Original Article

Which Hard and Soft Tissue Factors Relate with the Amount of Buccal Corridor Space during Smiling?

Il-Hyung Yang[a]; Dong-Seok Nahm[b]; Seung-Hak Baek[c]

ABSTRACT

Objective: To investigate which hard and soft tissue factors relate with the amount of buccal corridor area (BCA) during posed smiling.

Materials and Methods: The samples consisted of 92 adult patients (19 men and 73 women; 56 four first bicuspids extraction and 36 nonextraction treatment cases; mean age = 23.5 years), who were treated only with a fixed appliance and finished with Angle Class I canine and molar relationships. To eliminate the crowding effect on the buccal corridor area, lateral cephalograms, dental casts, and standardized frontal posed smile photographs were obtained at debonding stage and 28 variables were measured. Pearson correlation analysis, multiple linear regression analysis, and independent *t*-test were used to find variables that were related with buccal corridor area ratio (BCAR).

Results: Among the lateral cephalometric and dental cast variables, FMA, lower anterior facial height, upper incisor (U1) exposure, U1 to facial plane, lower incisor (L1) to mandibular plane, L1 to N-B, Sn (subnasale) to soft tissue menton (Me′), Sn to stomodium superius (stms), stms to Me′, and interpremolar width were significantly negatively correlated with BCAR. Occlusal plane inclination and buccal corridor linear ratio did not show any significant correlation with BCAR. Multiple linear regression analysis generated a three-variable model: Sn to Me′, U1 exposure, and sum of tooth material (STM) ($R^2 = 0.324$). There was no significant difference in BCAR between extraction and nonextraction groups.

Conclusions: To control the amount of BCA for achieving a better esthetic smile, it is necessary to observe the vertical pattern of the face, amount of upper incisor exposure, and sum of the tooth material.

KEY WORDS: Posed smiling; Buccal corridor area; Buccal corridor area ratio

INTRODUCTION

Although there have been numerous soft tissue analyses of the face,[1–8] those mostly dealt with the soft tissue profile in the sagittal plane. However, Arnett and Bergman,[7] Arnett et al,[8] and Proffit[9] emphasized the importance of the esthetics in the frontal view. Therefore, it is necessary for orthodontists to shift the focus from the sagittal plane to the frontal plane during evaluation of their patients when planning and assessing orthodontic treatment.[10]

In addition, orthodontic patients are concerned with not only their static appearances, but also with their dynamic appearances during conversation and smile.[11–15] The "smile designing" in orthodontic treatment is the social posed smile, which is known to be repeatable and reproducible.[12,16–19]

The buccal corridor is one of the evaluation points in smile esthetics.[20–22] It is a space between the maxillary lateral teeth and the corner of the mouth during smile, which appears as a black or dark space.[16,23] The narrow maxillary arch[13,14,24–25] and extraction in the upper dentition[26] were thought to be causes of the buccal corridor. Others suggested that the anterior-posterior

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position of the maxilla and the rotation of the upper molars could be influencing factors on the buccal corridor.[11,12,15,19,20]

Since the buccal corridor is actually two-dimensional on frontal view and can be seen differently according to light condition, quantification of the smile from the frontal photographs can be done using linear measurements, propoprtions,[12,15,16,19–21,27] and a mesh diagram with the extrapolation method.[15,19,28] Therefore, it is necessary to quantify color and density of the pixel unit of the buccal corridor in a histogram and to measure two-dimensionally the buccal corridor area (BCA). The purpose of this study was to quantify two-dimensionally the BCA and to determine which hard and soft tissue factors are related with the amount of BCA during posed smiling.

