar width varied from 0.343 to 0.386; and values for buccolingual inclination varied from 0.719 to 1.622. All of the values were within the acceptable limits (Table 1). The *r* values for correlation analysis of all measurements varied from 0.929 to 0.993 (Table 1). The measurement for this study was accurate and reliable.

Comparison of arch width between the two groups is shown in Table 2. Although there was a tendency for the Class II group to have a narrow maxillary arch, there was no significant difference in arch width of maxillary and mandibular first molars, first premolars, and second premolars between the two groups.

Comparison of alveolar width between the two groups is shown in Table 3. The results are similar to those with arch width comparison. There was no significant difference in alveolar width of maxillary and mandibular first molars, first premolars, and second premolars between the two groups.

Comparison of the buccolingual inclination between the two groups is shown in Table 4. The Class II division 1 malocclusion samples had significantly more lingually tilted maxillary first molars, first premolars,

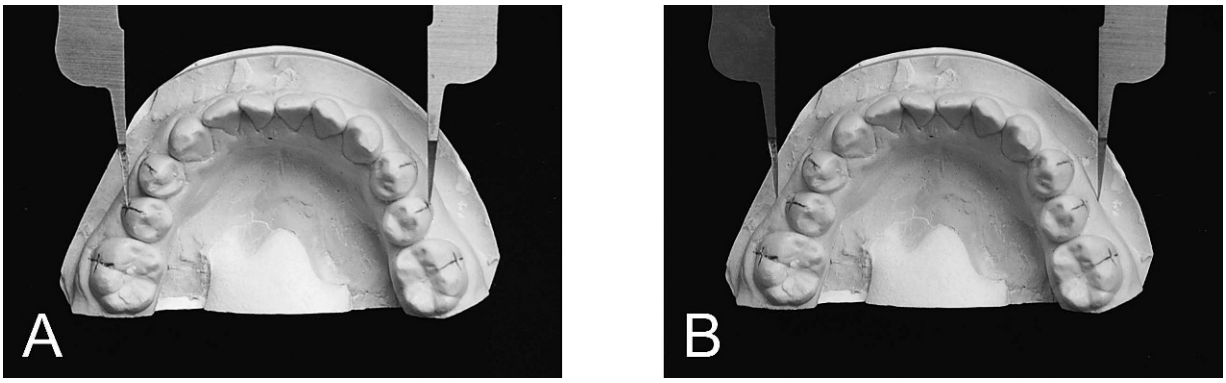

Figure 3. (A) Measurement of arch width. (B) Measurement of alveolar width.

Table 1. Error of the Method[a]

Transverse Measurements	Dahlberg Calculation	Reliability Coefficient
U4W	0.355	.984
U5W	0.389	.981
U6W	0.358	.986
L4W	0.362	.985
L5W	0.346	.991
L6W	0.410	.979
U4AW	0.343	.980
U5AW	0.386	.982
U6AW	0.354	.984
L4AW	0.340	.979
L5AW	0.370	.980
L6AW	0.376	.984
U4IN	0.719	.974
U5IN	0.982	.992
U6IN	1.622	.929
L4IN	1.057	.982
L5IN	1.199	.987
L6IN	0.986	.993

[a] U4W indicates arch width of the first maxillary premolars; L4W, arch width of the first mandibular premolars; U4AW, alveolar bone width of the first maxillary premolars; U4IN, buccolingual inclination of the first maxillary premolars. Other abbreviations are in the same manner.

and second premolars when compared to the Class I samples. Mandibular first premolars were significantly less lingually tilted in Class II division 1 malocclusion than in the Class I samples. There was a tendency for mandibular second premolars and first molars of the Class II division 1 group to be less lingually tilted than the Class I group, but the differences showed no statistical significance.

DISCUSSION

Transverse discrepancy in Class II malocclusion has been intensively investigated, and the results are still controversial. Staley et al.[5] and Sayin and Turkkahraman[4] considered that most of the Class II division 1 malocclusion was accompanied by a long and narrower arch form, which is partly caused by a palatal tilt of the posterior teeth. Sayin and Turkkahraman[4] also held a similar opinion, yet these need further investigation. On the contrary, Frohlich's research[7] demonstrated that there was no difference in arch width between Class II division 1 malocclusion and Class I occlusion in children.

