Maxillomandibular arch width differences at centers of resistance in skeletal Class III

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Maxillomandibular arch width differences at centers of resistance in skeletal Class III

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감사의 글

부족한 저를 지도해주신 교수님들의 많은 가르침이 있었기에 이 논문이 있을 수 있었습니다. 항상 많은 가르침과 세심한 지도로 이끌어주신 이기준 지도교수님께 진심으로 감사 드리며, 귀중한 시간을 내주시어 많은 관심과 조언을 아끼지 않으신 황충주 교수님, 유형석 교수님, 김기덕 교수님, 김희진 교수님께 깊은 감사를 드립니다. 또한 연세대학교 치과대학 교정과학교실에서 배움의 기회를 주시고 교정의로서 첫 발을 내딛는 데에 어려움이 없도록 인도해주신 백형선 교수님, 김경호 교수님, 차정열 교수님, 정주령 교수님, 최윤정 교수님께도 깊이 감사드립니다.

쉽지 않은 기회를 함께 하게 되어 서로의 버팀목이 되며 같은 길을 걷게 된 수련 동기 김경원, 윤지연, 이미림, 이영우, 이홍희, 최승완 선생과 의국 선배님들, 후배님들, 특히 금병탁, 서희주 선생에게 감사의 마음을 전합니다.

지금의 저를 있게 해주시고 아낌없는 지원과 응원을 보내주시는 사랑하는 가족들께 이 자리를 빌어 깊은 감사의 마음을 전합니다. 저를 믿고 도와주신 많은 분들께 감사 드리며 이 소중한 기쁨을 함께 나누고자 합니다.

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구 윤 진

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ABSTRACT

Maxillomandibular arch width differences at centers of resistance in skeletal Class III

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Introduction : The aim of this study were : (1) to compare the transverse dimensions and maxillomandibular transverse relationships between untreated normal occlusion and Class III groups, (2) to compare the basal arch dimensions between measured at CT scans and at casts, and (3) to find the possible transverse basal arch dimensions to establish normal occlusion in each tooth area.

Materials and Methods : The casts and 3D CT data of 30 normal occlusion and 30 skeletal Class III subjects requiring orthognathic surgery were selected. Using the casts, the dental arch widths (DAW) were measured at the respective cusp tips and the basal arch widths (BAW [cast]) were measured the distance between the points at the mucogingival junction (MGJ) above the respective cusp tips. The basal arch widths from the CT scans (BAW [CT]) were measured at the estimated centers of resistance (CR) at either furcation or one third of root length. The dimensions and maxillomandibular differences were analyzed.

Results : In contrast to the similarity in DAWs between two groups, the maxillary BAW [CT]s except at the 2^{nd} molar and all maxillary BAW [cast]s in Class III malocclusion were significantly smaller than those of normal occlusion group. All mandibular BAW [CT]s of Class III group were significantly greater than those of normal occlusion group. None of mandibular BAW [cast]s showed statistically significant differences between two groups. The maxillomandibular BAW differences on both CT and cast showed significant differences in all transverse measurements between two groups. Correlation analysis represented significant correlation between BAW [CT] variables and BAW [cast] variables.

Conclusions : The results indicated possible basal transverse discrepancy and transverse dental compensation in the skeletal Class III subjects. Correlation analysis represented significant correlation between BAW [CT] variables and BAW [cast] variables. The 1^{st} molar BAW [CT] differences of -0.39 ± 1.87 mm, BAW [cast] differences of 5.15 ± 2.56

mm in normal occlusion were obtained to represent optimal maxillomandibular transverse difference at the basal bone level.

Keywords : centers of resistance, arch width differences, Class III, transverse discrepancy

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I. Introduction

Class III malocclusion is common among Asians (Singh, 1999) and often requires surgical intervention. In making an orthodontic diagnosis, all three dimensions – sagittal, vertical and transverse – are taken into consideration. In particular, high prevalence of the maxillary transverse deficiencies in Class III has been addressed (Franchi and Baccetti, 2005; Sato et al., 2013). Considering that the anteroposterior jaw discrepancy affects transverse relationship, the diagnosis between absolute and relative transverse deficiency is crucial (Jacobs et al., 1980). The 'absolute' maxillary deficiency would require expansion of the basal bone via either orthopedic or surgical measures (Bailey et al., 1997; Betts et al., 1995; Bishara and Staley, 1987; Haas, 1965; Lee et al., 2010), while the 'relative' deficiency can be corrected simply by sagittal jaw relocation. Unlike the sagittal or vertical discrepancies, however, the transverse discrepancy is not readily detected using conventional two dimensional radiographs due to the underlying distortion, inaccuracy and overlapping images from the submentovertex or posteroanterior cephalogram (Baumrind and Frantz, 1971; Grummons and Kappeyne van de Coppello, 1987; Leonardi et al., 2008). Moreover, dentoalveolar transverse compensation often masks the underlying transverse deficiency, which may develop buccal crossbite following the alignment of teeth with rectangular wire (Betts et al., 1995; McNamara, 2000).

Previous studies have suggested various skeletal and/or dental measurements for transverse analysis (Andrews and Andrews, 2000; Betts et al., 1995; Howes, 1954; Lundstrom, 1925; Ricketts, 1981; Sergl et al., 1996). For instance, the posteroanterior cephalogram displays the basal bone widths at respective jugale points and antegonial notches (Ricketts, 1981), but they can hardly represent the alveolar bone widths especially in the mandible (Hesby et al., 2006). Model analyses provide interdental widths, widths at mucogingival junction or concavity around the alveolar vestibule. However, those have limitations because the measurements on the surface of dental casts are affected by the variation of overlying cortical bone/soft tissue thickness, the reliability of the landmarks and the variability of the vestibular depths etc (Cha et al., 2008; Lee et al., 2009; Masumoto et al., 2001).

The center of resistance (CR), or centroid, represents the center of gravity in a restrained body (Smith and Burstone, 1984) and has been considered as a reasonable landmark to define tooth position and its displacement (Burstone, 1977; Melsen et al., 1989). Unlike the cusp tips or root apices, it is not readily affected by the simple rotational movement of a body. Knowing that the location of CR points is possible on the radiographs, many of previous studies recruited the CR points on the lateral cephalograms for the evaluation of tooth movement along the sagittal plane (Bechtold et al., 2013; Burstone, 1977; Lee et al., 2011; Melsen et al., 1989). In contrast, location of CR points for transverse measurements from two dimensional radiographs such as posteroanterior or submentovertex view is not feasible due to the overlapping images in the posterior teeth area. Recent approaches to overcome this issue include the use of three-dimensional computed tomography (3D CT) (Suk et al., 2013). Therefore CT images may be useful to locate CR points for the evaluation of transverse dimension.