MATERIALS AND METHODS

The samples consisted of 92 adult patients (19 men and 73 women; 56 four first bicuspids extraction and 36 nonextraction treatment cases; mean age: 23.5 years) to eliminate growth changes of the hard and soft tissues. The patients had been treated only with a fixed appliance and finished with Angle Class I canine and molar relationships. The patients with facial asymmetry (chin point deviation $>$ 4 mm), temporomandibular joint disorder, cleft lip and palate, or any other syndromes, orthognathic surgery experience, and more than two missing teeth were excluded because these might result in abnormal neuromuscular activities during smile. Also, to get rid of any crowding effect on BCA, lateral cephalograms, dental casts, and standardized frontal posed smile photographs were obtained at the debonding stage.

Lateral cephalograms were taken with the patient's Frankfort horizontal (FH) plane parallel to the floor and with centric occlusion and unstrained lips. The tracings were digitized with a digitizer (Intuos2 graphic tablet, Wacom Technology Co, Vancouver, Canada) and analyzed by V-Ceph (Cybermed, Seoul, Korea). Reference lines and cephalometric landmarks are listed in Figures 1 and 2. For lateral cephalometric measurements, seventeen variables of the anteroposterior position of the maxilla, skeletal vertical pattern, denture pattern, and soft tissue vertical lengths were used and are listed in Figure 3. The values were measured up to 0.05° and 0.05 mm.

For measurements of the dental casts, the mesiodistal width of each tooth from the upper right to left first molar was measured with a digital vernier caliper (Mitutoyo, Aurora, Ill) in 0.01 mm units and their sum calculated. The intercanine, interpremolar, and basal arch widths were recorded. The angulation and inclination of the upper incisors and canines were mea-

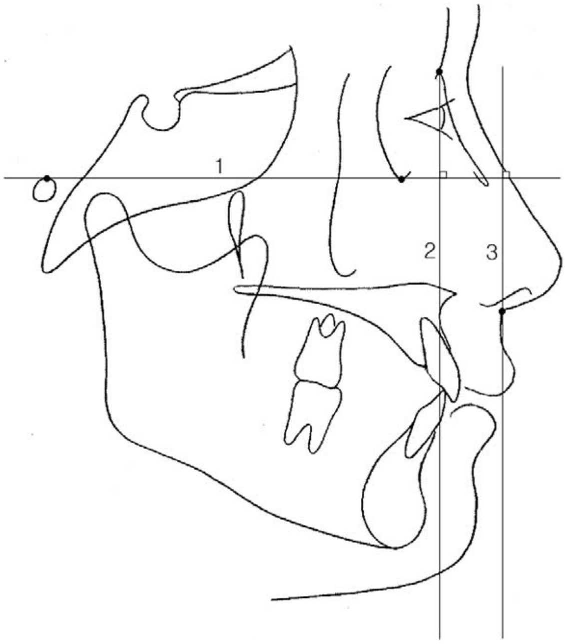

Figure 1. Reference lines. (1) Frankfort horizontal plane (porion to orbitale). (2) Nasion perpendicular line (N-perp, line perpendicular to FH plane through nasion). (3) Subnasale perpendicular line (Sn-perp, line perpendicular to FH plane through subnasale).