The term inclination of teeth was first proposed in the six keys by Andrews.[13] Most studies[23,24] focused on the labiolingual inclination of anterior teeth, which seems important to an esthetic profile. In recent years, the buccolingual inclination of posterior teeth has become intriguing to researchers for its important role in smile esthetics and interdigitated occlusion. Zachrisson[14] stated that lingual tilted posterior teeth would increase the negative corridor and consequently decrease the fullness of a smile. Because buccolingual inclination is another important transverse characteristic of occlusion, it is very important to identify the role of buccolingual inclination in a transverse discrepancy in Class II division 1 malocclusion.

Table 2. Comparison of Maxillary and Mandibular Arch Width[a]

	Class I Group (N = 45)		Class II Group (N = 45)		
	Mean, mm	SD	Mean, mm	SD	*P*
U4W	44.8	2.3	43.9	2.4	.845
U5W	50.3	2.4	49.4	2.6	.164
U6W	55.1	1.6	54.5	2.7	.302
L4W	39.2	1.9	40.3	2.4	.063
L5W	45.8	2.3	45.9	3.0	.868
L6W	53.4	1.7	53.0	2.5	.446

[a] U4W indicates arch width of the first maxillary premolars; L4W, arch width of the first mandibular premolars. Other abbreviations are in the same manner.
* $P < .05$; not significant, $P > .05$.

Most of the prior studies on transverse discrepancy did not consider the skeletal relationship, which might be the cause of transverse discrepancy.[5] ANB angle is a widely accepted diagnosis standard for sagittal jaw discrepancy and was employed in this research to investigate the relationship between transverse discrepancy and sagittal discrepancy.

Because we want to measure the buccolingual inclination of the posterior teeth solely, the occlusal plane, which is decided by both anterior and posterior teeth, is not suitable for this research. The POP was used as the reference plane mentioned by Janson et al.[21] This reference plane was more accurate to reflect the aims of this study.

Our result coincides with the hypothesis of Staley et al.[5] In normal or Class I occlusion, the maxillary posterior teeth are more buccally positioned than the mandibular posterior teeth. If the jaws of a Class I occlusion were put into a Class II relationship, the overjet would increase and make a scissor bite in the posterior region. To compensate for this condition and create occlusal contact, the maxillary posterior teeth

Table 3. Comparison of Maxillary and Mandibular Alveolar Width[a]

	Class I Group (N = 45)		Class II Group (N = 45)		
	Mean, mm	SD	Mean, mm	SD	*P*
U4AW	48.5	2.3	48.0	2.6	.773
U5AW	56.2	2.5	55.7	2.7	.532
U6AW	61.0	1.7	60.4	2.7	.334
L4AW	40.2	1.7	40.9	2.4	.561
L5AW	48.4	2.4	48.4	3.0	.965
L6AW	57.0	2.8	57.2	2.3	.538

[a] U4AW indicates alveolar bone width of the first maxillary premolars; L4AW, alveolar bone width of the first mandibular premolars. Other abbreviations are in the same manner.
* $P < .05$; not significant, $P > .05$.

Table 4. Comparison of Buccolingual Inclination of Maxillary and Mandibular Posterior Teeth[a]

	Class I Group (N = 45)		Class II Group (N = 45)		
	Mean, degrees	SD	Mean, degrees	SD	*P*
U4IN	−6.1	6.0	−11.0	5.3	.001**
U5IN	−8.3	5.7	−14.0	5.0	<.001***
U6IN	−12.0	6.3	−15.2	8.4	.030*
L4IN	−19.1	5.8	−15.2	8.4	.040*
L5IN	−23.3	6.7	−22.5	8.9	.683
L6IN	−31.5	6.4	−30.6	8.8	.659

[a] U4IN indicates buccolingual inclination of the first maxillary premolars; L4IN, buccolingual inclination of the first mandibular premolars. Other abbreviations are in the same manner.

* $P < .05$; ** $P < .005$; *** $P < .001$; not significant, $P > .05$.

would be more palatally positioned or more palatally tilted. At the same time, the mandibular posterior teeth would move or tilt buccally.