The aim of this study were : (1) to compare the transverse dimensions and maxillomandibular transverse relationships between untreated normal occlusion and Class III groups, (2) to compare the basal arch dimensions between measured at CT scans and at casts, and (3) to find the possible transverse basal arch dimensions to establish normal occlusion in each tooth area.

II. Materials and Methods

1. Subjects of study

A priori power analysis suggested that 30 subjects were required to achieve a power level of 80 % with α significance level of .05 and β significance level of .2. The dental casts, cephalograms and CT images from 30 subjects exhibiting normal occlusion and skeletal Class I relationship were retrieved from the archives in Yonsei University used for previous studies (Kim et al., 2014; Lee et al., 2009). The 30 Class III subjects with severe mandibular prognathism, Class III canine/molar keys were retrospectively selected among the orthognathic surgery cases in the Orthodontic Department, Yonsei University Dental Hospital, Seoul, Korea. Marked asymmetry patients with menton deviation greater than 4 mm and occlusal canting greater than 4 degrees, were excluded (Kim et al., 2013; Padwa et al., 1997). Inclusion criteria in terms of denture pattern for both groups are as follows; 1) all permanent teeth including the 2nd molars are present and fully erupted, 2) minimal crowding of less than 3 mm in each arch, 3) no history of orthodontic treatment, 4) no severe dental anomalies in crown/root shape. The descriptive statistics for the age, gender and cephalometric measurements of the two groups are shown in Table I and II. The dental casts, cephalograms and CT images for Class III subjects were taken to establish orthodontic and surgical treatment plans on an intend-to-treat basis.

Table I. Sample distribution by age and sex

	N	Mean Age (y)	SD (y)	Sex	n	Mean Age (y)	SD (y)	Min (y)	Max (y)
Normal occlusion	30	22.8	2.82	Male	20	22.87	3.14	20	30
				Female	10	22.57	1.51	21	25
Class III	30	21.5	3.88	Male	17	20.88	3.66	18	34
				Female	13	22.31	4.15	18	31

Table II. Sample characteristics of normal occlusion and Class III groups

Variables	Normal occlusion		Class III		*p* value
	Mean	SD	Mean	SD	
SNA (°)	81.87	2.68	80.99	3.50	0.292
SNB (°)	79.19	3.24	83.64	4.14	0.000‡
ANB difference (°)	2.68	2.12	-2.65	2.28	0.000‡
Wits (mm)	-2.96	2.50	-11.49	3.78	0.000‡
SN-GoMe (°)	33.39	6.01	34.27	7.08	0.616
U1 to SN (°)	104.83	7.32	111.39	5.41	0.000‡
IMPA (°)	95.99	6.49	83.01	5.50	0.000‡

Independent sample t-test ; *p <0.05 ; † p <0.01; ‡ p <0.001.

2. Cast measurements

All cast measurements were taken using digital calipers (Mitutoyo Corporation, Kawasaki, Japan) for assessment of dental arch widths (DAW) and basal arch widths (BAW [cast]). The DAWs were measured at the respective cusp tips and the BAW [cast]s were measured the distance between the points at the mucogingival junction (MGJ) above the respective cusp tips. DAW and BAW [cast] measurements are shown in Figure 1.

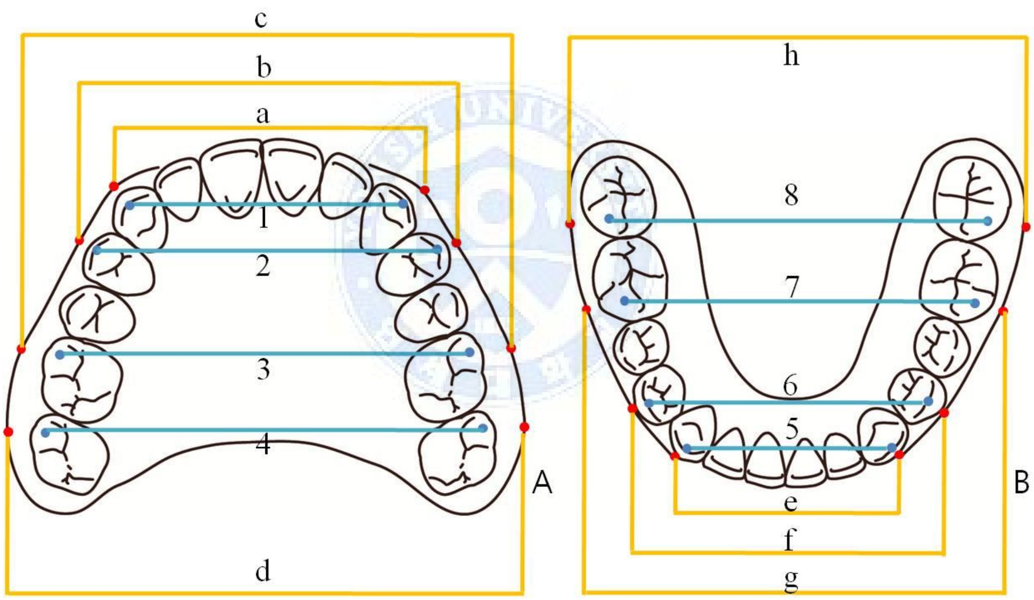

Figure 1. Dental Arch Width on cast (DAW). : **A**, Maxilla : **1**, canine; **2**, premolar; **3**, 1st molar; **4**, 2nd molar; **B**, Mandible : **5**, canine; **6**, premolar; **7**, 1st molar; **8**, 2nd molar. Basal Arch Width on cast (BAW [cast]). : **A**, Maxilla : **a**, canine; **b**, premolar; **c**, 1st molar; **d**, 2nd molar; **B**, Mandible : **e**, canine; **f**, premolar; **g**, 1st molar; **h**, 2nd molar. (modified from Uysal et al., 2005)