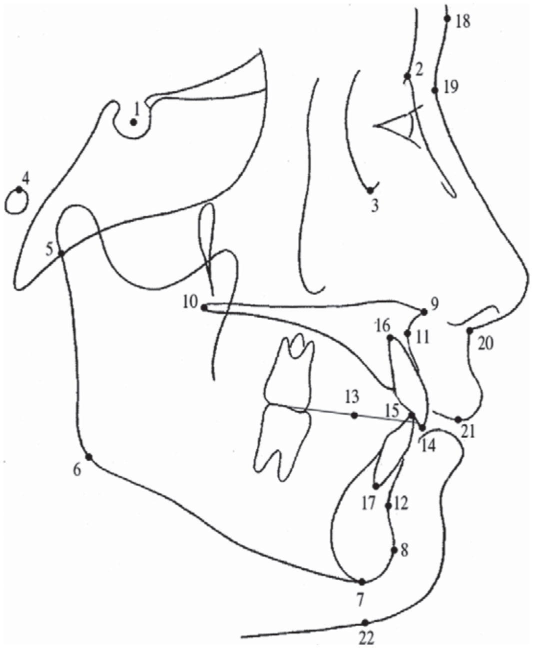

Figure 2. Cephalometric landmarks. (A) Skeletal and dental landmarks: 1. S (sella); 2. N (nasion); 3. Or (orbitale); 4. Po (porion); 5. Ar (articulare); 6. Go (gonion); 7. Me (menton); 8. Pog (pogonion); 9. ANS (anterior nasal spine); 10. PNS (posterior nasal spine); 11. Point A (subspinale); 12. Point B (supramentale); 13. Occlusal plane point; 14. U1E (incisor superius); 15. L1E (incisor inferius); 16. U1A (root apex of the upper central incisor); 17. L1A (root apex of the lower central incisor). (B) Soft tissue landmarks: 18. Gl (glabella); 19. N′ (soft tissue nasion); 20. Sn (subnasale); 21. stms (stomion superius); 22. Me′ (soft tissue menton).