According to our research, the palatal tilt of the maxillary posterior teeth played the most important role in such compensation. The maxillary premolars and molars in a Class II division 1 malocclusion demonstrated significantly, 4° to 5°, greater lingual tilt than those in Class I occlusion. Differences in mandibular inclination seemed less significant. Mandibular first premolars were less lingually tilted in Class II division 1 malocclusion than in Class I occlusion, but no such significant difference was observed in the mandibular second premolars and first molars. However, all mandibular posterior teeth showed a less lingual tendency, which was in accordance with the compensation hypothesis. The comparison of arch width is different from most of the previous studies. The arch width of the maxillary first molars and second premolars in the Class II malocclusion group was smaller than in the Class I occlusion group, but the difference was not statistically significant.

A literature review showed that only Frohlich's study[7] supported our results. Even in studies that agreed that Class II division 1 malocclusion has a narrower maxillary arch, there are some contradictions. The research of Uysal et al.[26] demonstrated a narrower interpremolar width but wider maxillary intermolar width in a Class II division 1 patient, while the Sayin and Turkkanhraman[4] result was just the opposite. They found the Class II division 1 group with narrower maxillary intermolar width and interpremolar width, but no narrower interpremolar width. It seems that the result of arch width difference may be influenced easily by both sample size and sample selection. According to our results, lingually tilted maxillary posterior teeth may induce a narrow arch width. There was a tendency for Class II division 1 malocclusion to have a narrower maxillary arch in our result, but the difference was not statistically significant. We concluded that, rather than arch width, the buccolingual inclination played a major role in transverse discrepancy in Class II division 1 malocclusion.

Clinicians have speculated several reasons for a transverse discrepancy of Class II division 1 malocclusion, including nasal obstruction, finger habits, and low tongue position.[5] Maxillary posterior teeth and mandibular posterior teeth have a correct buccal position to create a normal buccal overjet in normal occlusion. When the jaws are put from Class I relations into Class II, the posterior buccal overjet would increase and make a scissors bite in the posterior dental region. Therefore, during eruption the maxillary teeth should be more palatally positioned, and the mandibular teeth would be more buccally positioned to compensate the increased buccal overjet and create an interdigitated occlusion. Compensatory movement of teeth cannot be beyond the alveolar bone, which is not different between Class I and Class II occlusion in both previous studies[8,25] and in this study. Therefore, the lingual tilt of the maxillary posterior teeth has taken the most important role in this kind of compensation.

Previous studies suggested that Class II division 1 malocclusion tends to need expansion of the maxillary arch width to correct the transverse discrepancy,[4,25] which also coincides with our results. Considering the inclination of the maxillary posterior teeth, our study suggested that it is appropriate to use slow maxillary expansion (SME) to correct the transverse discrepancy because the SME induces more change in inclination which could be retained more stably.[27]

CONCLUSIONS

- The maxillary posterior teeth are significantly more lingual tilted significantly in Class II division 1 malocclusion compared with in Class I occlusion.
- The first mandibular premolars are less lingually tilted in Class II division 1 malocclusion than in Class 1 occlusion, whereas there is no difference in buccolingual inclination of mandibular second premolars and first molars between the two groups.
- The arch width of posterior teeth is not different between Class II division 1 malocclusion and Class I occlusion.
- The buccolingual inclination plays a more important role in transverse discrepancy of Class II division 1 malocclusion than arch width.

REFERENCES

1. Ast DB, Carlos JP, Cons NC. The prevalence and characteristics of malocclusion among senior high school students in upstate New York. *Am J Orthod*. 1965;51: 437–445.