3. CT measurements

3D CT data were obtained using CT equipment (Hispeed Advantage, GE Medical System, Milwaukee, Wis), with 120 kVp, 180 mA. The digital imaging and communication in medicine (DICOM) images were created in 1.0 mm slice thickness after scanning. The DICOM data were imported into the software program (InVivoDental® version 5.1, Anatomage, San Jose, Calif). Basal arch widths from the CT scans (BAW [CT]) were evaluated by digitizing the estimated CR at the level of the coronal one third for a single rooted teeth and the furcation for a multirooted tooth (Smith and Burstone, 1984). Positions of the estimated CR were pointed on the axial, sagittal and coronal sections using a slice locator of the InVivoDental® software program. BAW [CT] measurements are shown in Figure 2. The calibration of CT measurements was conducted using dry skull, as described in the previous study (Lee et al., 2009). Briefly, transverse measurements from an adult dentate dry skull embedded in acrylic box filled with distilled water were compared to those measured directly from dry skull. The ratio between two measurements was 0.9924 (SD 0.06), indicating high reliability of transverse measurements from CT images.

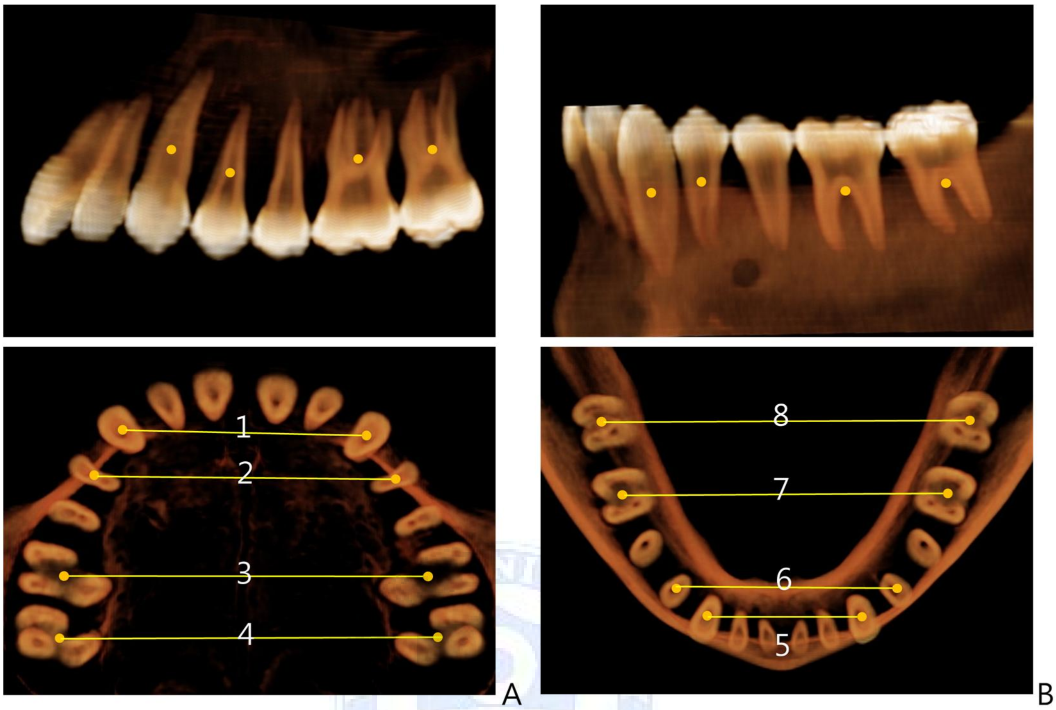

Figure 2. Basal Arch Width on 3D CT scans (BAW [CT]). The digitation of CR : a single rooted teeth, at the level of the coronal 1/3 of roots; a multirooted tooth, at the level of furcation. : **A**, Maxilla : **1**, canine; **2**, premolar; **3**, 1^{st} molar; **4**, 2^{nd} molar; **B**, Mandible : **5**, canine; **6**, premolar; **7**, 1^{st} molar; **8**, 2^{nd} molar.

4. Statistical analysis

One investigator (K.Y.J) conducted repeated measurements of each variable, with two weeks interval, from randomly selected 15 dental casts and 15 CT images. The intra-examiner reliabilities were calculated by intra-class correlation coefficients. Independent sample t-test was applied for comparison between normal occlusion group and Class III malocclusion group. The Pearson correlational analysis was conducted to investigate correlations of the followings: 1) correlation between transverse measurements and cephalometric skeletal measurements, 2) correlation between DAW variables and BAW [CT] variables, and 3) correlation between BAW [cast] variables and BAW [CT] variables. Statistical analysis was set at the 5% level of significance. All statistical analyses were performed using SPSS software (ver 20, IBM SPSS, Chicago, Il, USA).

III. Results

The intra-class correlation coefficients ranged from 0.94 to 0.99, indicating high reliability of all measurements. A Mann-Whitney U-test was preliminarily conducted to investigate gender dimorphism in each group. The results showed that except for maxillary DAW and BAW of premolar in normal occlusion, other transverse measurements in both the two groups represented no significant gender dimorphism. Therefore errors from gender difference were presumed to be minimal in this study. Table III summarized the transverse measurements in each group, including the DAWs, BAWs and their differences between maxilla and mandible. In the group comparison, none of the DAWs showed statistically significant differences between two groups. Also, there were no significant differences in the DAW differences between two groups. In contrast, maxillary BAW [CT]s of Class III group were smaller than those of normal occlusion group ($p < 0.01$ for canines and premolar, $p < 0.05$ for the 1^{st} molar) and maxillary BAW [cast]s of Class III group were smaller than those of normal occlusion ($p < 0.01$ except for the 2^{nd} molar, $p < 0.05$ for the 2^{nd} molar). In addition, all mandibular BAW [CT]s of Class III group were significantly greater than those of normal occlusion group ($p < 0.01$ for canine and premolar, $p < 0.05$ for the 1^{st} and 2^{nd} molars). In contrast, none of mandibular BAW [cast]s showed statistically significant differences between two groups. Consequently, the BAW differences on both CT and cast showed significant differences in all transverse measurements between two groups ($p < 0.05$).