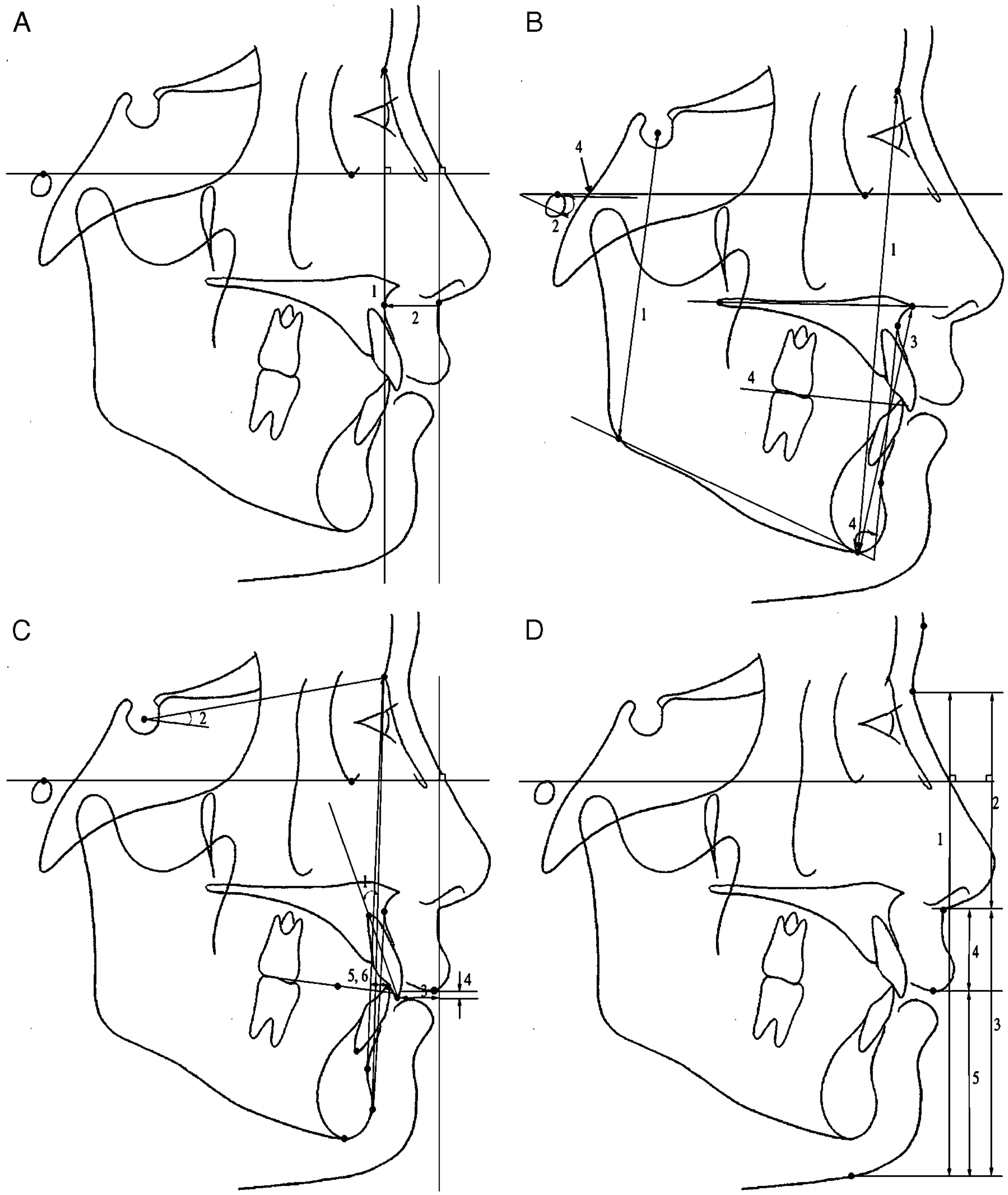

Figure 3. (A) Variables of anteroposterior position of maxilla: 1. A to N-perpendicular (mm); 2. A to Sn-perpendicular (mm). (B) Variables of the skeletal vertical pattern measurements: 1. Facial height ratio [(S-Go/N-Me) × 100, %]; 2. Frankfurt mandibular plane angle (FMA, degrees); 3. Lower anterior facial height (LAFH, ANS-Me, mm); 4. Overbite depth indicator (ODI, degrees). (C) Variables of denture pattern: 1. Upper incisor (U1) to facial plane (mm); 2. Occlusal plane to S-N (degrees); 3. U1 to Sn-perp (mm).; 4. U1 exposure (mm); 5. Lower incisor (L1) to A-Pog (mm); 6. L1 to N-B (mm). (D) Variables of the soft tissue vertical length: 1. N′ to Me′ (mm); 2. N′ to Sn (mm); 3. Sn to Me′ (mm); 4. Sn to stms (mm); 5. stms to Me′ (mm).

sured with an angulation- and inclination-measuring gauge (InvisiTech Co, Seoul, Korea) in 0.1° units. Variables of dental casts are listed in Figure 4. The cephalometric and cast measurements were reliable according to the results of Dahlberg's formula.

Posed smile photographs were taken with a Nikon FM2 analog film camera (Nikon, Tokyo, Japan) and KODAK Elite Chrome 35mm slide film (Eastman Kodak Co, Rochester, NY). The patients were positioned with the FH plane and the interpupillary line parallel to