2. Willems G, De Bruyne I, Verdonck A, Fieuws S, Carels C. Prevalence of dentofacial characteristics in a Belgian orthodontic population. *Clin Oral Investig*. 2001;5:220–226.
3. Lauc T. Orofacial analysis on the Adriatic islands: an epidemiological study of malocclusions on Hvar Island. *Eur J Orthod*. 2003;25:273–278.
4. Sayin MO, Turkkahraman H. Comparison of dental arch and alveolar widths of patients with Class II, division 1 malocclusion and subjects with Class I ideal occlusion. *Angle Orthod*. 2004;74:356–360.
5. Staley RN, Stuntz WR, Peterson LC. A comparison of arch widths in adults with normal occlusion and adults with Class II, division 1 malocclusion. *Am J Orthod*. 1985;88:163–169.
6. Tollaro I, Baccetti T, Franchi L, Tanasescu CD. Role of posterior transverse interarch discrepancy in Class II, division 1 malocclusion during the mixed dentition phase. *Am J Orthod Dentofacial Orthop*. 1996;110:417–422.
7. Frohlich F. A longitudinal study of untreated Class II type malocclusion. *Trans Eur Orthod Soc*. 1961;37:137–139.
8. Ball RL, Miner RM, Will LA, Arai K. Comparison of dental and apical base arch forms in Class II division 1 and Class I malocclusions. *Am J Orthod Dentofacial Orthop*. 2010;138: 41–50.
9. Gupta D, Miner RM, Arai K, Will LA. Comparison of the mandibular dental and basal arch forms in adults and children with Class I and Class II malocclusions. *Am J Orthod Dentofacial Orthop*. 2010;138:10 e11–e18; discussion 10–11.
10. Andrews LF. The six elements of orofacial harmony. *Andrews J. J Orthod Orofacial Harmony*. 2000;1:13–22.
11. Ronay V, Miner RM, Will LA, Arai K. Mandibular arch form: the relationship between dental and basal anatomy. *Am J Orthod Dentofacial Orthop*. 2008;134:430–438.
12. Trivino T, Siqueira DF, Andrews WA. Evaluation of distances between the mandibular teeth and the alveolar process in Brazilians with normal occlusion. *Am J Orthod Dentofacial Orthop*. 2010;137:308 e301–e304; discussion 308–309.
13. Andrews LF. The six keys to normal occlusion. *Am J Orthod*. 1972;62:296–309.
14. Zachrisson BU. Premolar extraction and smile esthetics. *Am J Orthod Dentofacial Orthop*. 2003;124:11A–12A.
15. Isik F, Sayinsu K, Nalbantgil D, Arun T. A comparative study of dental arch widths: extraction and non-extraction treatment. *Eur J Orthod*. 2005;27:585–589.
16. Uysal T, Sari Z, Basciftci FA, Memili B. Intermaxillary tooth size discrepancy and malocclusion: is there a relation? *Angle Orthod*. 2005;75:208–213.
17. Knott VB. Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence. *Am J Phys Anthropol*. 1961;19:263–284.
18. Knott VB. Longitudinal study of dental arch widths at four stages of dentition. *Angle Orthod*. 1972;42:387–394.
19. DeKock WH. Dental arch depth and width studied longitudinally from 12 years of age to adulthood. *Am J Orthod*. 1972;62:56–66.
20. Silman J. Dimensional changes of the dental arches: longitudinal study from birth to 25 years. *Am J Orthod Dentofacial Orthop*. 1964;50:824–842.
21. Janson G, Bombonatti R, Cruz KS, Hassunuma CY, Del Santo M Jr. Buccolingual inclinations of posterior teeth in subjects with different facial patterns. *Am J Orthod Dentofacial Orthop*. 2004;125:316–322.
22. Ross VA, Isaacson RJ, Germane N, Rubenstein LK. Influence of vertical growth pattern on faciolingual inclinations and treatment mechanics. *Am J Orthod Dentofacial Orthop*. 1990;98:422–429.
23. Houston WJB. The analysis of errors in orthodontic measurements. *Am J Orthod Dentofacial Orthop*. 1983;83: 382–390.
24. Cao L, Zhang K, Bai D, Jing Y, Tian Y, Guo Y. Effect of maxillary incisor labiolingual inclination and anteroposterior position on smiling profile esthetics. *Angle Orthod*. 2011;81: 121–129.
25. Spear FM, Kokich VG, Mathews DP. Interdisciplinary management of anterior dental esthetics. *J Am Dent Assoc*. 2006;137:160–169.
26. Uysal T, Memili B, Usumez S, Sari Z. Dental and alveolar arch widths in normal occlusion, Class II division 1 and Class II division 2. *Angle Orthod*. 2005;75:941–947.
27. Ciambotti C, Ngan P, Durkee M, Kohli K, Kim H. A comparison of dental and dentoalveolar changes between rapid palatal expansion and nickel-titanium palatal expansion appliances. *Am J Orthod Dentofacial Orthop*. 2001;119: 11–20.