Table III. DAW and BAW of normal occlusion and Class III groups

(unit : mm)	DAW			BAW [CT]			BAW [cast]		
	Normal occlusion	Class III	*p* value	Normal occlusion	Class III	*p* value	Normal occlusion	Class III	*p* value
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
Mx. Measurements									
Canine	36.40 ± 2.25	35.27 ± 2.59	0.078	31.99 ± 2.04	30.38 ± 1.93	0.004†	39.39 ± 2.28	37.24 ± 2.20	0.001†
Premolar	44.31 ± 2.25	43.73 ± 2.58	0.361	38.61 ± 1.98	37.12 ± 2.21	0.014*	49.60 ± 2.34	47.28 ± 2.85	0.002†
1st molar	55.35 ± 3.33	55.62 ± 3.08	0.741	48.36 ± 2.72	46.71 ± 2.84	0.023*	63.18 ± 3.18	60.5 ± 3.39	0.005†
2nd molar	61.79 ± 3.48	62.73 ± 3.55	0.301	51.14 ± 3.01	50.04 ± 3.31	0.218	67.96 ± 3.23	65.76 ± 3.45	0.020*
Mn. Measurements									
Canine	28.22 ± 1.64	27.52 ± 2.09	0.154	24.11 ± 1.68	25.52 ± 1.34	0.001†	31.17 ± 1.93	31.94 ± 1.53	0.110
Premolar	35.30 ± 2.29	34.13 ± 2.45	0.061	33.29 ± 1.91	35.26 ± 1.48	0.000‡	41.88 ± 1.89	42.36 ± 1.52	0.304
1st molar	46.91 ± 2.99	47.81 ± 2.93	0.246	48.75 ± 2.45	49.98 ± 2.11	0.037*	58.02 ± 2.95	57.80 ± 1.96	0.747
2nd molar	52.80 ± 3.65	52.88 ± 3.07	0.926	55.66 ± 2.93	56.98 ± 2.10	0.049*	65.26 ± 3.30	65.37 ± 2.11	0.893

Difference (Mx. measurements – Mn. measurements)									
Canine	8.18 ± 1.57	7.57 ± 1.97	0.359	7.87 ± 1.71	4.86 ± 2.33	0.000‡	8.21 ± 1.52	5.31 ± 2.38	0.000‡
Premolar	9.01 ± 1.66	9.60 ± 2.84	0.325	5.32 ± 1.88	1.86 ± 2.55	0.000‡	7.71 ± 1.75	4.92 ± 2.48	0.000‡
1st molar	8.43 ± 2.22	7.81 ± 2.83	0.349	-0.39 ± 1.87	-3.17 ± 3.17	0.000‡	5.15 ± 2.56	2.75 ± 3.05	0.003†
2nd molar	8.98 ± 2.23	9.85 ± 3.32	0.240	-4.52 ± 2.76	-6.95 ± 3.55	0.006†	2.69 ± 3.09	0.40 ± 3.32	0.011*

Independent sample t-test ; *P <0.05 ; †P <0.01; ‡P <0.001.

Correlation analysis revealed no significant correlation between DAWs and lateral cephalometric measurements except for the positive correlation between molar DAWs and body lengths. However, BAW [CT]s were significantly correlated with the sagittal skeletal discrepancy, such as between maxillary molar BAW [CT]s and SNA and Wits appraisal, between mandibular molar BAW [CT]s and SNB, body lengths, ANB and Wits appraisal. Maxillomandibular differences in BAW [CT]s of molars were positively correlated with ANB and Wits appraisal, suggesting a relationship between the basal arch discrepancy and sagittal skeletal discrepancy. (Table IV)

Table IV. Correlations between transverse measurements of molars and cephalometric skeletal measurements

Correlation coefficient	DAW						BAW [CT]					
	Mx. Measurements		Mn. Measurements		DAW difference (Mx.- Mn.)		Mx. Measurements		Mn. Measurements		BAW [CT] difference (Mx.- Mn.)	
	1st molar	2nd molar	1st molar	2nd molar	1st molar	2nd molar	1st molar	2nd molar	1st molar	2nd molar	1st molar	2nd molar
SNA	0.257	0.229	0.148	0.239	0.159	0.012	0.414†	0.295*	0.184	0.145	0.232	0.148
SNB	0.179	0.290*	0.234	0.126	-0.043	0.207	0.069	0.055	0.353†	0.275*	-0.218	-0.182
ANB	0.008	-0.156	-0.158	0.058	0.195	-0.248	0.285	0.196	-0.273*	-0.212	0.480‡	0.359†
Wits	-0.025	-0.167	-0.162	-0.012	0.180	-0.221	0.319*	0.167	-0.357†	-0.323*	0.578‡	0.427†
SN-GoMe	0.044	-0.007	-0.102	0.012	0.149	-0.021	-0.122	0.015	0.109	0.185	-0.198	-0.142
Body length	0.271*	0.316*	0.374†	0.277*	-0.051	0.074	0.228	0.253	0.385†	0.423†	-0.099	-0.125

Pearson correlation analysis ; $^{*}p<0.05$; $^{\dagger}p<0.01$; $^{\ddagger}p<0.001$.

In contrast, there were no significant correlation between maxillomandibular DAW differences and maxillomandibular BAW [CT] differences, despite significant correlations between respective DAW and BAW [CT] in each arch. (Table V)

Table V. Correlations between DAW variables and BAW [CT] variables

	Between Mx. DAW and Mx. BAW [CT]				Between Mn. DAW and Mn. BAW [CT]			
Correlation coefficient	canine	premolar	1st molar	2nd molar	canine	premolar	1st molar	2nd molar
	$0.612^{\ddagger}$	$0.610^{\ddagger}$	$0.714^{\ddagger}$	$0.647^{\ddagger}$	0.301^{*}	$0.358^{\dagger}$	$0.633^{\ddagger}$	$0.542^{\ddagger}$

	Between DAW difference and BAW [CT] difference			
Correlation coefficient	canine	premolar	1st molar	2nd molar
	0.248	0.109	0.243	0.257

Pearson correlation analysis ; *p <0.05 ; $^{\dagger}p$ <0.01; $^{\ddagger}p$ <0.001.

The ratios between DAW to BAW [CT] reflecting the degree of transverse dental compensation are shown in Table VI. Significantly greater ratios in the Class III group were found in the maxillary molar area, while the ratios of mandible were significantly smaller at the canine and premolar area ($p < 0.01$).