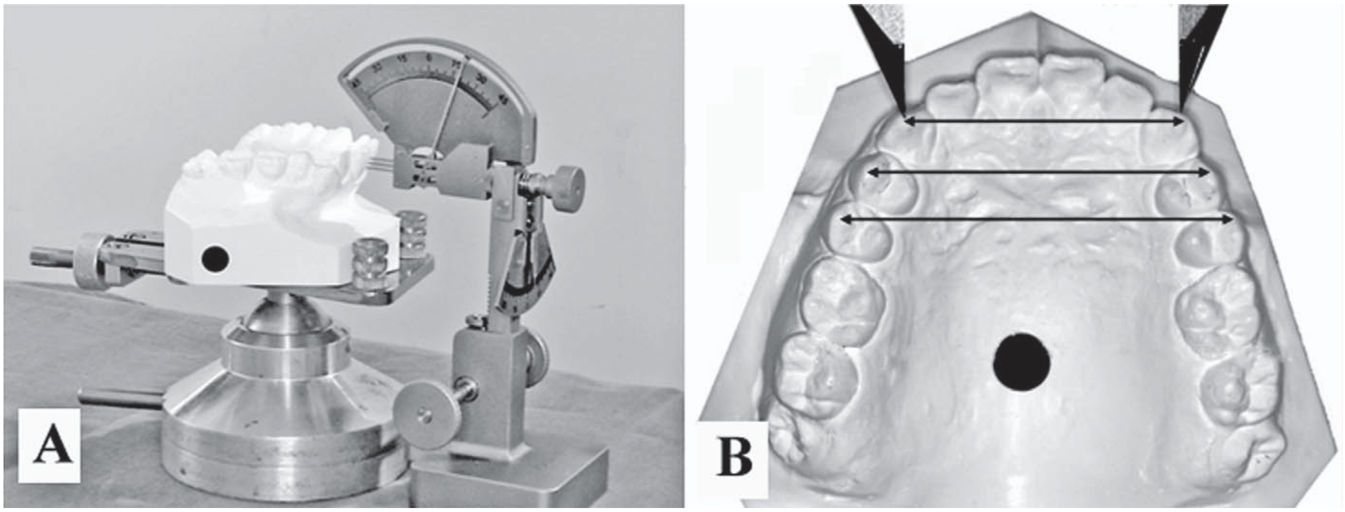

Figure 4. Variables of dental casts. (A) Measurement of the inclination and angulation of the teeth with an angulation- and inclination-measuring gauge (Invisitech Co, Seoul, Korea) in the units of 0.1°. Variables are as follows: IA (average angulation of the upper central and lateral incisors of both sides), CA (average angulation of upper canines of both sides), CI (average inclination of upper canines of both sides), PI (average inclination of upper first and second premolars of both sides), occlusal plane was used as a reference plane. (B) Measurement of the arch widths and mesiodistal width of each tooth on the dental cast with a digital vernier caliper (Mitutoyo, Aurora, Ill). Variables are as follows: ICW (intercanine width between cusp tips of upper canines), IPW (average interpremolar width at contact point between first and second premolar in nonextraction case and interpremolar width at second premolars in extraction case), ICBAW (intercanine basal arch width between the upper canines), IPBAW (interpremolar basal arch width at centroid between the upper first and second premolars), Sum of tooth material (sum of the mesiodistal widths of the teeth from the upper right to left first molars, STM).

the floor and were asked to touch their teeth slightly and to smile. When we took a picture of the posed smile, we created a standardized repeatable and reproducible method. The imaginary center line of the patient's face was aligned to the center vertical line on the grid of the viewfinder and both sides of the patient's ears showed the same amount to prevent transverse rotation.

Since the buccal corridor can be seen differently according to different light conditions, all procedures were carried out in a studio under standardized light conditions to get the actual BCA. The photographs were developed and fixed by a professional. They were then scanned with Epson Expression 1680/pro scanner (Epson, Long Beach, Calif) under 24-bit color mode and 600 dpi. The scanned images were saved as JPEG files (standard baseline format) at the maximum quality as set at level 12. The mouth area in each photograph was magnified to fill the screen of a 14.1 inch TFT SXGA+ monitor (1400 × 1050 pixels, Flatron L1720B, LG, Seoul, Korea), using Adobe Photoshop 7.0 software (Adobe Systems Inc, San Jose, Calif).

Variables of posed smile photographs are listed in Figure 5. For calculation of the buccal corridor linear ratio (BCLR), intercanine and intercommissural widths were measured in 0.01 mm units with the linear measuring tool in Adobe Photoshop 7.0 software. For precise area measurements, a polygonal lasso to select the smile areas and magic wand (options: tolerance [15–25], anti-aliased [on], and contiguous [on]) were used to decide the buccal corridors. The pixel number in both areas was attained in the pixel histogram menu and the buccal corridor area ratio (BCAR) was calculated. These were verified with the reliability test; $r = .999$ for the smile area, $r = .989$ for the buccal corridor area. To analyze the test-retest reliability of the BCAR measurement techniques, the smile area and BCA of 30 randomly selected smile photographs were measured 4 weeks after initial measurement. Intraclass correlation coefficient was computed for assessment of the test-retest data, which was 0.989 ($P < .01$) for BCA using the magic wand tool and 0.999 ($P < .01$) for the smile area using the polygonal lasso tool. The result substantiated the reliability of these computer-aided area measurement techniques.

To find variables that were related with the BCAR, Pearson correlation analysis was performed. Independent *t*-test was performed to compare the means of BCAR between extraction and nonextraction groups. With the variables showing the statistically significant correlation, a multiple linear regression analysis was used to remove its intercorrelation among these independent variables as well as to discover the more important variables which could predict the amount of BCA.

RESULTS

According to Pearson correlation analysis, FMA ($P < .05$), LAFH ($P < .01$), U1 exposure ($P < .01$), U1

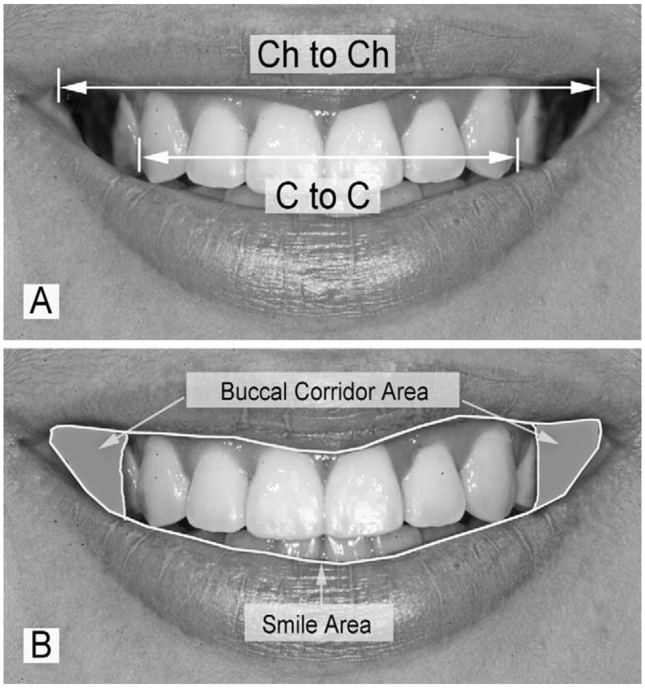

Figure 5. Variables of posed smile photographs. (A) Buccal corridor linear ratio ([C to C / Ch to Ch] × 100 [%]), C means distal surface of the upper canine; Ch, corner of the mouth. (B) Buccal corridor area ratio ([buccal corridor area / smile area] × 100 [%]). Smile area means area between upper and lower lip; Buccal corridor area, Total area of right and left buccal corridors.

to facial plane ($P < .01$), L1 to mandibular plane ($P < .01$), L1 to N-B ($P < .05$), Sn to Me′ ($P < .01$), Sn to stms ($P < .05$), and stms to Me′ ($P < .01$) were significantly correlated with the BCAR (Table 1). Among the dental cast measurements, the sum of tooth material ($P < .05$) and interpremolar width ($P < .05$) were significantly correlated. Occlusal plane inclination and buccal corridor linear ratio did not show any significant correlation with BCAR.

There was no statistically significant difference in BCAR between the extraction and nonextraction groups (Table 2).

Multiple regression analysis produced a three-variable model, which consisted of Sn to Me′, U1 exposure, and sum of tooth material with the adjusted $R^2 = 0.324$ (Table 3).