Table VI. The ratios between DAW to BAW [CT] of normal occlusion and Class III groups

	Ratio (DAW/BAW [CT])		
	Normal occlusion	Class III	p value
	Mean ± SD	Mean ± SD	
Mx. measurements			
Canine	1.14 ± 0.06	1.16 ± 0.08	0.277
Premolar	1.15 ± 0.05	1.18 ± 0.07	0.055
1st molar	1.15 ± 0.05	1.19 ± 0.05	0.001†
2nd molar	1.21 ± 0.05	1.25 ± 0.06	0.003†
Mn. Measurements			
Canine	1.17 ± 0.06	1.08 ± 0.09	0.000‡
Premolar	1.06 ± 0.06	0.97 ± 0.07	0.000‡
1st molar	0.96 ± 0.03	0.96 ± 0.06	0.671
2nd molar	0.95 ± 0.06	0.93 ± 0.04	0.121

Independent sample t-test ; *p <0.05 ; †p <0.01; ‡p <0.001.

Correlation analysis represented significant correlation between BAW [CT] variables and BAW [cast] variables (p < 0.001). (Table VII)

Table VII. Correlations between BAW [CT] variables and BAW [cast] variables

	Between Mx. BAW [CT] and Mx. BAW [cast]				Between Mn. BAW [CT] and Mn. BAW [cast]			
	canine	premolar	1st molar	2nd molar	canine	premolar	1st molar	2nd molar
Correlation coefficient	0.848‡	0.853‡	0.810‡	0.818‡	0.657‡	0.663‡	0.791‡	0.793‡

	Between BAW [CT] difference and BAW [cast] difference			
	canine	premolar	1st molar	2nd molar
Correlation coefficient	0.754‡	0.878‡	0.686‡	0.765‡

Pearson correlation analysis ; *p <0.05 ; †p <0.01; ‡p <0.001.

IV. Discussion

Appropriate diagnostic methods are prerequisites to define underlying transverse discrepancy. Undetected maxillary constriction, for instance, may lead to improper buccal relationship near the end of treatment. Excessive lateral movement of buccal segment beyond the limit of the basal bone may cause detrimental periodontal problems such as buccal dehiscence and gingival recession (McNamara, 2000; Vanarsdall, 1995, 1999). Above all, one should be able to assess the balance in the maxillomandibular transverse dimension in individual case in order to establish desirable occlusal scheme, for which the average maxillomandibular difference in transverse dimension may help. However, there have been few studies on the reasonable maxillary and mandibular basal arch dimensions in normal occlusion and/or Class III group. In particular, defining the transverse relationship in the 2nd molar area has been difficult.

The sources for datasets in this study were two fold; DAWs and BAW [cast]s from dental casts and BAW [CT]s from the CT images, respectively. Lim et al. found no significant differences between dental measurements from plaster models and from CT images taken with the mouth open, suggesting the use of CT images to replace model analysis (Lim and Lim, 2009). However, the present study used CT images taken at maximum intercuspation position, where density of teeth interfering with each other and the streak artifacts from minor dental restoration may affect the accuracy of dental landmarks (Barrett and Keat, 2004; Suojanen et al., 1992). Therefore dental casts were primarily used for dental measurements and additional calibration for the measurements from the CT images was performed.

The transverse denture dimension in Class III subjects compared to normal occlusion group varies among studies (Braun et al., 1998; Kuntz et al., 2008; Lee and Son, 2002; Uysal et al., 2005). Kuntz et al. demonstrated smaller maxillary molar DAWs in Class III patients than the normal occlusion subjects (Kuntz et al., 2008). In contrast, Braun et al. demonstrated larger maxillary and mandibular DAWs in Class III group than normal occlusion group, both beginning in the premolar and molar area (Braun et al., 1998). Uysal et al. contradicts Braun’s study, indicating greater maxillary arch widths in Class III subjects (Uysal et al., 2005). In Korean subjects, however, there was no significant differences between the two groups (Lee and Son, 2002). The present study also showed no significant differences in dental parameters between Class III and normal occlusion groups. These conflicting results are associated with the landmarks used in each study and may be related to possible racial difference. Since the denture dimension is affected by the degree of compensation, comparison of the maxillomandibular difference in the basal bone area may have more clinical significance.

An interesting finding was that in contrast to the similarity in DAWs between groups, BAWs showed remarkable differences in the group comparison (Table III). The maxillary BAW [CT]s except at the 2nd molar and all maxillary BAW [cast]s in Class III malocclusion were significantly smaller than those of normal occlusion group. In addition, all mandibular BAW [CT]s of Class III group were significantly greater than those of normal occlusion group. In contrast, none of mandibular BAW [cast]s showed statistically significant differences between two groups. This finding about BAW [cast] is supported by previous studies showing no significant difference in BAW between normal occlusion and Class III groups at mandibular first molar area (Kuntz et al., 2008; Uysal et al., 2005). However, It is known that the transverse analysis of the basal bone on the dental cast is hindered by the presence of variable thickness of buccal bone and soft tissue covering the roots, depending on the vertical facial pattern and/or masticatory function (Masumoto et al., 2001). In addition, Lee et al. reported that buccal bone thickness differed depending on the heights and increased in 2nd molar area especially in mandible ((Lee et al., 2009). To overcome these limits, Suk et al. introduced RC points, similar to center of resistance, to evaluate mandibular arch form (Suk et al., 2013). However, it is admitted that RC points could be used only in flat occlusal plane. Therefore, it is implicated that the use of estimated CR in the transverse denture analysis may provide meaningful information for the understanding on the occlusal phenotypes, and may enable an area-specific evaluation of transverse dimension at the basal bone level, regardless of the thickness of buccal plate and the flatness of occlusal plane.

In the normal occlusion group, the mean DAW differences between maxilla and mandible were relatively uniform, ranging from 8.18 mm to 9.01 mm. The Class III group also did not show significant differences compared to the normal occlusion group. However, the range of mean BAW [CT] differences was from - 4.52 mm (the 2nd molar) to 7.87 mm (canine) in the normal occlusion group. In figure 3 A, the BAW [CT] difference of the 1st molar was close to zero in normal occlusion group and the BAW [CT] of mandible were increased in the 2nd molar area, implying the basal arch shape in the respective arch, i.e. U-shaped maxillary arch and V-shaped mandibular arch (Enlow and Bang, 1965; Enlow and Harris, 1964). This study indicated that the BAW [CT] differences of Class III group were significantly greater than that of normal occlusion both the 1st molar and the 2nd molar, implying possible inherent transverse discrepancy in skeletal Class III group (Figure 3 B).