DISCUSSION

To measure the actual area instead of the linear ratio of the buccal corridor space, the BCAR was used as a dependent variable for correlation analysis in this study (Table 1). In Pearson correlation analysis for determining the correlation between BCAR and the other variables (Table 1), the variables for the anteroposterior position of the maxilla (A to N perp and A to Sn perp) and the inclination of the occlusal plane did not show statistically significant correlations, which conflicted with results of former studies.[12–15,20]

Among the variables for the skeletal vertical pattern, FMA ($P < .05$, Table 1) and LAFH ($P < .01$, Table 1) showed statistically significant negative correlations. There were also significant negative correlations in the variables of the soft tissue vertical length; Sn to Me′ ($P < .01$, Table 1), Sn to stms ($P < .05$, Table 1), and stms to Me′ ($P < .01$, Table 1). However, there was no significant correlation in N to Sn. Therefore, vertical length in the lower half of the soft tissue profile was significantly negatively correlated with the amount of BCAR. A possible reason why stms-Me′ showed the strongest correlation was the possible relationship with the activities of the lips. During smiling the lower lip showed a larger extent of motion than the upper lip. Together with these results the long face can be said to have a tendency for less buccal corridor.

Among the denture pattern measurements, there were statistically significant negative correlations in U1 exposure ($P < .01$, Table 1), U1 to facial plane ($P < .01$, Table 1), L1 to mandibular plane ($P < .01$, Table 1), and L1 to N-B ($P < .05$, Table 1). These suggest that the more anteriorly and downwardly positioned the upper incisors and anteriorly and upwardly positioned the lower incisors were, the less the BCAR was. These incisor positions could be a part of the dental compensation effect of the hyperdivergent tendency in a skeletal vertical pattern.

In dental cast measurements, interpremolar width ($P < .05$, Table 1) showed a statistically significant negative correlation with BCAR. The narrower the interpremolar width was, the larger the BCAR. This was in accord with the results of former studies.[13,14,24,25]

Although sum of tooth material ($P < .05$, Table 1) showed a negative correlation coefficient, which suggested the extraction group had a high possibility of having a large buccal corridor, there was no statistically significant difference of the BCAR between the extraction and nonextraction groups (Table 2). This was in discord with the results of former studies.[26] Those findings mean that the amount of buccal corridor space did not correlate with whether extractions were done or not, but with the sum of tooth material. If the size of each tooth was slightly larger than normal in extraction cases, eventually the sum of tooth material could be larger than normal and vice versa for the nonextraction group.

These discords[12–15,20,26] and accords[13,14,24,25] to former studies were mainly due to the newly-introduced method of measuring the buccal corridor space in this study. Former methodology was horizontal linear measurement, but the method used in this study dealt with two dimensions. This is the reason the vertical com-

Table 1. Correlation Between Buccal Corridor Area Ratio and Other Variables[a]

	Variables	Mean	SD	Pearson Correlation Coefficient[b]
Anteroposterior position of the maxilla	A to N-perpendicular, mm	0.94	2.41	−0.075
	A to Sn-perpendicular, mm	−14.35	2.23	0.156
Skeletal vertical pattern	Facial height ratio (FHR)	0.63	0.05	0.082
	Frankfurt mandibular plane angle (FMA), degrees	28.41	6.17	−0.219*
	Lower facial height ratio (LAFH), degrees	46.78	4.22	−0.428**
	Overbite depth indicator (ODI), degrees	68.38	5.83	0.001
Occlusal plane inclination	Occlusal plane to S-N, degrees	20.62	4.86	−0.054
Denture pattern	U1 Exposure, mm	3.16	1.62	−0.421**
	U1 to Facial plane, degrees	8.74	3.36	−0.370**
	U1 to Sn-perpendicular, mm	−9.43	2.49	0.186
	L1 to A-Pog, mm	1.82	3.09	0.044
	L1 to Mandibular plane, mm	46.03	3.41	−0.410**
	L1 to N-B, mm	6.03	2.34	−0.260*
Soft tissue vertical length	N′ to Sn, mm	55.62	3.88	−0.196
	Sn to Me′, mm	79.13	5.46	−0.438**
	Sn to stms, mm	25.16	2.20	−0.256*
	stms to Me′, mm	53.96	4.19	−0.437**
Dental cast	Sum of tooth material (STM), mm	43.83	2.88	−0.221*
	Incisor angulation (IA), degrees	3.93	2.44	0.076
	Canine angulation (CA), degrees	5.43	4.74	−0.083
	Canine inclination (CI), degrees	−1.70	6.63	−0.011
	Premolar inclination (PI), degrees	−5.23	6.14	0.175
	ICW, mm	36.90	1.85	−0.181
	IPW, mm	46.82	1.90	−0.229*
	ICBAW, mm	34.23	2.97	−0.084
	IPBAW, mm	47.46	3.17	−0.091
Smile photographs	BCLR, %	71.80	5.12	0.962
	BCAR, %	5.27	1.75	—

* $P < .05$.