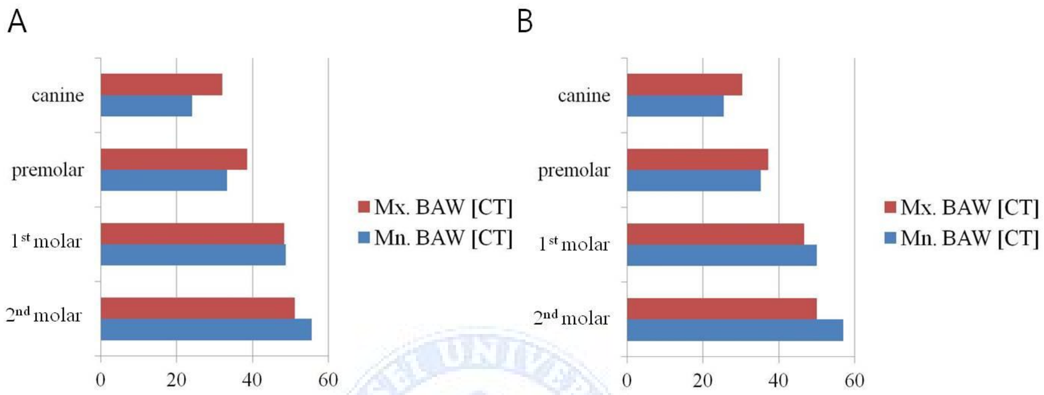

Figure 3. Comparison of maxillary and mandibular BAW [CT]s. **A**, normal occlusion group; **B**, Class III group. Units : mm.

The DAW difference of the 1st molar was 8.43 ± 2.22 mm in normal occlusion group, which was similar to that of previous study (Lee and Son, 2002; Lee et al., 2004; Uysal et al., 2005). The minor difference among studies may be attributed by the landmarks used. The mandibular dimension measured at the groove instead of buccal cusp tip may reduce the maxillomandibular difference (Uysal et al., 2005). The BAW [CT] difference of the 1st molar was - 0.39 ± 1.87 mm in normal occlusion group, unlike the relatively large difference in DAWs. This value suggests that the CRs of respective the 1st molars be aligned along the vertical axes of occlusion, facilitating the distribution of masticatory load through the stress trajectories (Robert, 2012). In this context, the BAW [CT] difference at the 2nd molar, (- 4.52 ± 2.76 mm in normal occlusion group) is somewhat striking. However, to date very few studies have shown the transverse basal dimension at the 2nd molar area, possibly due to the technical limitation using the dental casts (Kuntz et al., 2008; Lee and Son, 2002; Uysal et al., 2005). These measurements may reflect the inherent transverse deficiency at the rearmost area regardless of the adequate dimension at the 1st molar area and presumably substantiates the frequent occlusal aberration at the 2nd molar, such as buccal crossbite (Jonsson et al., 2007). Besides, the non-working side interferences caused by prominent palatal cusp tip of the 2nd molar may be related to this (McNamara, 2000).

Correlation analysis showed that BAW [CT] variables were significantly correlated with the sagittal skeletal discrepancy (Table IV), unlike the DAWs. Also, the maxillomandibular BAW [CT] differences were significantly correlated with cephalometric measurements, indicating maxillomandibular sagittal skeletal discrepancy. These results also suggest possible high prevalence of the maxillary transverse deficiencies in Class III (Franchi and Baccetti, 2005; Sato et al., 2013).

Correlation analysis showed that there were no significant correlation between maxillomandibular DAW differences and BAW [CT] differences (Table V). This result implicate that even without obvious dental transverse discrepancy, un underlying basal transverse discrepancy may exist, and more prevalently in skeletal Class III malocclusion subjects. In the Class III group, the transverse compensation of molar occurred in maxilla mainly, by buccal tipping (Table VI, Figure 4).

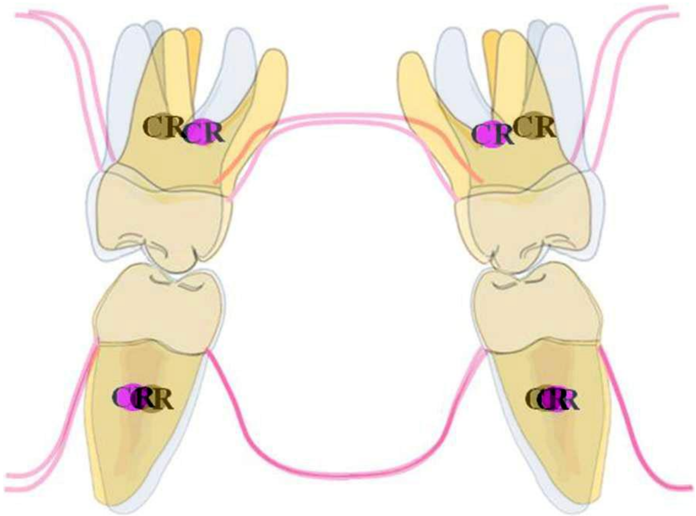

Figure 4. Schematic diagrams based on the results of this study (the 1st molars of the Class III group [orange] and the normal occlusion group [blue]). In the Class III group, the occlusion was maintained by buccal tipping of maxillary molars despite basal transverse discrepancy.

This notion was shown to be associated with the posture of tongue (Ovsenik and Primozic, 2014). It is speculated that gradual forward growth of mandible contributes the increase in the lateral tongue dimension which in turn may cause narrowing of the maxillary basal bone and inhibiting lingual tipping of mandibular molars (Braun et al., 1998). Therefore orthopedic and/or surgical intervention for maxillary expansion may be required more frequently in Class III subjects, to establish a transversely normal occlusion.

Correlation analysis represented significant correlation between BAW [CT] variables and BAW [cast] variables (Table VII). These results suggest that the alveolar bone reflect the position of the root and BAW [cast] can be usefully employed in the evaluation of transverse relationships.

Taken together, it is suggested that the maxillomandibular BAW [CT]s differences (- 0.39 ± 1.87 mm) and BAW [cast] differences (5.15 ± 2.56 mm) be used as an useful index (Yonsei Transverse Index) to assess the transverse relation regardless of the presence of occlusal transverse phenotypes. In particular, careful diagnosis in severe Class III patients requiring orthognathic surgery is crucial to decide the need for active transverse correction of the basal bone using appropriate treatment modalities such as surgically assisted or nonsurgical palatal expansion, and segmental surgery etc (Bailey et al., 1997; Betts et al., 1995; Bishara and Staley, 1987; Haas, 1965; Jacobs et al., 1980; Lee et al., 2010; Vanarsdall, 1999). Additionally, since this study mainly focused on the relationship between anteroposterior and transverse discrepancies, further studies to specify additional factors affecting the transverse dimension, for example the vertical facial pattern, needs to follow.

V. Conclusions

1. The results indicated possible basal transverse discrepancy and transverse dental compensation in the skeletal Class III subjects.
2. Correlation analysis represented significant correlation between BAW [CT] variables and BAW [cast] variables.
3. The 1st molar BAW [CT] differences of - 0.39 ± 1.87 mm, BAW [cast] differences of 5.15 ± 2.56 mm in normal occlusion were obtained to represent optimal maxillomandibular transverse difference at the basal bone level.

References

Andrews L, Andrews W: The six elements of orofacial harmony. *Andrews J* 1(1): 13-22, 2000.

Bailey LJ, White RP, Jr., Proffit WR, Turvey TA: Segmental LeFort I osteotomy for management of transverse maxillary deficiency. *J Oral Maxillofac Surg* 55(7): 728-731, 1997.

Barrett JF, Keat N: Artifacts in CT: recognition and avoidance. *Radiographics* 24(6): 1679-1691, 2004.

Baumrind S, Frantz RC: The reliability of head film measurements. 1. Landmark identification. *Am J Orthod* 60(2): 111-127, 1971.

Bechtold TE, Kim JW, Choi TH, Park YC, Lee KJ: Distalization pattern of the maxillary arch depending on the number of orthodontic miniscrews. *Angle Orthod* 83(2): 266-273, 2013.

Betts NJ, Vanarsdall RL, Barber HD, Higgins-Barber K, Fonseca RJ: Diagnosis and treatment of transverse maxillary deficiency. *Int J Adult Orthodon Orthognath Surg* 10(2): 75-96, 1995.

Bishara SE, Staley RN: Maxillary expansion: clinical implications. *Am J Orthod Dentofacial Orthop* 91(1): 3-14, 1987.

Braun S, Hnat WP, Fender DE, Legan HL: The form of the human dental arch. *Angle Orthod* 68(1): 29-36, 1998.

Burstone CR: Deep overbite correction by intrusion. *Am J Orthod* 72(1): 1-22, 1977.

Cha BK, Lee YH, Lee NK, Choi DS, Baek SH: Soft tissue thickness for placement of an orthodontic miniscrew using an ultrasonic device. *Angle Orthod* 78(3): 403-408, 2008.

Enlow DH, Bang S: Growth and remodeling of the human maxilla. *Am J Orthod* 51: 446-464, 1965.

Enlow DH, Harris DB: A study of the postnatal growth of the human mandible. *Am J Orthod* 50: 25-50, 1964.

Franchi L, Baccetti T: Transverse maxillary deficiency in Class II and Class III malocclusions: a cephalometric and morphometric study on postero-anterior films. *Orthod Craniofac Res* 8(1): 21-28, 2005.

Grummons DC, Kappeyne van de Coppello MA: A frontal asymmetry analysis. *J Clin Orthod* 21(7): 448-465, 1987.

Haas AJ: The treatment of maxillary deficiency by opening the midpalatal suture. *Angle Orthod* 35: 200-217, 1965.

Hesby RM, Marshall SD, Dawson DV, Southard KA, Casko JS, Franciscus RG, et al.: Transverse skeletal and dentoalveolar changes during growth. *Am J Orthod Dentofacial Orthop* 130(6): 721-731, 2006.

Howes AE: A polygon portrayal of coronal and basal arch dimensions in the horizontal plane. *American Journal of Orthodontics* 40(11): 811-831, 1954.

Jacobs JD, Bell WH, Williams CE, Kennedy JW, 3rd: Control of the transverse dimension with surgery and orthodontics. *Am J Orthod* 77(3): 284-306, 1980.

Jonsson T, Arnlaugsson S, Karlsson KO, Ragnarsson B, Arnarson EO, Magnusson TE: Orthodontic treatment experience and prevalence of malocclusion traits in an Icelandic adult population. *Am J Orthod Dentofacial Orthop* 131(1): 8.e11-18, 2007.

Kim SJ, Choi TH, Baik HS, Park YC, Lee KJ: Mandibular posterior anatomic limit for molar distalization. *Am J Orthod Dentofacial Orthop* 146(2): 190-197, 2014.

Kim SJ, Lee KJ, Lee SH, Baik HS: Morphologic relationship between the cranial base and the mandible in patients with facial asymmetry and mandibular prognathism. *Am J Orthod Dentofacial Orthop* 144(3): 330-340, 2013.

Kuntz TR, Staley RN, Bigelow HF, Kremenak CR, Kohout FJ, Jakobsen JR: Arch widths in adults with Class I crowded and Class III malocclusions compared with normal occlusions. *Angle Orthod* 78(4): 597-603, 2008.

Lee HK, Son WS: A study on basal and dental arch width in skeletal Class III malocclusion. *Korean J Orthod* 32(2): 117-127, 2002.

Lee KJ, Joo E, Kim KD, Lee JS, Park YC, Yu HS: Computed tomographic analysis of tooth-bearing alveolar bone for orthodontic miniscrew placement. *Am J Orthod Dentofacial Orthop* 135(4): 486-494, 2009.

Lee KJ, Park YC, Hwang CJ, Kim YJ, Choi TH, Yoo HM, et al.: Displacement pattern of the maxillary arch depending on miniscrew position in sliding mechanics. *Am J Orthod Dentofacial Orthop* 140(2): 224-232, 2011.

Lee KJ, Park YC, Park JY, Hwang WS: Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism. *Am J Orthod Dentofacial Orthop* 137(6): 830-839, 2010.

Lee SJ, Moon SC, Kim TW, Nahm DS, Chang YI: Tooth size and arch parameters of normal occlusion in a large korean sample. *Korean J Orthod* 34(6): 473-480, 2004.

Leonardi R, Annunziata A, Caltabiano M: Landmark identification error in posteroanterior cephalometric radiography. A systematic review. *Angle Orthod* 78(4): 761-765, 2008.