** $P < .01$.

[a] SD indicates standard deviation; U1, upper central incisor; L1, lower central incisor; STM, sum of tooth material which is sum of the mesiodistal widths of the teeth from the upper right to left first molars; IA, average angulation of the upper central and lateral incisors of both sides; CA, average angulation of upper canines of both sides; CI, average inclination of upper canines of both sides; PI, average inclination of upper first and second premolars of both sides; ICW, intercanine width between cusp tips of upper canines; IPW, average interpremolar width at contact point between first and second premolar in nonextraction case and interpremolar width at second premolars in extraction case; ICBAW, intercanine basal arch width between the upper canines; IPBAW, interpremolar basal arch width at centroid between the upper first and second premolars; BCLR, buccal corridor linear ratio; BCAR, buccal corridor area ratio.

[b] Pearson correlation analysis. In this study the correlation coefficients greater than +0.20 and less than −0.20 had statistical significance ($r > +.26$, $r < -.26$, $P < .01$; $r > +.20$, $r < -.20$, $P < .05$, 2-tailed).

ponents of the cephalometric and cast measurements had an important effect on the BCA.

In multiple linear regression analysis of BCAR (Table 3), the hard and soft tissue factors affecting the amount of BCAR were the soft tissue vertical length (Sn to Me′), the amount of upper incisor exposure, and sum of tooth material. The reason why these three variables were selected follows: The variables in the skeletal vertical pattern (FMA and LAFH) were excluded because of the collinearity with Sn to Me′. That is, Sn to Me′ can explain the vertical pattern of the underlying skeletal structures. Because most of the persons

Table 2. Comparison of Buccal Corridor Area Ratio Between the Nonextraction and Extraction Groups[a]

Variable	Nonextraction Group (N = 36)		Extraction Group (N = 56)			
	Mean	SD	Mean	SD	P Value	Significance (2-Tailed)
BCAR	5.15	1.61	5.34	1.84	.62	NS

[a] Independent *t*-test, BCAR indicates buccal corridor area ratio; SD, standard deviation; NS, nonspecific.

Table 3. Multiple Linear Regression Analysis of Buccal Corridor Area Ratio[a]

Significant Variables	Coefficient	Adjusted R^2	*P* value
Sn-Me′, mm	−0.117	0.183	<.001
U1 exposure, mm	0.357	0.289	<.001
Sum of tooth material, mm	−0.124	0.324	.02

[a] Multiple linear regression analysis. N = 92, $P < .05$, adjusted $R^2 = .324$. U1 indicates upper central incisor.

with large Sn to Me′ tend to have large Sn to stms and stms to Me′, these two soft tissue vertical length variables were also excluded in the multiple linear regression analysis. The variables on the position of the lower incisors (L1 to mandibular plane and L1 to N-B) were excluded because the lower incisors were well located in a given small range of position according to the position of the upper incisors after orthodontic treatment. Because sum of tooth material had a strong correlation ($r = 0.720$, $P < .001$) from the correlation matrix, the interpremolar width was excluded from the regression model.

CONCLUSIONS

- With the newly-introduced method for BCA, the buccal corridor is a multifactorial phenomenon. To control the amount of BCA for achieving a better esthetic smile, it is necessary to observe the vertical pattern of the face, amount of upper incisor exposure, and sum of the tooth material.
- Extraction or nonextraction treatment did not affect the amount of BCA.

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