Lim MY, Lim SH: Comparison pf model analysis measurements among plaster model, laser scan digital model, and cone beam CT image. *Korean J Orthod* 39(1): 6-17, 2009.

Lundstrom AF: Malocclusion of the teeth regarded as a problem in connection with the apical base. *International Journal of Orthodontia, Oral Surgery and Radiography* 11(10): 933-941, 1925.

Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K: Relationships among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible. *Eur J Orthod* 23(1): 15-23, 2001.

McNamara JA: Maxillary transverse deficiency. *Am J Orthod Dentofacial Orthop* 117(5): 567-570, 2000.

Melsen B, Agerbaek N, Markenstam G: Intrusion of incisors in adult patients with marginal bone loss. *Am J Orthod Dentofacial Orthop* 96(3): 232-241, 1989.

Ovsenik M, Primozic J: [How to push the limits in the transverse dimension? Facial asymmetry, palatal volume and tongue posture in children with unilateral posterior cross bite: a three-dimensional evaluation of early treatment]. *Orthod Fr* 85(2): 139-149, 2014.

Padwa BL, Kaiser MO, Kaban LB: Occlusal cant in the frontal plane as a reflection of facial asymmetry. *J Oral Maxillofac Surg* 55(8): 811-816; discussion 817, 1997.

Ricketts RM: Perspectives in the clinical application of cephalometrics. The first fifty years. *Angle Orthod* 51(2): 115-150, 1981.

Robert WE: Chapter 10. Bone physiology, metabolism, biomechanics in orthodontic practice. In: Orthodontics : current principles and techniques 5th ed. Graber LE, Vanarsdall Jr RL, Vig KW, eds. 2012.

Sato FR, Mannarino FS, Asprino L, de Moraes M: Prevalence and treatment of dentofacial deformities on a multiethnic population: a retrospective study. *Oral Maxillofac Surg*: 173-179, 2013.

Sergl HG, Kerr WJ, McColl JH: A method of measuring the apical base. *Eur J Orthod* 18(5): 479-483, 1996.

Singh GD: Morphologic determinants in the etiology of class III malocclusions: a review. *Clin Anat* 12(5): 382-405, 1999.

Smith RJ, Burstone CJ: Mechanics of tooth movement. *Am J Orthod* 85(4): 294-307, 1984.

Suk KE, Park JH, Bayome M, Nam YO, Sameshima GT, Kook YA: Comparison between dental and basal arch forms in normal occlusion and Class III malocclusions utilizing cone-beam computed tomography. *Korean J Orthod* 43(1): 15-22, 2013.

Suojanen JN, Mukherji SK, Dupuy DE, Takahashi JH, Costello P: Spiral CT in evaluation of head and neck lesions: work in progress. *Radiology* 183(1): 281-283, 1992.

Uysal T, Usumez S, Memili B, Sari Z: Dental and alveolar arch widths in normal occlusion and Class III malocclusion. *Angle Orthod* 75(5): 809-813, 2005.

Vanarsdall RL: Orthodontics and periodontal therapy. *Periodontol 2000* 9: 132-149, 1995.

Vanarsdall RL, Jr.: Transverse dimension and long-term stability. *Semin Orthod* 5(3): 171-180, 1999.

국문요약

골격성 III급 부정교합자에서 저항중심을 이용한 상하악궁 폭경 차이

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서론 : 이 연구의 목적은 (1) 정상교합자와 골격성 III급 부정교합자군의 횡적 폭경 및 상하악 횡적 관계를 비교하고, (2) 저항중심에서 계측한 기저골 너비와 cast 에서 계측한 기저골 너비 비교를 통하여 기저골 너비 계측점을 검증하고자 하였다. (3) 또한 각 치아부위에서 정상교합을 이룰 수 있는 기저골 폭경에 관하여 알아보기 위함이다.

연구재료 및 방법 : 정상교합군 30명, 악교정 수술예정인 골격성 III급 부정교합 30명을 대상으로 하였으며, 치관에서의 폭경 (dental arch width, DAW)은 각 치관의 교두정 (견치, 소구치의 경우 협측 교두정, 구치의 경우 근심협측 교두정) 사이의 거리를 계측하였다. 기저골에서의 폭경 (basal arch width, BAW) 계측은 진단모형과 전산화 단층촬영 (CT)을 이용하였으며, 진단모형에서는 각 치관 계측점 상방의 점막치은경계부 상의 점 사이의 거리를, CT 영상에서는 각 치아의 저항중심 (단근치의 경우 치근 길이의 1/3 지점, 다근치의 경우 치근이개부) 사이의 거리를 계측하였다. (진단모형 계측치; BAW [cast], CT 계측치; BAW [CT])

연구결과 : 각 악궁에서 DAW 비교시 정상교합군과 골격성 III급 부정교합군 사이에 유의한 차이를 보이지 않았다. 상악 BAW 비교시 골격성 III급 부정교합군의 BAW [CT], BAW [cast]가 유의하게 작은 것으로 나타났다. 하악 BAW 비교시, BAW [CT]는 골격성 III급 부정교합군이 유의하게 컸으며, BAW [cast]는 두 군간에 유의한 차이가 없었다. 상하악 너비차이 비교시 DAW는 두 군간에 유의한 차이가 없었고, BAW [CT]와 BAW [cast]는 유의한 차이를 보였다. BAW [CT] 계측치와 BAW [cast] 계측치는 유의한 상관관계를 보였다.

결론 : 본 연구 결과, 골격성 III급 부정교합군에서 기저골 수준에서의 횡적 부조화 및 보상적 치아경사가 존재함을 알 수 있었다. 따라서 횡적관계 평가시

DAW 보다는 기저골 수준에서의 평가가 필요하며, BAW [CT] 와 BAW [cast] 의 계측을 통하여 가능할 것이다. 정상교합자에서 제1대구치 부위의 상하악 BAW [CT] 차이는 - 0.39 ± 1.87 mm, 상하악 BAW [cast] 차이는 5.15 ± 2.56 mm이며, 이는 기저골 수준에서 양호한 상하악 횡적 관계를 이룰수 있는 상하악 너비차이인 것으로 생각한다.

핵심 되는 말 : 저항중심, 상하악 너비 차이, 골격성 III 급 부정교합, 횡적 부조화